ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 660525

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental [] Direct Revision [X] Change ECN [ ] Temporary [ ] Standby [ ] Supersedure [ ] Cancel/Void [ ]	M. K. Ullah, T5-54, 6-2944	[X] Yes [ ] No	6-30-00
	6. Project Title/No./Work Order No. PFP FSAR Annual Update-2000	7. Bldg./Sys./Fac. No. PFP Facilities	8. Approval Designator SQ D 2/27/01
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) HNF-SD-CP-SAR-021, Rev.1	10. Related ECN No(s). N/A	11. Related PO No. N/A

12a. Modification Work	12b. Work Package No.	12c. Modification Work Complete	12d. Restored to Original Condition (Temp. or Standby ECN only)
[] Yes (fill out Blk. 12b) [X] No (NA Blks. 12b, 12c, 12d)	N/A	N/A Design Authority/Cog. Engineer Signature & Date	N/A Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

13b. Design Baseline Document? [X] Yes [ ] No

The Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR), HNF-SD-CP-SAR-021 Rev.1, is changed as a part of the annual update to reflect all approved changes with negative Unreviewed Safety Question (USQ). Changes that constitute positive USQ have also been incorporated for DOE approval. All chapters were revised according to the Criteria Document (HNF-5738) for year 2000. Refer to the chapter prefaces for a summary of specific information regarding the changes in each chapter. All changes are highlighted by redlines and strikeouts. This updated FSAR once approved by DOE will be Revision 2, and it will supersede Revision 1. The Revision 2 incorporates in its entirety the Addendum 0-K analysis. After the approval of Revision 2, 0-K will no longer be the Authorization Basis.

0-L 6/28/00

~~Also see USQ Evaluation #ECN-660525 attached.~~

See EDT 630164 for the USQs. 2/23/01

14a. Justification (mark one)

Criteria Change	[X]	Design Improvement	[ ]	Environmental	[ ]	Facility Deactivation	[ ]
As-Found	[X]	Facilitate Const	[ ]	Const. Error/Omission	[ ]	Design Error/Omission	[ ]

14b. Justification Details

The annual FSAR update required by the DOE Orders. Refer to each chapter for additional information for specific changes. Some changes were editorial in nature to reflect current configuration and correct description of system.

15. Distribution (include name, MSIN, and no. of copies)

See attached sheet for distribution.

1) Controlled Copy Distribution by Phillis Jones 2/23/01

2) "Information Only" Distribution Sheet attached. 2/23/01

RELEASE STAMP

FEB 28 2001

DATE:

STA: 5

HANFORD RELEASE

ID: 12

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1. ECN (use no. from pg. 1): 660525

16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
[] Yes	Additional	[ ] $	Additional	[ ] $ N/A	Improvement	[ ]
[X] No	Savings	[ ] $ N/A	Savings	[ ] $ N/A	Delay	[ ] N/A

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[ ]	Seismic/Stress Analysis	[ ]	Tank Calibration Manual	[ ]
Functional Design Criteria	[ ]	Stress/Design Report	[ ]	Health Physics Procedure	[ ]
Operating Specification	[ ]	Interface Control Drawing	[ ]	Spares Multiple Unit Listing	[ ]
Criticality Specification	[ ]	Calibration Procedure	[ ]	Test Procedures/Specification	[ ]
Conceptual Design Report	[ ]	Installation Procedure	[ ]	Component Index	[ ]
Equipment Spec.	[ ]	Maintenance Procedure	[ ]	ASME Coded Item	[ ]
Const. Spec.	[ ]	Engineering Procedure	[ ]	Human Factor Consideration	[ ]
Procurement Spec.	[ ]	Operating Instruction	[ ]	Computer Software	[ ]
Vendor Information	[ ]	Operating Procedure	[ ]	Electric Circuit Schedule	[ ]
OM Manual	[ ]	Operational Safety Requirement	[ ]	ICRS Procedure	[ ]
FSAR/SAR	[ ]	IEFD Drawing	[ ]	Process Control Manual/Plan	[ ]
Safety Equipment List	[X]	Cell Arrangement Drawing	[ ]	Process Flow Chart	[ ]
Radiation Work Permit	[ ]	Essential Material Specification	[ ]	Purchase Requisition	[ ]
Environmental Impact Statement	[ ]	Fac. Proc. Samp. Schedule	[ ]	Tickler File	[ ]
Environmental Report	[ ]	Inspection Plan	[ ]	None	[]
Environmental Permit	[ ]	Inventory Adjustment Request	[ ]		[ ]

20. Other Affected Documents : (NOTE: Documents listed below will not be revised by this ECN.) Signatures below Indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision
HNF-SD-CP-TI-108, Rev. 17		

21. Approvals

	Signature	Date
Design Authority A. L. Ramble	A. L. Ramble T5-54	6/28/00
Cog. Eng. M. K. Ullah	M. K. Ullah T5-54	6/28/00
Cog. Mgr. R. A. Burk	NA	
QA D. R. Groth	per telecon 6/29/00 12:30 PM D. R. Groth	6/29/00
Safety S. E. Nunn	S. E. Nunn T5-51	6/28/00
Environ. J. E. Bramson	NA	
Other OSR rep. J. P. King	for J. P. King T5-54	6/29/00
Ind. Reviewer R. H. Meichle	R. H. Meichle	6/28/00
R. D. Redekopp PRR/SRB chair	R. D. Redekopp	6/29/00
R. L. Rholen	R. L. Rholen	6/28/00
B. J. Gray	B. J. Gray	6/28/00
USA Evaluator L. E. Edvalson	L. E. Edvalson	2/23/2001
USA Evaluator M. K. Ullah	M. K. Ullah	2/23/01

	Signature	Date
Design Agent		
PE		
QA		
Safety		
Design		
Environ.		
Other		

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature: DOE-RL letter # 01-ABD-044 dated 2/12/01, Supplement 9 to SER for PFP.

ADDITIONAL

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution (Information copy)	M. K. Ullah	Date 2/23/01
Project Title/Work Order		EDT No. N/A
HNF-SD-CP-SAR-021,Rev 2 Plutonium Finishing Plant Final Safety Analysis Report		ECN No. 660525

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
K. A. Hadley	T5-57	x			
R. H. Risenmay	T5-55	x			
C. S. Sutter	T5-50	x			
M. D. Talbot	T5-15	x			
R. E. Gregory	T5-08	x			
R. D. Cantwell	T5-57	x			
S. M. Sax	T5-15	x			
A. L. Ramble	A0-26	x			
D. G. Satterwhite	B4-46	x			
J. W. Todd	T5-54	x			
J. E. Spets	T5-54	x			
J. J. McCracken	R3-79	x			
S. S. Seth	A5-11	x			
H. E. Bell	R3-79	x			
S. K. Sen (DOE Headquarter)		x			
LIBRARIES					
270-Z Engineering Library	T5-54	x			
MO-032 Engineering Trailer	T4-20	x			

HNF-SD-CP-SAR-021
Revision 2
Volume 1,2 and 3
Copy No. __

PLUTONIUM FINISHING PLANT FINAL SAFETY ANALYSIS REPORT

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200
Fluor Hanford
P.O. Box 1000
Richland, Washington

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Revision 2
Volume 1,2 and 3

ECN 660525
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PLUTONIUM FINISHING PLANT FINAL SAFETY ANALYSIS REPORT

Document Type: SAR Division: NMS

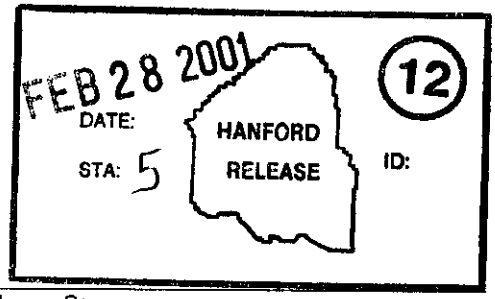
M K (Kaleem) Ullah
Fluor Hanford, Inc.

Date Published
February 2001

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P.O. Box 1000
Richland, Washington



2/26/01

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Revision 2
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Printed in the United States of America

Total Pages: 2493

RECORD OF REVISION

(1) Document Number: HNF-SD-CP-SAR-021

(2) Title: Plutonium Finishing Plant Final Safety Analysis Report

Change Control Record

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
		(5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) Initial release of entire PFP FSAR (EDT 141815)	J.E.Shapley	L.E. Johnson
0-A	Replace Chapter 2 in its entirety and Table of Contents (ECN 169397)	G.A. Funston	L.H. Rodgers
0-B	Replace Chapter 1 in its entirety and FSAR master Table of Contents (ECN 169397)	G.A. Funston	L.H. Rodgers
0-C	Replace Chapter 12 in its entirety and FSAR master Table of Contents (ECN 193441)	G.A. Funston	L.H. Rodgers
0-D	Replace affected pages in Chapter 9 (Too numerous to list) (ECN 189861)	G.A. Funston	L.H. Rodgers
0-E	Replace Chapter 3 in its entirety and FSAR master Table of Contents (ECN 193436)	G.A. Funston	L.H. Rodgers
0-F	Replace Chapter 4 in its entirety and FSAR master Table of Contents (ECN 193437)	G.A. Funston	L.H. Rodgers
0-G	Replace Chapter 5 in its entirety and FSAR master Table of Contents (ECN 193438)	G.A. Funston	L.H. Rodgers
0-H	Replace Chapter 6 in its entirety and FSAR master Table of Contents (ECN 193439)	G.A. Funston	L.H. Rodgers
0-I	Replace Chapter 7 in its entirety and FSAR master Table of Contents (ECN 193440)	G.A. Funston	L.H. Rodgers
0-J	Replace Chapter 8 in its entirety and FSAR master Table of Contents (ECN 193442)	G.A. Funston	L.H. Rodgers
0-K	Replace page changes to master TOC, Chapters 1,2,4,5,6,&9 and add addendum (TS) (ECN 632069)	A.L. Ramble	P.E. Roege
0-L	Replace page changes to master TOC, Chapters 1,2,4,5,6,&9 and add addendum (LPC) (ECN 638707)	A.L. Ramble	P.E. Roege
1	Reissue of entire FSAR (ECN 605799) See page 1-2 for incorporated ECN's	A.L. Ramble	P.E. Roege
RS 2	Reissue of entire FSAR (ECN-660525) incorporating ECNs against Rev.1 issued by March 15, 2000.	M.K.Ullah 2/26/01	R.E.Heineman,Jr 2-27-01
	Continued Rev.2: See attached listing of ECNs showing status of ECNs incorporated in Rev.2.		

ENGINEERING CHANGE NOTICE STATUS OF INCORPORATION

(6 sheets)

ECN No.	Change Description	Release Date	Incorp. in SAR Rev. No.
191508	Incorporate Project B-610-transfer control of Bldg. 2736-ZB HVAC from Allen-Bradley Programmable controller to PFP distributed control system (MICON™)	1/10/96	1
605799	Complete revision and reissue of entire FSAR	8/99	1
611939	Incorp. Installation of ANN-714 for safety class and safety significant alarms (part of MICON™ system)	2/5/97	1
616606	Changed sanitary sewer source description	3/16/00	2
616618	Change effluent sources to Sanitary Drain 2607-Z	6/19/98	1
629275	Change ventilation zones and controller setpoints to improve ventilation operations	6/14/96	1
631022	Implement changes to the air sample systems HEPA filtration	5/17/96	1
632069	Add Thermal Stabilization addendum and related chapter page changes to FSAR	6/16/99	0-K
634398'	241-Z Tank concentration changed	5/99	2
638707	Add Laboratory Prototype Calciner Addendum and related chapter page changes to FSAR	6/24/99	0-L
638722	ECN not issued	-	-
638850L	ESPC - plant change not done - no FSAR change	4/99	N/A
638853	ESPC - plant change not done - no FSAR change	3/99	N/A
638854	ESPC - plant change not done - no FSAR change	3/99	N/A
638855	ESPC - plant change not done - no FSAR change	3/99	N/A
640208'	Seismic shutdown switch connection to Laboratory Prototype Calciner	6/99	2
642356	Add description of calibration, functional testing and check source for neutron detectors	7/24/97	1
642358'	HA-21I glovebox criticality prevention features	2/00	2

ENGINEERING CHANGE NOTICE
STATUS OF INCORPORATION

(6 sheets)

ECN No.	Change Description	Release Date	Incorp. in SAR Rev. No.
643007	ESPC - plant change not done - no FSAR change	3/99	N/A
643008	ESPC - plant change not done - no FSAR change	3/99	N/A
643011	ESPC - plant change not done - no FSAR change	3/99	N/A
643012	ESPC - plant change not done - no FSAR change	3/99	N/A
643013	ECN not issued	-	-
643014L	ESPC - plant change not done - no FSAR change	3/99	N/A
643015L	Diesel Generator and wiring - plant change not done - no FSAR change	3/99	N/A
643016L	ESPC -plant change not done - no FSAR change	3/99	N/A
643207	Delete PRF CCL_4 alarm	7/6/98	1
645216	Production Calciner seismic solenoid valves - no FSAR change - Production Calciner operation not authorized.	12/12/97	N/A
646356	Sprinkler head designation -No FSAR change	5/99	N/A
646359	Production Calciner seismic solenoid valve - No FSAR change - Production Calciner operation not authorized.	2/10/98	N/A
646623	Beta CAM removal from PPSL	4/21/98	1
646781	Deletes use of hygrometer and relocates hygrometer	3/24/99	2
646804	Include a description of the access delay door override feature of the CAS	4/21/98	1
647385[1]	Change fire protection safety designation	7/99	2
647395	Delete specific locations of fire extinguishers	12/8/98	2
648960[1]	Relocate hygrometer	3/99	2
648973[1]	Adds drains in duct level	7/99	2
649626[1]	Updates glovebox dispersible plutonium limits in the OSR document for PFP	9/1/98	1
649765	Clarify CAS battery charger description	8/18/98	1
649770	Revise CAM & CAS text and location drawings	9/24/98	1

ENGINEERING CHANGE NOTICE STATUS OF INCORPORATION

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ECN No.	Change Description	Release Date	Incorp. in SAR Rev. No.
649771	Affects evacuation alarms	10/98	2
649932	Affects glovebox shielding description for gloveboxes HC-18M & HC-18BS	7/99	2
649940	Air compressor for Laboratory Calciner	7/99	2
649956	Added or changed material relating to thermal stabilization operations in Glovebox HC-21C and related gloveboxes. Complete revision of Chapter 12.0, revised glovebox inventory limits, and added appendix of PFP Hazard Evaluation	10/30/98	1
649957	Updates glovebox dispersible plutonium limits in the OSR document for PFP	9/17/98	1
649958	Revise table of Safety Systems and related equipment	10/30/98	1
650067	ECN not issued.	-	-
650068	ECN not issued	-	-
650830	Adds drains in duct level	7/99	2
650869	Disconnects unused evacuation alarms	2/99	2
651332	Vault fire sprinklers deactivation	3/99	2
651333	Vault fire sprinklers deactivation	3/12/99	2
651334	Vault fire sprinklers deactivation	3/12/99	2
651369	Electrical transformer removal	2/99	2
651387	Disconnect various electrical supplies - no impact on FSAR	3/99	N/A
651396	Affects safety designation of filters	3/99	2
651397	SEL changes - no impact on FSAR	3/99	N/A
651398	Supplemental ECN for miscellaneous changes to update FSAR	9/99	2
651399	Supplemental ECN to update filter loading in the seismic event accident analysis	9/99	2

ENGINEERING CHANGE NOTICE STATUS OF INCORPORATION

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ECN No.	Change Description	Release Date	Incorp. in SAR Rev. No.
651491	Seismic shutdown switch connection to Laboratory Prototype Calciner	5/99	2
651784	PRF roof repairs - no FSAR change required	1/99	N/A
651787	PRF roof repairs - no FSAR change required	1/99	N/A
651788	PRF roof repairs - no FSAR change required	1/99	N/A
651812	PRF roof repairs - no FSAR change required	1/99	N/A
651820	PRF roof repairs - no FSAR change required	2/99	N/A
652208	PR container drum sleeve added for 3 L polybottle	12/99	2
652804	Electrical transformer modifications	3/99	2
652825	Laboratory Calciner seismic shutdown -no change required	6/99	N/A
652967	Seismic shutdown switch connection to Laboratory Prototype Calciner	6/99	2
653352	Building 234-5Z and 242-Z description	4/6/99	2
653367	Changes building designations	7/99	2
653584	Remove Tank A-114 from Building 236-Z; work not done - no change to FSAR.	3/99	N/A
653595	Adds thermal stabilization in Glovebox HA-21I	1/25/00	2
653598	Changes operational control for Glovebox HA-21I	2/23/00	2
653739	Related to Cementation - not incorporated in FSAR	8/99	N/A
654336	Related to Cementation - not incorporated in FSAR	9/99	N/A
654348	Seismic shutdown switch connection to Laboratory Prototype Calciner	8/99	2
654414	Air compressor for Calciner	7/99	2
654420	PPSL sink removal	12/20/99	2
654879	Description of CO2 supply to Glovebox HC-21C	10/20/99	2
655239	Glovebox lead glass addition to Gloveboxes HC-18M & HC-18BS	11/99	2

ENGINEERING CHANGE NOTICE
STATUS OF INCORPORATION

(6 sheets)

ECN No.	Change Description	Release Date	Incorp. in SAR Rev. No.
655244	Glovebox lead glass addition to Gloveboxes HC-18M & HC-18BS superseded by ECN-655245	12/99	N/A
655245	Glovebox lead glass changes in Gloveboxes HC-18M & HC-18BS	1/00	2
655247	HA-21I glovebox criticality prevention feature addition	1/00	2
656225	HEPA waste segregation requirement change	10/25/99	2
656247	Repackaging glovebox modification	3/00	2
656248	PPSL sink removal	12/99	2
656251	Temporary transformer - no change to FSAR	12/99	N/A
656252L	Temporary transformer - no change to FSAR	12/99	N/A
656253L	Temporary transformer - no change to FSAR	12/99	N/A
656257	Temporary transformer - no change to FSAR	11/99	N/A
656260	Electrical panelboard update - no impact on FSAR	11/99	N/A
656263	Glovebox HC-21C furnace redesignation - no impact on FSAR	1/00	N/A
656264	Glovebox HC-21C furnace redesignation - no impact on FSAR	1/00	N/A
656916	HA-21I glovebox criticality prevention feature addition	12/99	2
657075	Description of respiratory protection requirements change	11/15/99	2
657097	HA-21I glovebox criticality prevention feature addition	2/00	2
657600	Steam heating addition to Building 241-Z - no impact on FSAR	12/99	N/A
657609	PR container drum sleeve added for 3 L polybottle	2/29/00	2
657610	HC-21C furnace redesignation ~~to~~ impact on FSAR	2/11/00	2 ~~N/A~~ 2/28/01
657612	Thermal Stabilization ECN reissue for FSAR Rev.1- ~~no~~ impact on FSAR	2/7/00	~~N/A~~ 2 2/28/01
657613	Vault 225 assignment of responsibility change	2/29/00	2

ENGINEERING CHANGE NOTICE STATUS OF INCORPORATION

(6 sheets)

ECN No.	Change Description	Release Date	Incorp. in SAR Rev. No.
657614	Airborne sampling & monitoring requirements description change	1/24/00	2
657627[1]	HA-21I glovebox criticality prevention feature addition	2/00	2
657636	Repackaging glovebox airflow description change	3/21/00	2
657674	Change backup power source description	3/00	2
659385	Glovebox inventory limits incorporated as applicable to FSAR Rev. 2 accident analysis.	4/00	2
708423	Delete references to gaseous effluent levels in tables and text	6/23/98	1
709055L	Laboratory Calciner air filter regulator temporary change - no impact on FSAR	6/99	N/A
710041	Clarify waste drum closure and handling requirements	3/2/00	2

[1] Note: This ECN is for reference only.

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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 1.0

INTRODUCTION AND GENERAL PLANT DESCRIPTION

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 1.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) includes modifications for the following:

- Changes in the management and organizational structure of the PHMC and the PFP
- Changes in the physical scope of the 234-5Z Building
- Changes in the list of active processes at the PFP
- Incorporation of the Magnesium Hydroxide Precipitation Process
- Incorporation of the Bagless Transfer System

Other minor changes include editorial changes and additional clarifications.

It is noted that various sections of Chapter 1.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner located in the Plutonium Process Support Laboratories. Operation of either the production calciner or the laboratory calciner for solution stabilization is not authorized at this time and the related portions of Chapter 1.0 will be updated, if necessary, prior to initiation of operations.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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1.0 INTRODUCTION AND GENERAL PLANT DESCRIPTION

1.1 INTRODUCTION

The Plutonium Finishing Plant (PFP) is located on the U.S. Department of Energy (DOE) Hanford Site in south central Washington State. The DOE Richland Operations (DOE-RL) Project Hanford Management Contract (PHMC) is with Fluor Hanford Inc. (FH). Westinghouse Safety Management Systems (WSMS) provides management support to the PFP facility.

Since 1991, the mission of the PFP has changed from plutonium material processing to preparation for decontamination and decommissioning (D&D). The PFP is in transition between its previous mission and the proposed D&D mission. The objective of the transition is to place the facility into a stable state for long-term storage of plutonium materials before final disposition of the facility. Accordingly, this update of the Final Safety Analysis Report (FSAR) reflects the current status of buildings, equipment, and operations during this transition.

The primary product of the PFP was plutonium metal in the form of 2.2-kg, cylindrical ingots called "buttons". Plutonium nitrate was one of several chemical compounds containing plutonium that were produced as an intermediate processing product. Plutonium recovery was performed at the Plutonium Reclamation Facility (PRF) and plutonium conversion (from a nitrate form to a metal form) was performed at the Remote Mechanical C (RMC) Line as the primary processes. Plutonium oxide was also produced at the Remote Mechanical A (RMA) Line. Plutonium processed at the PFP contained both weapons-grade and fuels-grade plutonium materials. The capability existed to process both weapons-grade and fuels-grade material through the PRF and only weapons-grade material through the RMC Line although fuels-grade material was processed through the line before 1984. Amounts of these materials exist in storage throughout the facility in various residual forms left from previous years of operations.

Plutonium recovery, plutonium conversion, and oxide production are no longer performed at the PFP. Parts of the plutonium conversion process area are now used for reactive plutonium-bearing material stabilization and for plutonium-bearing solution stabilization operations. These operations convert the plutonium material into a more stable oxide form. Additional information concerning plutonium products can be found in Chapter 4.0.

Limited discussions of past plutonium conversion and recovery processes are retained in order to convey understanding of the current conditions. More detailed discussions of previous processes are presented in Chapter 6.0, Sections 6.4.3 and 6.6.

Plutonium material at the PFP is categorized according to the level of protection needed to prevent diversion. Individual Material Balance Area (MBA) inventories of category 1 material at any given time are classified information. The plutonium material inventory in any given location at the PFP is based on Criticality Prevention Specification (CPS) requirements and/or the limits established as a result of the accident analyses presented in Chapter 9.0. Control of these limits is assured by inclusion in the plant Operational Safety Requirements (OSR) (see Chapter 11.0) that are contained in

WHC-SD-CP-OSR-010, *Plutonium Finishing Plant Operational Safety Requirements* (WHC 1994). The theoretical maximum inventory at the PFP can be determined by summing the individual limits using the following assumptions.

- All process lines contain the maximum possible inventory based on the OSRs.
- All storage locations contain the maximum possible inventory based on the OSRs.
- All hoods, gloveboxes, and other nonprocess line operating areas contain the maximum inventory based on the OSRs.

It is not readily possible to separate the plant inventory into specific chemical or physical forms at any given point in time. Since processes have been curtailed, the principal solid chemical forms are plutonium oxide (PuO_2) and plutonium metal. The bulk of the plutonium solution is plutonium nitrate [$Pu(NO_3)_4$]. Other compounds, such as PuF_4 or plutonium oxalate, comprise a minor percentage of the limit and were normally found in the RMC Line. Additionally, there are a number of storage containers holding materials that are not well characterized chemically. See Chapter 4.0, Section 4.2.1, and Chapter 8.0, Section 8.2, for discussions of the various plutonium-bearing chemical compounds that may be identified in the PFP inventory.

The responsibility for operation of the facility is assigned to WSMS. Organizational responsibilities for the PFP are described in *Plutonium Finishing Plant Administration*, FSP-PFP-5-8. See Chapter 10.0 for discussion of the PFP organizational structure.

1.1.1 Safety Analysis Report Overview

This PFP FSAR replaces all previous PFP safety analysis reports. Efforts for developing an integrated FSAR for the PFP began in December 1988 using guidance from the January 1976 version of U.S. Nuclear Regulatory Commission Regulatory (NRC) Guide 3.39, *Standard Format and Content of License Applications for Plutonium Processing and Fuel Fabrication Plants*, (NRC 1976), and HNF-PRO-704, *Hazard and Accident Analysis Process.*

As originally prepared and approved by the DOE, the scope of Revision 0 of the FSAR included operation of the principal facility plutonium material processes and attendant activities. Accordingly, the FSAR presented detailed descriptions of production operations, equipment, and processes. The FSAR has been updated to more accurately reflect the current operational status of the PFP since fiscal year (FY) 1995 in accordance with operating contractor management agreement to maintain the FSAR by performing annual updates and by implementing the Unreviewed Safety Question (USQ) process. This update of the PFP FSAR also serves to incorporate commitments made to DOE as documented in the *Plutonium Finishing Plant Safety Evaluation Report* issued by the DOE (DOE 1995a) and addenda. As a result of changes in the plant mission, many of the operations described and analyzed in the original FSAR are now inactive or shut down. Active processes are those that are both operational (i.e., equipment is in place and functional) and authorized by this FSAR to operate. Inactive or shutdown operations, equipment, or facilities may either be

operable (or operational) and not authorized for operations (not in use) or may not be operational and would require modifications before use. Additional supporting documentation, including safety analyses, must be approved before a new or modified process may be operated. From a safety analysis perspective, the PFP USQ Determination process ensures that changes to operable processes are properly incorporated into the PFP authorization basis. The current status of major portions of the PFP is as follows.

1.1.1.1 **Active Processes**. The following comprise the current, active processes at the PFP:

- Plutonium material storage and support activities in the 2736-Z, 2736-ZA, and 2736-ZB Buildings, 2736-ZD vault, and the gloveboxes and vaults in the 234-5Z Building
- Reactive plutonium-bearing material stabilization in the 234-5Z Building using Glovebox HC-21C and HA-21I.
- Waste packaging and reactive residue storage
- Transfer operations in gloveboxes HC-227S/T in the 234-5Z Building
- Low-level waste and waste water treatment in the 241-Z Complex and 243-Z Building, respectively
- The PFP Analytical Laboratory (PFP AL), Standards Laboratory, and PPSL in the 234-5Z Building
- Facility support systems [e.g., heating, ventilation, air conditioning (HVAC), radiation monitoring, steam, electricity, etc.].
- Bagless Transfer system operations in Glovebox HA-53BTS in the RMA Line in the 234-5Z Building
- Magnesium Hydroxide Precipitation Process operations in Gloveboxes HC-230C-3 and HC-230C-4 in the RMC Line in the 234-5Z Building

1.1.1.2 **Inactive Processes**. The following comprise the now inactive processes that are not currently authorized under the current mission objectives:

- Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner in Building 234-5Z
- Plutonium-bearing solution stabilization using the Laboratory Prototype Calciner in the Plutonium Process Support Laboratory (PPSL) in Building 234-5Z
- Plutonium recovery in the 236-Z Building
- Plutonium conversion in the 234-5Z Building
- Waste treatment in the 242-Z Building

- Laboratory waste concentrator.

1.1.2 Facility Overview

The PFP buildings and structures are shown in Figure 1-1. The majority of the buildings and structures that comprise the PFP are listed in Table 1-1. The principal PFP structure, the 234-5Z Building, was completed in 1949 to purify plutonium nitrate solutions, reduce the nitrate to plutonium metal, and fabricate plutonium metal into buttons. The 234-5Z Building houses plutonium processing operations, process support services, laboratories (PFP AL, Standards, and PPSL), and facility services. The 241-Z Liquid Waste Treatment Facility and the 291-Z Building, which houses ventilation exhaust fans and mechanical service equipment, were built at the same time as the 234-5Z Building. An incinerator, housed in the 232-Z Building, was completed in 1961 and was used to recover plutonium from combustible scrap. Plutonium reclamation and waste treatment equipment are housed in the 236-Z and 242-Z Buildings, respectively, which were completed in 1964. See Chapter 5.0, Sections 5.1 and 5.2, for details of PFP facilities construction history and current functions of specific buildings.

The original design of the PFP process facilities provided for all of the planned operations and laboratories to be located in the 234-5Z Building, except for waste collection and disposal. With increases in production, storage, and scrap recovery requirements, these major additions were made: the PRF (236-Z Building), the Waste Treatment Facility (242-Z Building), Waste Incinerator Facility (232-Z Building), and the Support/Storage Complex (2736-Z, 2736-ZA, 2736-ZB, and 2721-Z Buildings). Subsequently, the Low-Level Waste Treatment Facility (LLWTF) (also referred to as the 243-Z Building) and an upgraded men's changeroom (234-5ZA Building) became operational. See Chapter 5.0, Section 5.2, for details of specific facility buildings.

Various facilities are used for storage of compressed gases, chemicals, and other process materials. See Chapter 5.0, Sections 5.2, 5.4.4, and 5.4.13 for more details of specific facilities used for chemical and process materials storage.

1.1.2.1 General Services. The Hanford Site utilities servicing the PFP provide for electricity and water. A description of each is provided in Chapter 5.0, Section 5.4. A summary description is provided below.

- Normal power supply--Electrical power is supplied to the Hanford Site from the Bonneville Power Administration substation at Midway through a 230-kV loop to all outer areas. The H. J. Ashe switchyard provides a redundant supply of 230-kV electrical power. This source is switched automatically into the 230-kV loop to all outer areas on loss of power from the Midway substation. See Chapter 5.0, Section 5.4.2, for details of the electrical systems supporting the PFP facilities.

- Standby power--Standby power is available from three 325-kW diesel generators, housed in the 2721-Z Building. See Chapter 5.0, Section 5.4.2, for details of the backup power system used at the PFP.

- Uninterruptible power supplies--An uninterruptible power supply (UPS), in the form of batteries, is provided for operation of the seismic shutdown system, critical computer systems, critical equipment, some alarm systems, backup power systems, and communications system (i.e., the PAX system) when there is loss of normal and emergency power. See Chapter 5.0, Section 5.4.2, for details of the UPS system.

- Water supply and distribution system--All of the water supply needs for the PFP are provided by three sanitary water system lines. Water is routed from the 283-W filter plant and clear wells to the PFP sanitary water service loop via a 10 in. diameter line that feeds into the loop at the southeast corner, an 8 in. diameter line on the north side, and a 12 in. dia line that feeds into the loop at the northeast corner. See Chapter 5.0, Section 5.4.7, for details of the water system.

Steam is furnished to the PFP from dedicated oil-fired boilers located in Building 234-5Z-BA which is just to the north of the PFP facility, outside its security fence, and near the 231-Z Building. The steam supply from the dedicated boilers is used for space heating, heating of ventilation system supply air, steam-turbine-driven emergency exhaust fans, and jet transfers of liquid wastes.

1.1.3 Operations Overview

During the transition phase between operations (plutonium production-related activities) and D&D, the following activities are conducted in the PFP:

- Plutonium material receiving, storage, and shipping (includes transfer operations in gloveboxes HC-227S/T)

- Reactive plutonium-bearing material stabilization

- Plutonium-bearing solution stabilization using the Laboratory Prototype Calciner in Glovebox 188-1 (not authorized for operation)

- Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner in Glovebox HC-230C-2 (not yet authorized)

- Laboratory and engineering support

- Waste handling

- Active and inactive facilities surveillance.

Additional details of plutonium material receiving, storing, and shipping activities are provided in Chapter 6.0, Sections 6.2 and 6.3. Reactive plutonium-bearing material stabilization and plutonium-bearing solution stabilization are described more fully in Chapter 6.0, Section 6.4. The equipment associated with past operations of plutonium recovery and plutonium

conversion are identified in Chapter 5.0. Laboratory and engineering support is provided by the PPSL, Standards Laboratory, and the PFP AL. These laboratories are described in more detail in Chapter 5.0, Section 5.4.14, and Chapter 6.0, Section 6.5. Waste handling is discussed in Chapter 7.0. Active and inactive facility surveillance is discussed in Chapters 5.0, 6.0, and 8.0. Brief summaries of these activities are provided in Chapter 1.0, Section 1.3.

The operations listed above comprise the major activities considered in this FSAR. For clarity, some operations and the associated equipment are discussed briefly even though they are out of service and not expected to be used again. These former operations include the following:

- RMC Line plutonium conversion operations: 234-5Z Building
- PRF plutonium recovery operations: 236-Z Building
- Electrolytic metal dissolution: 236-Z Building/glovebox MT-3
- Incinerator ash calcination: 234-5Z Building/glovebox HA-40F
- Polycube calcination: 236-Z Building/glovebox MT-4
- RMA Line button and oxide production gloveboxes: 234-5Z Building/ rooms 235-A1, 235-A2, and 235-A3
- 232-Z Incinerator Building
- Waste treatment and americium extraction: 242-Z Building.

Plutonium conversion (i.e., from a nitrate form to a metal form) and plutonium recovery operations are no longer conducted in the 234-5Z and 236-Z Buildings. Reactive plutonium-bearing material stabilization operations and plutonium-bearing solution stabilization operations are performed in the 234-5Z Building (see Chapter 5.0, Section 5.2.1.2, for details of the equipment used in the stabilization processes and Chapter 6.0, Section 6.4, for details of the processes). If plutonium conversion or recovery operations are resumed at the PFP, new analyses will be performed, if necessary, and the FSAR will be updated appropriately.

To properly evaluate the impact to the environs from catastrophic natural events, the residual plutonium material remaining from former campaigns are included in the source terms used in the accident analyses. The impact of these source terms has been addressed in the analyses in Chapter 9.0 and other chapters where appropriate.

Since the PFP startup in 1949, operations necessary to decontaminate and decommission (D&D) obsolete process lines and cleanout facilities have been conducted as required. At the PFP these activities are referred to variously as facility cleanout, or terminal cleanout operations and D&D. Information on conduct of operations for D&D activities is found in Chapter 10.0. The status of specific facilities at the PFP is discussed in Chapter 5.0.

1.2 GENERAL PLANT DESCRIPTION

1.2.1 Site Characteristics

The PFP is located in a semi-arid desert in south-central Washington State (Figure 1-2). The facility is in the west-central portion of the Hanford Site, in the 200 West Area (Figure 1-3). Major activities of various areas of the Hanford Site are as follows.

- 100 Areas--These areas contain retired plutonium production reactors and spent fuel storage facilities.
- 200 East and 200 West Areas--The 200 Areas are dedicated to waste management activities, laboratory support, waste characterization, and nuclear material processing.
- 300 Area--The major activity in this area is nuclear research and development. Unirradiated nuclear fuel is also stored in this area.
- 400 Area--This area contains the shutdown Fast Flux Test Facility (FFTF), the Fuel Cycle Plant (i.e., Fuels and Materials Examination Facility, which was never activated) and related support facilities for the liquid metal reactor program (inactive).
- 600 Area--The 600 Area includes all of the Hanford Site not occupied by the other listed areas. Some of the land uses include the Fitzner/Eberhardt Arid Lands Ecology Reserve; a small 100-acre tract privately leased for the burial of commercial low-level nuclear waste; the Energy Northwest lease for the operation of the Columbia Generating Station nuclear power plant; a U.S. Fish and Wildlife Refuge; a recreational game site leased to the Washington State Department of Game; and the Laser Interferometer Gravitational Observatory.
- 700 Area--The 700 Area primarily serves as an administrative center for government employees involved in overseeing contractor-operated facilities and programs at the Hanford Site.
- 1100 Area--This area serves as a center for central warehousing and transportation/distribution.
- 3000 Area--This area is not generally used by the Hanford Site contractors.

The location of the PFP relative to other plants located in the 200 West Area is shown in Figure 1-4. The PFP Emergency Response Zone in the 200 West Area is shown in Chapter 5.0, Figure 5-4. The PFP is well above the present groundwater and flood plains of nearby rivers, as discussed in Chapter 3.0.

Chapter 3.0 provides the site characteristics of the PFP. Typical meteorological conditions include a small amount of precipitation, light snowfall, moderate temperatures, and winds primarily from the northwest. Tornado occurrence is so low that it need not be analyzed per *Standard*

Architectural Civil Design Criteria, Design Loads for Facilities, SDC-4.1 (DOE-RL 1993), which is based on UCRL 15910, *Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards* (Kennedy et al. 1990). Hydrological events; severe cold; acute thaws; and heavy rain, snow, or ice storms do not occur with intensities requiring special design. Design criteria (e.g., criteria for natural phenomena hazards) for the PFP Complex are discussed in Chapter 4.0.

The nearest known geological fault lies within 5 mi of the PFP site (see Chapter 3.0, Section 3.6. The nearest volcanic activity is 100 mi away (see Chapter 3.0, Section 3.6.6).

1.2.2 Facility Description

1.2.2.1 Plutonium Finishing Plant Buildings. The buildings and support facilities/structures comprising the PFP are shown in Figure 1-1 and listed in Table 1-1. The major PFP buildings are briefly described below with more detailed descriptions given in Chapter 5.0, Section 5.2. More detailed descriptions of the facilities listed in Table 1-1 are provided in Chapter 5.0. The PFP design criteria and compliance with codes and standards is presented in Chapter 4.0, while waste-handling facilities are discussed in Chapter 7.0. Discussion of the facilities' support systems can be found in Chapter 5.0, Section 5.4. Discussion of the processes performed in the buildings is provided in Chapter 6.0.

1.2.2.1.1 The 234-5Z Building. The 234-5Z Building is approximately 180 ft wide by 500 ft long and extends from 9.5 ft below grade to 46.8 ft above grade. Floor levels are designated as the basement, first floor, duct level, second floor, and roof level. Noncombustible materials of construction are used. The frame is of structural steel with an outer sheathing of aluminum panels over rock wool insulation and 16-gauge sheet steel. The first floor is a concrete slab, the duct level is sheet metal roof decking, and the second floor is a concrete slab. The roof is insulated metal decking. Interior walls are reinforced-concrete steel structure, metal studs, metal lath, and plaster. The vault and process area doors are constructed of steel with combination safe-type locks. An aerial view of the PFP with a cutaway view of the 234-5Z Building is shown in Figure 1-5.

The 234-5Z Building basement primarily consists of pipe tunnels containing drain piping and sumps. The first floor houses the two former plutonium processing lines (RMA and RMC Lines) and associated control rooms; reactive plutonium-bearing material stabilization gloveboxes; plutonium-bearing solution stabilization gloveboxes; plutonium storage vaults; the plutonium nitrate feed load-in/load-out (LI/LO); blending and storage facilities; the PPSL, Standards Laboratory, and PFP AL; the instrument maintenance shops; the building maintenance shops; locker rooms with change facilities and restrooms; and office spaces. The duct level contains most of the service piping, ventilation ducts, and some filterboxes.

The lunchroom, a plastics shop, conference room, materials storage room, chemical feed preparation and aqueous makeup rooms, locker rooms with change facilities and restrooms, and office spaces are on the second floor. The second floor also contains exhaust-air ductwork including filterboxes, filter

rooms, and the fan room. The fan room houses the ventilation supply fans, the steam inlet and distribution system, air dryers, the distilled water still, air chilling units, and the vent and balance control room.

1.2.2.1.2 The 236-Z Building. The 236-Z Building, commonly known as the PRF, is south of the southeastern corner of the 234-5Z Building and is connected to it by the 242-Z Building. A cutaway view of the building is shown in Figure 1-6. The 236-Z Building is essentially a four-story structure, surmounted by a two-story penthouse. Its dimensions are approximately 79 ft wide by 71 ft long. Its principal internal feature is a single process equipment cell that is 32 ft wide by 52 ft long.

The 236-Z Building is of reinforced-concrete construction, with the exception of the roof and the fourth-floor ceiling. The roof is of open-web steel joist framing, steel decking, rigid insulation, and graveled built-up roofing. A portion of the southern building wall is also the south wall of the process cell and includes an opening in the reinforced concrete wall, filled by a door and surrounding block wall. The concrete block wall has been steel-plated and reinforced to withstand seismic effects.

Maintenance shop facilities are located on the service (east) side of the building on the ground floor. The second floor of the service side is used for a maintenance glovebox and ventilation exhaust filters. Building service equipment and electrical switch gear are on the third floor of the service area. The fourth floor was used for chemical preparation, miscellaneous treatment, operating control room, slag and crucible dissolver equipment, and a column room in which vertical sections of two liquid extraction columns penetrating the room from above and below are housed in a glovebox. The first through the fourth floors are serviced by a service elevator on the east side of the building.

1.2.2.1.3 The 232-Z Building. The 232-Z Building (shown in Figure 1-7) housed the contaminated waste recovery process and is commonly called the "Incinerator Building." The contaminated waste recovery process underwent partial D&D in 1984 and again in 1995 and 1996. The 232-Z Building is located approximately 200 ft south of the main portion of the 234-5Z Building and is approximately 100 ft west of the 291-Z-1 stack.

The 232-Z Building is of concrete block construction and is approximately 37 ft wide by 57 ft long. It is divided into areas for processing, storage, a changeroom, chemical preparation, ventilation, and electrical equipment.

1.2.2.1.4 The 241-Z Complex. The 241-Z Complex (shown in Figure 1-8) is the liquid waste treatment facility. It is the Resource Conservation and Recovery Act (RCRA)-permitted treatment, storage, and disposal facility for PFP radioactive mixed waste. It is a buried, reinforced-concrete structure with a sheet metal enclosure over the top. The enclosure houses a hoist for removing cell covers and the ventilation piping and filters. The buried structure consists of five separate ventilated cells, each containing a 20,000-L tank (one tank, TK-D6, has been isolated and left in place). The tanks (TK-D4, TK-D5, TK-D7, and TK-D8) are used to accumulate and treat the radioactive liquid wastes (RLW) generated in the PFP before transfer to the tank farms. The 241-Z Building is approximately 20 ft wide, 92 ft long,

and 22 ft deep, and is located approximately 330 ft south of the 234-5Z Building.

At the southwest corner of the 241-Z vault deck is a weather enclosure containing the equipment for the 241-Z vessel vent filters and vault ventilation system. The 24-ft-high stack, 296-Z-3, and its associated fans, and controls are located on a 14-ft by 18-ft concrete pad.

The 241-Z Complex also consists of the 241-ZA Sampling Building, 241-ZB Caustic Tank, and the 241-Z-RB Retention Basin (the caustic tank and retention basin are to be removed soon).

1.2.2.1.5 The 242-Z Building. The 242-Z Building houses portions of the waste treatment facility and the americium facility, which are inoperable. A cutaway view of the 242-Z Building is shown in Figure 1-9. The 242-Z structure lies between the southeastern corner of the 234-5Z Building, and the 236-Z Building. A corridor along the east side connects the 234-5Z, 242-Z, and 236-Z Buildings. An entrance enclosure along the west side is for outside entry into both 242-Z and the analytical laboratory area in the 234-5Z Building. Both the east side corridor and the west side entrance are considered to be part of the 234-5Z Building, not the 242-Z Building.

The building is approximately 40 ft wide, 26 ft long, and 23 ft high. The south portion, approximately 40 ft wide by 10 ft long, is the tank room (tank cell). This room extends the full inside building height. The north portion, designated the control room, has a mezzanine over its west half for chemical addition tanks.

The south wall of the 242-Z Building is of reinforced concrete. The remainder of the building has a structural steel frame covered with metal lath and plaster internally, and insulating material wall panels externally. The slightly peaked roof is constructed of metal decking, covered by insulation and built-up asphalt and gravel.

The tank room in the 242-Z Building houses large, empty process vessels, with pipe connecting to the process gloveboxes in the control room. The 242-Z Building shares its ventilation system with the main ventilation system in the 234-5Z Building. All nonessential utilities and services have been isolated.

1.2.2.1.6 The 291-Z Building. The 291-Z Building (also known as the Exhaust Fan House, Exhaust Air Stack Building, and Compressor and Fan House) is a reinforced-concrete structure approximately 53 ft south of the central part of the 234-5Z Building. A cutaway view is shown in Figure 1-10. Of irregular shape, its approximate dimensions are 74 ft wide by 143 ft long. Its overall height is approximately 23 ft, with only 4 ft above grade. This building houses the exhaust fans, the mechanical service equipment, and an electrical substation.

Auxiliary to the 291-Z Building is the 200-ft-high 291-Z-1 stack. Constructed of reinforced concrete, its center is 63 ft from the near end of 291-Z and 230 ft from the south wall of the 234-5Z Building.

1.2.2.1.7 The 2736-Z Complex.

The 2736-Z Building. The 2736-Z Building, shown in Figure 1-11, is the primary PFP plutonium storage facility. The 2736-Z Building is approximately 65 ft long by 56 ft wide. The building consists of four vaults for the storage of plutonium materials, divided by a corridor running the width of the building. Each storage room is approximately 28 ft by 28 ft in size. The building is constructed of reinforced concrete walls, 14 in. thick, supported by cast-in-place concrete columns. The roof is a cast-in-place concrete slab, 6.5 in. thick.

The 2736-ZA Building. The 2736-ZA Building, approximately 5 ft west of the 2736-Z Building, contains exhaust fans and HEPA filters, stack CAMs and sampler, and instrumentation related to operation of the 2736-Z Building.

The 2736-ZB Building. The 2736-ZB Building, located immediately to the south of the 2736-Z Building, is approximately 132 ft by 90 ft with reinforced concrete walls (except for administrative areas) and roof. A cutaway view is shown in Figure 1-12.

The 2736-ZB Building shipping and receiving areas are each provided approximately 1,000 ft^2 of floor space to accommodate a maximum of 100 shipping containers the size of 55-gal drums. Adequate spacing is provided between containers to meet criticality prevention and personnel exposure specifications, as well as allowing corridor access to staging areas. The two areas are physically separated by a wall.

Separate airlocks are provided for personnel and material access. In addition, administrative controls maintain security and safeguards control during the shipping and receiving operations.

The 2736-ZC Loading Dock. The 2736-ZC consists of an enclosed loading dock and corridor for the 2736-ZB Building.

The 2736-ZD Vault. The 2736-ZD storage vault is an outside, cylindrical concrete vault used to store three Experimental Breeder Reactor (EBR)-II casks.

The 2721-Z Building. The 2721-Z Building houses the backup electrical power generators for the PFP Complex.

1.2.2.1.8 The 243-Z Building.

The 243-Z Building, known as the Low-Level Waste Treatment Facility, provides for treatment of the PFP effluents to remove low-level radioactive and chemical contamination. The building consists of five rooms with a vestibule providing direct access to the change room and then from there, into the process area. The associated 243-ZA Building contains the sump for the 243-Z tanks. The 243-ZB is a concrete slab for the closed-loop cooling water system.

The process area contains tanks, pumps, filters, and the associated piping and instrumentation necessary for operation and monitoring the equipment and incoming waste streams. After the building influent has been processed, it is monitored to ensure that it meets the environmental

requirements for release. If the effluent does not meet requirements, it can be recycled and retreated.

1.2.2.2 Principal Design Criteria. The principal safety-related design criteria for the PFP facilities met applicable criteria at the time of construction. A detailed discussion of design criteria is provided in Chapter 4.0. The design criteria for the major PFP buildings are discussed in Chapter 5.0, Section 5.2.

1.2.2.3 Utility and Service Systems. The only utilities distributed throughout the Hanford Site are electricity, water, and telecommunications. Other utilities (e.g., steam and sewer) are confined to specific operating areas. The DOE has a contract with the Bonneville Power Administration that gives the Hanford Site electricity supply priority over other users.

Four 13.8-kV electrical overhead distribution lines provide electrical power to the 200 West Area (two of which supply the PFP) from the 251-W substation. Major components in the supply of electric power to the PFP are high voltage transmission lines, transformers, large switchgear units, diesel generators, and battery stations. Backup electricity generators are provided to supply electrical power for the PFP following the interruption of normal power. A detailed description of the electrical system for the PFP is presented in Chapter 5.0, Section 5.4.2.

The water supply system for the PFP is obtained from the 283-W filter plant and clear wells via three feed lines that lead into the sanitary water loop. The PFP process buildings are supplied with main branches that are connected directly to the PFP sanitary water loop. The majority of these mains are for fire protection and the rest are for sanitary and process water. The largest normal use of sanitary water is to feed the ventilation supply units for air washing and evaporative cooling for air conditioning the supply air. A detailed description of the water supply system for the PFP is presented in Chapter 5.0, Section 5.4.7.

1.2.2.3.1 Supply Air and Gas Systems. The PFP has three categories of compressed-air supply systems available: process, instrument, and dry. The process air system is provided as a general purpose air supply throughout the PFP for air cylinders, aspirators, air tools, etc., by two water-cooled, two-stage, reciprocating compressors. Process air is distributed from a receiver tank in the 291-Z Building to a general distribution air header in the 234-5Z Building. Separate lines provide general purpose air to other buildings. The instrument air system is also provided via the same air compressors. The dry air system in the 234-5Z Building is currently used to supply compressed air only while a separate system is functional in the 2736-ZB Building. A detailed description of the compressed air system for the PFP is presented in Chapter 5.0, Section 5.4.3.

Breathing air is provided by the Portable Cascade Bottle System for use in radiation or toxic areas where respiratory protection is required. Breathing air at the PFP is discussed in Chapter 8.0, Section 8.5.1.

Process air for plutonium-bearing solution stabilization operations using the production vertical denitration calciner process is supplied by compressed air cylinders in the 234-5Z Building. The air is used to atomize the calciner

feed solutions and to backwash filters in the calciner. Compressed air for solution stabilization operations is discussed in Chapter 5.0, Section 5.2.1.2.2 and Chapter 6.0, Section 6.4.1.1.1A.

Air supply for operation of the laboratory prototype calciner in PPSL Room 188 is provided by a dedicated high-quality air compressor located at the west end of the Building 234-5Z duct level.

Nonradioactive gases are supplied from bottle storage buildings (sheds) located adjacent to the major PFP Buildings. Gases include P-10, oxygen, compressed argon, etc. Detailed descriptions of the PFP gas systems are presented in Chapter 5.0, Section 5.4.4.

1.2.2.3.2 Vacuum Systems. There are three basic types of vacuum systems used in the PFP processes; the 26-in. mercury system, 17-in. mercury systems, and the 5-in. mercury system. The 26-in. mercury system is used for vacuum transfers of process liquids, to provide the vacuum requirements needed for the plutonium-bearing solution stabilization process and for other high vacuum requirements, the 17-in. mercury system provides the motive force for the continuous air monitors and fixed air samplers, and the 5-in. mercury system is used to draw offgasses during the thermal stabilization process. Detailed discussions of these systems are presented in Chapter 5.0, Section 5.4.5. A detailed discussion of plutonium holdup associated with the vacuum systems is located in Chapter 8.0, Section 8.2.1.

1.2.2.3.3 Facility Confinement Features. Several design features are included in the PFP to assure confinement of the radioactive materials in their designated areas (see Chapters 4.0 and 8.0 for details of the facility confinement features in use at the PFP).

Features of the process areas in the 234-5Z Building (e.g., arrangement of piping) ensure the confinement of radioactive materials and reduce personnel exposure. The arrangement of the areas provide the following features:

- Many, but not all, gloveboxes are connected by an enclosed conveyor so that removal of product from gloveboxes is not required during processing.
- Process steps are combined to reduce transfers.
- Maintenance and Operations personnel access is provided through doors from a separate corridor along the back of the rooms housing the gloveboxes.
- Access to all sides of the gloveboxes is provided wherever practicable.

In all cases practicable, piping for radioactive materials is within an encasement that can be monitored for leaks. Ongoing system upgrades are replacing the concrete encasements for liquid effluent lines with encased piping (i.e., a pipe within a pipe). Vacuum is used wherever practical to transfer radioactive solutions to avoid transfer of solutions under pressure.

Standard confinement zone designations specify the inner contaminated zones as zone 1 and the outer clean zones as zones 3, 4, etc. However, except for the 2736-ZB Building, the PFP zone designations are reversed such that zones 3 and 4 are the contaminated inner zones and zone 1 is the clean outer zone.

Design criteria for new facilities specify that zone 3 and zone 4 areas be surrounded by zone 1. This buffer zone provides additional assurance of containment. Some of the PFP buildings have exterior walls that provide containment for zone 3 and zone 4 areas [e.g., the south side of Building 234-5Z (zone 3) and the south and west sides of the 232-Z Building (zone 3); the south wall of 236-Z (zone 4 the canyon cell)]. The separation of zone 3 or 4 from the environment by only an exterior wall is no longer an acceptable practice.

Glovebox Ventilation. The ventilation of process areas provides ambient air pressures that are lower than any adjoining space so that incidental leakage will flow toward the negative pressures (i.e., into areas of successively higher contamination potential). The lowest pressures of all are within the processing gloveboxes.

Nontestable high-efficiency particulate air (HEPA) filters are provided on the ventilation exhaust outlet from all gloveboxes so that, to the degree practicable, the radioactive particulates can be kept out of the ventilation duct work and prolong the life of filters further down the exhaust line. However, much of the duct work has become contaminated over time. All gloveboxes supplied air from the room around the glovebox are equipped with HEPA filters on the inlet to the glovebox to reduce the amount of particulate matter that would be carried out of the glovebox to the room in case of a pressure reversal. A detailed discussion of the glovebox ventilation system is presented in Chapter 5.0, Section 5.4.1.

1.2.2.3.4 Heating, Ventilation, and Air Conditioning Systems. The PFP buildings are provided ventilation by six separate systems:

- 2736-Z and 2736-ZA Buildings
- 241-Z and 241-ZA Buildings
- 243-Z Building
- 232-Z Building
- 234-5Z, 236-Z, 242-Z, and 291-Z Buildings
- 2736-ZB Building.

All buildings served by the PFP ventilation systems are zoned (i.e., zones 1, 3, or 4) to ensure confinement of radioactive materials. Note that zones 2 and 3 have been combined and designated zone 3. Zone 1 areas in the 234-5Z, 232-Z, 236-Z, 241-Z, and 242-Z Buildings are those where plutonium contamination is not normally present (e.g., office areas, lunchrooms, certain maintenance shops, hallways). Zones 3, 3A, and 3B (collectively referred to as zone 3) consist of areas where radioactive materials (e.g., plutonium) are stored or handled in contained form, where there is potential for contamination to occur (e.g., rooms with hoods and gloveboxes). Zone 4 consists of the inside of hoods, gloveboxes, and process cells where there is direct contact with radioactive materials and gross contamination may be present.

Within the 2736-Z Complex (2736-Z, 2736-ZA, and 2736-ZB Buildings), ventilation zones conform to standard designations (they are reversed in the other PFP buildings). Zone 1 designates the area having the highest potential for contamination (e.g., the repackaging hood) and zone 4 designates areas where contamination is not normally present.

Radioactive materials in process areas are confined as close to the point of origin as practicable through the use of HEPA filters installed on the exhaust ducts of hoods and on both the supply and exhaust ducts of gloveboxes. Exhaust ventilation air from zone 3 areas is filtered via one stage of testable HEPA filtration before discharge to atmosphere via a stack. Exhaust ventilation air from zone 4 areas is filtered via two stages of testable HEPA filtration before discharge to atmosphere via a stack. These designations are reversed in the 2736-Z Complex where zone 1 is the area of higher contamination potential.

Ventilation is on a "once-through" basis except for small-volume recycle of room air to supply laboratory refrigeration air-conditioning systems and for the 2736-ZB Building.

Differential pressures are maintained between areas so that air flows from areas of lower contamination potential to areas of higher contamination potential. Detailed descriptions of the PFP ventilation systems are presented in Chapter 5.0, Section 5.4.1. Chapter 7.0 provides a description of ventilation exhaust monitoring.

1.2.2.3.5 Steam Systems. Steam at up to 100 lbf/in^2 gauge is furnished to the PFP Complex from three dedicated Johnson Controls oil-fired packaged boilers located in Building 234-5Z-BA which is to the north of the PFP facility (outside the security fence) near the 231-Z Building. See Chapter 5.0, Section 5.4.6, for a detailed discussion of the steam supply and distribution system.

1.2.2.3.6 Lighting. Fluorescent lighting is used throughout the PFP. Shower rooms, tunnels, and underground fan and compressor rooms use incandescent fixtures. In the ceiling over processing areas, open fluorescent fixtures are mounted over airtight glass panels.

No PFP process building has natural lighting. Emergency lighting is provided by incandescent lamps provided at strategic locations in the building. Emergency lighting is discussed in Chapter 5.0, Section 5.4.10.

1.2.2.3.7 Communication and Alarm Systems. The PFP Complex communication and alarm systems are comprised of the following:

- Plant or "outside" telephones
- Internal telephone and public address system
- Intercom system
- Wailing siren (take cover)
- Steady siren (evacuation)
- Criticality alarm system
- Continuous air monitor system
- Audible fire alarm system.

The PFP communication and alarm systems provide audible and/or visual information concerning abnormal conditions. The communication systems provide standard and emergency communication exchanges. Standard alarm signals are used at the PFP to provide notification of specific abnormal conditions. Chapter 5.0, Section 5.4.10, provides additional detail on the PFP Complex communication and alarm systems.

1.2.2.3.8 Cold Chemical Systems. Cold (nonradioactive) chemical systems consist of storage, transfer, and makeup of chemical solutions used in plutonium processing and the PPSL, Standards Laboratory, and PFP AL. Since the shutdown of plutonium recovery and conversion operations, large quantities of process chemicals have been removed from the PFP. Small quantities of chemicals stored and used in the laboratories present no significant hazard other than those normally associated with industrial laboratories. Detailed descriptions of the cold chemical systems for the PFP are presented in Chapter 5.0, Section 5.4.13. Administrative controls and engineered barriers help prevent the release of chemicals to the environment (see Chapter 7.0, Section 7.2.2).

1.2.2.3.9 Fire Protection Systems. The PFP fire protection systems consist of many individual communication and operating systems (e.g., fire alarms and sprinkler systems). The PFP design includes compartmentalization and placement of fire barriers to protect against exposure hazard and provide for fire isolation to limit damage and allow personnel egress. Fire protection is discussed in more detail in Chapter 5.0, Section 5.4.11.

1.2.2.4 Program Support.

1.2.2.4.1 Criticality Safety. The criteria used to establish acceptable criticality safety control and the engineered and administrative controls used for prevention of criticality accidents are provided in Chapter 4.0, Section 4.4.4. PHMC contractor requirements and responsibilities for criticality safety are contained in procedures HNF-PRO-334 and HNF-PRO-537 through 550 which implement the DOE requirements.

1.2.2.4.2 Radiological Safety. Shielding is provided to reduce radiation intensities in occupied spaces during all phases of the PFP operation. The activities in the PFP are designed and controlled to limit personnel radiation exposure. A detailed discussion of radiological safety appears in Chapter 8.0.

The *Hanford Site Radiological Controls Manual*, HSRCM-1 (DOE-RL 1995) sets forth the requirements to be followed by all employees who perform work with radioactive materials and radiation-generating devices. All radiation workers are required to understand and abide by the requirements stated in radiation work permits issued in accordance with this manual. The spread and release of contamination is mitigated by several different methods. Radiation survey instruments are provided at strategic locations throughout the facility and continuous air monitors (CAMs) monitor ambient workplace air to provide workers with alarms warning of airborne radioactivity. Also, exhaust air stack and liquid effluent monitoring and alarm systems are provided to monitor a release to the environment. A detailed discussion of radiological safety appears in Chapter 8.0.

1.2.2.4.3 Industrial Health and Safety. Hanford Site Contractor requirements and responsibilities for industrial hygiene and industrial safety are contained in the Occupational Safety and Health topical series of procedures which implement the DOE requirements. The procedures apply to all contractor activities that affect industrial hygiene and safety. A discussion of industrial safety appears in Chapter 4.0, Section 4.4.

1.2.2.4.4 Hazardous Substances. The requirements for working with or near hazardous substances are embodied in the overall PFP health and safety programs that include such items as hazardous material training, hazard communication programs, plant operating procedures, and operator training programs. These programs ensure that employees are fully informed of the potential hazards in their work area and of the necessary protective measures that must be taken (See Chapters 4.0, Section 4.3 and Chapter 10 Section 10.4.5).

1.2.2.4.5 Emergency Preparedness. It is Hanford Site policy to maintain emergency preparedness plans that provide for the protection of people, the environment, and property in the event of emergencies.

These plans provide a coordinated emergency response organization with the capability of handling nuclear, industrial, security, radiological, and nonradiological hazardous materials events. The plans contain mutual aid agreements, identify lines of communication and responsibility, and specify other relationships with local, state, and federal emergency response organizations. These emergency plans also include response to natural phenomena or national emergencies that effect Hanford Site personnel or facilities.

The Emergency Preparedness Plan is implemented by HNF-IP-0263-PFP, *Building Emergency Plan for Plutonium Finishing Plant Complex* (HNF 1998), through subtler plans and procedures as described in Chapter 10.0, Section 10.5, and meets the requirements of local, state, and federal emergency planning agencies.

1.3 GENERAL PROCESS DESCRIPTION

1.3.1 Process Description

During the transition phase between operations (plutonium production-related activities) and D&D, the following activities are conducted within the PFP Complex:

- Plutonium material receiving, storage, and shipping
- Reactive plutonium-bearing material stabilization
- Plutonium-bearing solution stabilization using the Laboratory Prototype Calciner in Room 188 in Building 234-5Z (not authorized for operation)

- Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner in Room 230C in Building 234-5Z (not authorized for operation)
- Plutonium-bearing solution stabilization using the Magnesium Hydroxide Precipitation Process in Room 230C in Building 234-5Z
- Plutonium material packaging using the Bagless Transfer System in the RMA Line in Building 234-5Z
- Laboratory and engineering support
- Waste handling
- Active and inactive facilities surveillance.

Detailed descriptions of process operations are presented in Chapter 6.0 and summarized below.

1.3.1.1 Special Nuclear Material Receiving, Storage, and Shipping.

1.3.1.1.1 Receiving. Shipments of plutonium material are received at the 2736-ZC loading dock. Shipment to the PFP from offsite requires a preapproved shipping plan that assure that plutonium material containers and contents comply with PFP storage specifications. Shipment is made by the safe secure transport (SST) truck and is unloaded at the 2736-ZC loading dock. The plutonium material shipping documents are checked and the shipping containers are moved into the 2736-ZB Building for inspection, weighing, and nondestructive analysis (NDA) measurement of fissile material contents. If the material requires repackaging, this also is done in the 2736-ZB Building. If the materials are determined to be unstable (e.g., gas evolution, liquid, etc.), a recovery plan that provides for interim safe storage and stabilization is developed and implemented. Stable materials are moved to the 2736-Z Building vaults for storage until final disposition. Chapter 6.0, Section 6.2, provides greater detail of plutonium material shipping and receiving. Chapter 7.0 provides a description of waste handling operations. See Chapter 5.0, Section 5.2.8.4, for more details on the 2376-ZC off-loading dock.

Transfer Operations in Glovebox HC-227S and Hood HC-227T. Previous operations of this glovebox and hood supported the RMC Line conversion of plutonium nitrate to plutonium metal which started with a batch (lot) of nitrate solution selected from various sources to give the correct mix of plutonium isotopes. The batch was loaded into the glovebox HC-227S bank tanks via the hood HC-227T load-in head. The solutions were blended by circulating through the HC-227S bank tanks. This served as a staging glovebox for feed to the RMC Line. The RMC Line is no longer used for conversion of plutonium nitrate to plutonium metal. Currently, the glovebox and hood are used in the LI/LO operations, plutonium-bearing nitrate solutions blending and sampling processes and transfer of nitrate solutions to the RMC Line for stabilization processing using the Production Vertical Denitration Calciner process in glovebox HC-230C-2 (see Chapter 6.0, Sections 6.2 and 6.4.1, for details of these processes). Plutonium nitrate solutions are also transferred to Room 188 in the PPSL for stabilization processing using the Laboratory Prototype

Calciner in Glovebox 188-1 (see the Laboratory Prototype Calciner FSAR addendum for details of this process).

1.3.1.1.2 Storage. Plutonium-bearing materials at the PFP can generally be divided into three categories: (1) stable/shippable material, (2) reactive material (generates gas), and (3) potentially reactive material. The stable/shippable materials (e.g., plutonium metal and PuO_2) are stored in the various PFP vaults. The majority of the cans containing plutonium material are stored on pedestals inside cubicles in the 2736-Z vaults, with additional cans of plutonium material temporarily stored in the 2736-ZB Building which are in transition to and from the NDA laboratory or vault storage in the 2736-Z storage vaults. The concrete walls of the cubicles isolate the pedestals from neutron interaction with the other cubicles. Thermal loading for the cans of materials in storage is limited to 15 W each at the time of storage. The heat output is determined by calculations based on isotopic analytical data and weight of the material. The amount of plutonium in a can is reduced if it is determined to generate more than 15 W. Plutonium nitrate solutions are stored in product receiver (PR) and 10-L polyethylene bottles that are specifically vented to prevent pressurization. The product receiver and bottles are shipping containers that are also used for long-term vault storage. See Chapter 5.0, Sections 5.2.8.3.2 for details on the 2736-ZB Building. See Chapter 6.0, Section 6.3, for details on storage processes. See Chapter 8.0, Section 8.2, for details on the characteristics of the types of plutonium-bearing materials at the PFP and the storage methods of such materials.

1.3.1.1.3 Shipping. Only stable, solid plutonium-bearing materials are shipped offsite. The materials are contained in packages of food pack cans in compliance with shipping containers certificate of compliance. The packages to be shipped are placed in shipping containers and moved to the 2736-ZC dock, where they are placed in cargo restraint transporters which are, in turn, secured in the SST Truck for shipment. See Chapter 6.0, Section 6.2, for details on shipping processes.

1.3.1.2 Reactive Plutonium-bearing Material Stabilization. Miscellaneous plutonium-bearing materials were produced during previous PFP operations. This inventory of plutonium is in the form of pure and mixed oxides, fluorides, oxalates, silicates, and organic-based sludges and residues. Reactive plutonium-bearing materials must be stabilized before long-term storage to prevent the formation of excessive hydrogen or nitrated organic compounds.

1.3.1.2.1 Thermal Stabilization. The thermal stabilization process uses gloveboxes HC-21C and HA-21I, with gloveboxes HC-21A, HC-18BS, HA-23S, HC-18M, HC-13MD, HC-1, HC-2, HC-3, HC-4, HA-22B and HA-28 providing support. The reactive plutonium-bearing materials are converted to a stable form by heating the material to high temperatures in a furnace. See Chapter 6.0, Section 6.4.1, for more details on the thermal stabilization process. See Chapter 5.0, Section 5.2.1.2, for descriptions of the components used in the thermal stabilization process.

1.3.1.2A Plutonium-bearing Solution Stabilization. The PFP currently contains significant quantities of plutonium-bearing solutions which are in a

form considered unsuitable for long-term storage. These solutions primarily consist of:

- Product plutonium nitrate solutions
- Concentrated filtrate solutions
- Flush solutions.

As part of the PFP cleanout operations, these solutions are stabilized by conversion to plutonium oxide which is suitable for long term storage. A vertical denitration calciner (VDC) process is used to stabilize the solutions by heating the material to a temperature of 1000 °C. Either of the two calciners may be used for stabilization of solutions: the Production VDC and/or the Laboratory Prototype Calciner. Only the product plutonium nitrate solutions are suitable for direct stabilization using the VDC process. The other two solutions require pretreatment prior to processing in the VDC. Only processing of the plutonium nitrate solutions in the VDC are covered in this revision of the PFP FSAR. The pretreatment and processing of the other two solutions will be added in a future revision of the FSAR.

1.3.1.2A.1 Production Vertical Denitration Calciner. Processing using the Production VDC begins by loading in the plutonium nitrate solutions using the LI/LO glovebox and hood, HC-227S/HC-227T. The solutions are sampled and blended, as needed, and pumped to the VDC glovebox, HC-230C-2, where it is processed through the VDC. The finished product is transferred to glovebox HC-18M where a sample is removed. The sample is transferred to the PFP analytical laboratory where the loss-on-ignition (LOI) is determined. In the future, it is planned to do LOI testing in Glovebox HC-18M using thermogravimetric analysis equipment which is to be installed. If the LOI results are acceptable, the finished product is appropriately packaged and transferred to the storage vaults. If the LOI results are unacceptable, the material is further stabilized using the reactive material stabilization furnaces as discussed in Section 1.3.1.2.

See Chapter 6.0, Section 6.4.1, for details of the solution stabilization operations using the Production VDC and Chapter 5.0, Section 5.2.1.2, for descriptions of the components used in the solution stabilization operations.

1.3.1.2A.2 Laboratory Prototype Calciner. Processing of plutonium-bearing solutions using the Laboratory Prototype Calciner is described in the addendum to the FSAR titled, *Laboratory Prototype Calciner*. The addendum describes the process and equipment, provides the hazards and accident analyses, and defines the operational controls required.

1.3.1.3 Laboratory and Engineering Support. The laboratories are chartered to operate nonradioactive and radioactive chemically-oriented process and equipment demonstration laboratories to support numerous programs across the Hanford Site and, on occasion, other DOE sites. The PPSL facilities include necessary connections to essential building services including ventilation, drains, vacuum, electricity, water, distilled water, and compressed air. The PPSL supports process facility flowsheet evaluation, troubleshooting, new technology implementation, and process demonstration. The above activities are performed on both bench- and pilot-plant scales. The PPSL also analyzes nonroutine samples for process support and develops new methods that are transferred to other organizations when the methodology is well established

and the need becomes routine. The PPSL also processes limited quantities of plutonium material to demonstrate processes whenever the PPSL has exclusive expertise. See Chapter 6.0, Section 6.5, for details on laboratory support. See Chapter 5.0, Section 5.4.11, for laboratory descriptions.

1.3.1.4 Waste Handling. Waste streams from the PFP are categorized as gaseous, liquid, or solid wastes. Waste streams are either nonradiological or radiological, with liquid and solid wastes also being either nonhazardous or hazardous.

The PFP effluents are managed in accordance with Hanford Site procedures as described in Chapter 7.0. The procedures define the requirements and guidelines used by Hanford contractors to: (1) protect the environment from radioactive materials and other dangerous substances, (2) protect people from radionuclides and other dangerous substances in the environment, and (3) provide a centralized technical interpretation of DOE orders and other pertinent state, federal, and local laws, rules, or regulations promulgated for environmental protection.

Hanford contractors have undertaken an aggressive program to upgrade facilities, laboratories, and administrative systems and to enhance personnel training, etc., to comply with the June 1987 DOE directive to manage radioactive hazardous constituents in accordance with the *Resource Conservation and Recovery Act of 1976* and the subsequent *Hazardous and Solid Waste Amendments of 1984*. Detailed assessments of the PFP environmental compliance to applicable regulations have been conducted during this period. With the aid of these assessments, the PFP management has developed and is implementing upgrade plans to achieve compliance with the applicable regulations. A more detailed description of waste management regulations and processes at the PFP is provided in Chapter 7.0.

1.3.1.5 Active and Inactive Facilities Surveillance. Active and inactive facilities remain on ventilation control and effluent monitoring as long as dispersible radioactive materials remain. Continuous air monitors are also maintained active or portable units are brought in if infrequent entry into an area where dispersible plutonium is present is required. Fire protection and alarms are also generally maintained active. Criticality incident detection is normally not maintained for inactive facilities once fissile material quantities, forms, or configurations ensure criticality prevention. Also, for inactive facilities, equipment is isolated from electrical power and motor control centers may be removed.

Surveillance of the inactive facilities is conducted on a once-per-shift to infrequent basis. For example, surveillance of 242-Z is made only when corrective action maintenance or repairs are necessary in the 242-Z facilities. Surveillance is conducted in the 232-Z Building on a shiftly (at least once every 12 h) frequency for detection of abnormalities. The remaining inactive facilities, which are within the 234-5Z Building, are checked on a daily to once-per-shift basis.

Surveillances are conducted primarily to ascertain that conditions within the facility have not changed. The condition of gloveboxes and equipment are noted. Particular emphasis is placed on noting if water is present. Ventilation is checked to determine if it is operating. Radiation surveys are

made on a prescribed frequency depending on the facility, the potential for loss of control, and the potential consequences of a loss of control.

1.3.2 Process Support Activities

1.3.2.1 Plutonium Finishing Plant Analytical Laboratory. The PFP AL, located in the east end of the 234-5Z Building, is used to perform chemical analysis and physical test analysis on plutonium samples. The samples come from transition operations (within the PFP), the PPSL, and a few special test samples from other locations. A more detailed description of the PFP AL is presented in Chapter 5.0, Section 5.4.14.

The samples received and analyzed represent process control, material accountability, and product analysis. Both chemical analyses and physical tests are performed. The samples may be liquids, solids (metal and oxide), or filter media.

Chemical analyses are performed to determine major and minor element content, isotopic ratios, radiochemical characteristics, and pH. Physical tests to determine LOI, particle size, and density are also performed.

All laboratory activities are done by procedure. The activities performed by trained personnel and their performance is controlled and monitored by a quality control program that includes analysis of standards, compliance overchecks, and audits.

1.3.2.2 Standards Laboratory. The standards preparation unit support provided in rooms 221-C, 221-D, and 221-E is devoted to the formulation, verification, packaging, and distribution of actinide-containing destructive and nondestructive standards needed in the laboratories. A detailed description of the Standards Laboratory is presented in Chapter 5.0, Section 5.4.14.

1.3.2.3 Plutonium Process Support Laboratory. The PPSL is located in the southwest corner of the 234-5Z Building in rooms 179B through 191, and room 202. The laboratory is chartered to operate chemical demonstration facilities involving both nonradioactive and radioactive materials. The PPSL also analyzes nonroutine samples for process support, develops new methods that are transferred to other organizations after the methodology is well established and the need becomes routine, and processes limited quantities of SNM to demonstrate processes whenever the PPSL has exclusive expertise.

1.3.2.4 Safeguards and Security. The Hanford Site Safeguards and Security program is designed to protect SNM, government facilities and equipment, and classified information. DOE Order 470.1, *Safeguards and Security Program* (DOE 1995b), requires that line management be directly responsible for assuring a secure operation.

Security is maintained to provide the protection to materials through the use of fences, guards, secured facilities, and other physical protection. The details of these systems are classified.

1.3.2.5 Special Nuclear Material Management. Plutonium, in a number of physical and chemical forms, can be received, stored, processed, and staged for shipment at the PFP. There are a number of classified plans, reports, and forecasts that support the long-term plans.

1.3.2.6 Cleanout Operations and Decontamination and Decommissioning.

1.3.2.6.1 Cleanout Operations. The cleanout operations of processing areas is intended to (1) allow recovery and stabilization of residual scrap plutonium and (2) leave the areas in a stable standby condition requiring minimal surveillance pending final disposition.

Recovery of plutonium scrap will occur at selected sites based on the amount of plutonium available for recovery, ease of access, and technology requirements for recovery. These sites consist of gloveboxes, plutonium processing equipment installed in gloveboxes and process cells, and service systems for the processing areas (ventilation, vacuum, and transfer lines).

Facility stabilization will occur throughout the plutonium processing areas identified for cleanout operations. All service piping should be disconnected with the exception of those required for ventilation and fire protection. Electrical services, with the exception of lighting, should be disconnected to remove potential ignition sources. Most combustible material should be removed from the facility and all glovebox openings, with the exception of inlet and outlet HEPA filters, should be covered with metal plates. The cleanout operations include the stabilization and storage of potentially unstable scrap recovered during cleanout operations.

1.3.2.6.2 Decontamination and Decommissioning. Facilities selected for D&D are those previously placed in a stable condition through terminal cleanout operations (TCO) of areas identified for cleanout, which include gloveboxes, plutonium processing equipment installed in gloveboxes and process cells, and service systems (ventilation, vacuum, and transfer lines) for these areas. The objective of D&D is to remove these facilities and appropriately characterize and dispose of them as waste. See Chapter 4.0, Section 4.5 for a discussion of D&D activities.

1.3.2.7 Waste Processing. Liquid TRU-containing wastes are disposed of via 241-Z and transferred to tank farms. Low-level (non-TRU) waste water is treated by the 243-Z Building (LLWTF) and sent to the Treated Effluent Disposal Facility (TEDF) for disposal. Solid wastes are disposed of by transfer to the Central Waste Complex low level waste burial grounds or an offsite TSD facility. See Chapter 7.0 for a discussion of waste processing activities.

1.3.2.8 Maintenance Support. Maintenance support consists mainly of in-plant forces backed up by area shop personnel when required. In-plant personnel perform routine maintenance on a day-to-day basis. Shop crews support the routine maintenance, perform major repairs, and provide a wide variety of shop prefabricated items. In-plant process work on contaminated equipment is carried out in either open-faced hoods, gloveboxes, or other means as required to maintain personnel contamination and exposure as low as reasonably achievable (ALARA) in the PFP. See Chapter 8.0 for discussion of the implementation of ALARA policies at the PFP.

1.3.2.9 Safety Analysis Report for Packaging. A Safety Analysis Report for Packaging (SARP) provides a comprehensive technical evaluation and review of the design, testing, operational procedures, maintenance procedures, and quality assurance program to demonstrate compliance with the NRC regulatory safety standards, U.S. Department of Transportation (DOT) standards, or equivalent standards established by the DOE for approving packaging and issuing certifications of compliance. All SARPs are implemented through PFP procedures.

1.4 IDENTIFICATION OF AGENTS AND CONTRACTORS

The FH Nuclear Material Stabilization (NMS), as the PFP facility operating contractor, interfaces with many Hanford Site organizations. Fluor Hanford Inc. (FH) is the Hanford Site integrating contractor. Finally, there are three other organizations that contract directly with DOE-RL for specific services at the Hanford Site. The integrating contractor, and other DOE-RL contractors are described in more detail in Chapter 10.0, Section 10.1.16.

1.5 MEMORANDUMS OF UNDERSTANDING

Memorandums of Understanding (MOUs) are documents used at the PFP to formally establish communication between the management and employees of two organizations regarding the assignment of responsibilities. They are prepared and implemented by cognizant personnel who are directly involved with each individual system or facility. Each MOU describes interface points between two organizations and assigns responsibilities for the operation, maintenance, and configuration management of a system or service.

1.5.1 Plutonium Finishing Plant Memorandums of Understanding

The following are MOUs that the PFP has with various supporting organizations, as identified in FSP-PFP-0821-PUO, *Plutonium Operations Administration*.

1.5.1.1 Steam and Water Interface Agreement. This document provides an agreement between 200 W Area Water Utilities. A similar agreement is in place with Johnson Controls to ensure steam delivery to the PFP.

1.5.1.2 Electrical Utilities. This document augments an agreement between the 200 West Area, PFP, and Electrical Utilities, and to further describe the interface points and responsibilities of the operation, maintenance, and configuration management of electrical systems and services.

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DOE, 1995a, *Plutonium Finishing Plant Safety Evaluation Report*, DOE/DP-0130, Office of Defense Programs, U.S. Department of Energy, Washington, D.C.

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NRC, 1976, *Standard Format and Content of License Applications for Plutonium Processing and Fuel Fabrication Plants*, Regulatory Guide 3.39, U.S. Nuclear Regulatory Commission, Washington, D.C.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

BWHC, 1998, *Plutonium Finishing Plant Operational Safety Requirements*, HNF-SD-CP-OSR-010, B&W Hanford Company, Richland, Washington.

HNF, 1998, *Building Emergency Plan for Plutonium Finishing Plant Complex*, HNF-IP-0263-PFP, B&W Hanford Company, Richland, Washington.

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Table 1-1. Plutonium Finishing Plant Buildings and Structures.
(3 sheets)

Building number	Contents/purpose
200-Z	Maps, outside and underground facilities
207-Z	Retention basin
216-Z-1[c]	Crib (isolated: pipe has been capped or removed)
216-Z-1A[c]	Tile field, sanitary tile field (isolated: pipe has been capped or removed)
215-Z-1AA[c]	Tile field (isolated: pipe has been capped or removed)
216-Z-1AB[c]	Tile field (isolated: pipe has been capped or removed)
216-Z-1AC[c]	Tile field (isolated: pipe has been capped or removed)
216-Z-7[c]	Crib (isolated: pipe has been capped or removed)
216-Z-8[c]	French drain (isolated: pipe has been capped or removed)
216-Z-9[b,c]	Crib (isolated: pipe has been capped or removed)
216-Z-9A[b,c]	Contaminated soil removal facility
216-Z-9B[b,c]	Industrial building; prefab building
216-Z-9C[b,c]	Industrial building; prefab building
216-Z-10[c]	Reverse wells (isolated: pipe has been capped or removed)
216-Z-11[c]	Ditch (isolated: pipe has been capped or removed)
216-Z-12[c]	Crib (isolated: pipe has been capped or removed)
216-Z-13	French drain
216-Z-14	French drain
216-Z-15	French drain
216-Z-16[c]	Crib (isolated: pipe has been capped or removed)
216-Z-18[c]	Crib (isolated: pipe has been capped or removed)
216-Z-19	Ditch (abandoned)
216-Z-20[c]	Crib (isolated: pipe has been grout-capped), Z8 manhole grouted
216-Z-21[c]	Pond (isolated: pipe has been grout-capped)
231-Z[b]	Materials Engineering Laboratory/Building (200ADP facility - contains Plutonium Finishing Plant Plutonium material)
232-Z[a]	Waste Incinerator Facility (not used)
234-5Z[a]	Plutonium Finishing Plant; plutonium conversion facility
234-5ZA	Change room and MICON™ control station
234-ZB	Miscellaneous storage for construction forces (FFS-owned actylene, propane, oxygen, argon nitrogen storage)
234-ZC[a]	Loading dock for waste drums and special nuclear material containers (West End)
236-Z[a]	Plutonium Reclamation Facility (not used). Temporary storage of in-process material in access gloveboxes.
241-Z[a]	Liquid waste storage and treatment tanks in underground concrete cells
241-Z-RB	Waste water retention basin (not used)
241-ZA	Sample building: sample/loadout building
241-ZB	Curbed concrete pad housing the D-9 caustic tank
241-ZG	241-Z change room
241-Z-361	Underground liquid waste settling tank (no longer used)
242-Z[a]	Waste Treatment facility (not used)
242-ZA	Monitoring building (also known as TC-66)
243-Z[a]	Low-Level Waste Treatment Facility
243-ZA	Tank
243-ZB	Cooling towers and concrete pads for closed-loop cooling water system
252-Z-1	Electrical transformer (North of 234-5Z)
252-Z-2	Electrical transformer (in 291-Z Building)
2607-W-8	Septic tank
2607-WA	Septic tank
2607-WB	Septic tank

Table 1-1. Plutonium Finishing Plant Buildings and Structures. (3 sheets)

Building number	Contents/purpose
2607-Z	Septic tank
2607-Z-1	Septic tank
267-Z	Valve house for water supply to a 234-5Z sprinkler system (Riser #9 valve house)
270-Z	PFP support facility (office building) (houses emergency control center)
291-Z[a]	Ventilation exhaust fan house
291-Z-1[a]	Ventilation exhaust stack for 232-Z, 234-5Z, and 242-Z Buildings
296-Z-3[a]	Ventilation exhaust stack for 241 cells and tanks
296-Z-5[a]	Ventilation exhaust stack for 2736-ZB Building
296-Z-6[a]	Ventilation exhaust stack for 2736-Z Building
296-Z-14[a]	Ventilation exhaust stack for 232-Z Building
296-Z-15[a]	Ventilation exhaust stack for 243-Z Building
2503-Z	Electrical distribution system for PFP (switch yard)
2701-ZA	Central station alarm facility (criticality alarm portion)
2701-ZD	PFP badge house
2702-Z	Microwave tower
2704-Z	PFP support building (office building)
2705-Z	Operations control facility
2706-Z	Septic tank
2712-Z	291-Z-1 stack sampler and monitor shack
2715-Z	Paint shop (paint, oil, solvent, and drum storage)
2721-Z[a]	Backup electric power generators (diesel driven)
2722-Z	Concrete pad for truck load-out station
2727-Z	Storage of miscellaneous operations and laboratory equipment
2729-Z	Storage of miscellaneous maintenance materials
2731-Z	Storage of empty flushed plutonium drums
2731-ZA	Laundry storage
2734-Z	Gas bottle storage
2734-ZA	Empty cylinder storage
2734-ZB	Breathing air cylinder storage
2734-ZC	P-10 gas supply, P-10 and oxygen cylinder storage
2734-ZD	Empty non-flammable cylinder storage
2734-ZF	Standby gas bottle storage (not used)
2734-ZG	Nitrogen gas supply
2734-ZH	Argon bottle supply (not used)
2734-ZJ	Liquid nitrogen storage tank
2734-ZK	Gas bottle storage, acetylene, argon, propane
2734-ZL	HF gas bottles and supply piping (not used)
2735-Z	Chemical storage of HNO_3, and ANN (not used)
2736-Z[a]	Plutonium material storage
2736-ZA[a]	2736-Z exhaust fans
2736-ZB[a]	Shipping and receiving SNM
2736-ZC[a]	Loading dock
2736-ZD[a]	Experimental Breeder Reactor II cask storage
2900-Z	Underground lines
2901-Z	Water tower
2902-Z	Elevated sanitary water tank and valvepit (not used)
2904-Z	Monitoring building
2904-ZA[b]	Sheet metal structure that housed 216-Z-20 crib stream effluent sampling, flow measurement, pH and alpha monitoring equipment (not used)

Table 1-1. Plutonium Finishing Plant Buildings and Structures.
(3 sheets)

Building number	Contents/purpose
2904-ZB[b]	Sheet metal structure that housed 216-Z-20 crib stream effluent sampling, flow measurement, pH and alpha monitoring equipment (not used)
225-WC[b]	Houses the sampling and monitoring equipment for the waste water discharge to Treated Effluent Disposal Facility
MO-011[b]	200 W Patrol headquarters trailer
MO-014[b]	Mobile office building; office trailer
MO-015[b]	Mobile office building; office trailer
MO-016[b]	Mobile office building; office trailer
MO-017[b]	Mobile office building; office trailer
MO-031[b]	Mobile office building; office trailer
MO-032[b]	Mobile office building; office trailer
MO-244[b]	Mobile office building; Patrol change trailer
MO-249[b]	Mobile office building; office trailer
MO-250[b]	Mobile office building; office trailer
MO-290[b]	Mobile office building; IRM computer hub trailer
MO-428	Mobile office building; office trailer
MO-429	Mobile office building; office trailer
MO-432	Mobile office building; office trailer
MO-544[b]	Mobile office building; field trailer at carbon tetrachloride site
MO-834	Mobile office building; FFS lunchroom/office trailer
MO-839	Mobile office building; FFS lunchroom/office trailer
MO-939	Mobile office building; office trailer FFS
No #s	Hazardous waste staging areas (various locations)
No #s	Fenced material control areas
No #s	FFS storage shed (West of 234-ZB Building)
No #s	Moveable storage structures (FH and FFS -owned)
HS-045	Hazardous waste storage unit - No. 2 (West of MO-432)
HS-043	Hazardous waste storage unit - No. 3 (West of MO-432)
HS-047	Hazardous waste storage unit - No. 1 (East of 234-5Z Building); Recyclable oil and miscellaneous absorbents storage
HS-046	Hazardous waste storage unit - No. 4 (East of 234-5Z Building); Temperature controlled chemical storage unit
E Maintenance Conex	Miscellaneous maintenance supplies storage
G Maintenance Conex	Miscellaneous maintenance supplies storage
Material Control Conex #1	Filter storage
Material Control Conex #2	JCS job-related hardware and components
Maintenance D Conex	-
Maintenance F Conex	Oil storage
234-5Z-BA (Oil-fired packaged boiler)[b]	Dedicated boiler provides steam supply to the PFP facility for various uses (Boiler operated and maintained by separate DOE-RL contractor)

[a]Major PFP structures: Those structures that were identified as having a source term and/or containing major processing equipment or one of the confinement systems.
[b]These items are located outside of the PFP Exclusion Area.
[c]Under jurisdiction of River Protection Project.

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Figure 1-1. Plutonium Finishing Plant Site.
(Ref. Dwg. H-2-80249, Sheet 1)

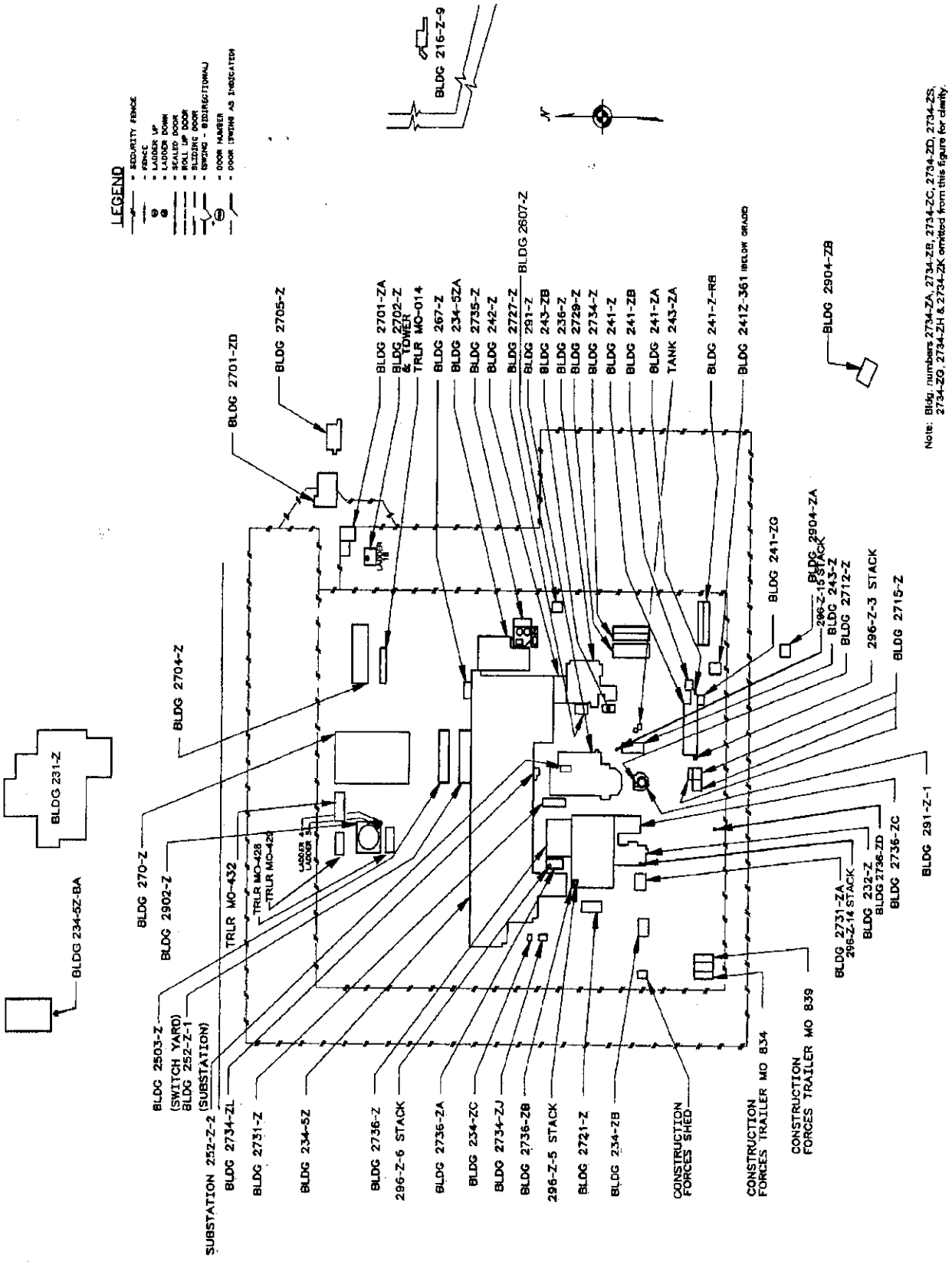


Figure 1-2. Location of the Hanford Site.

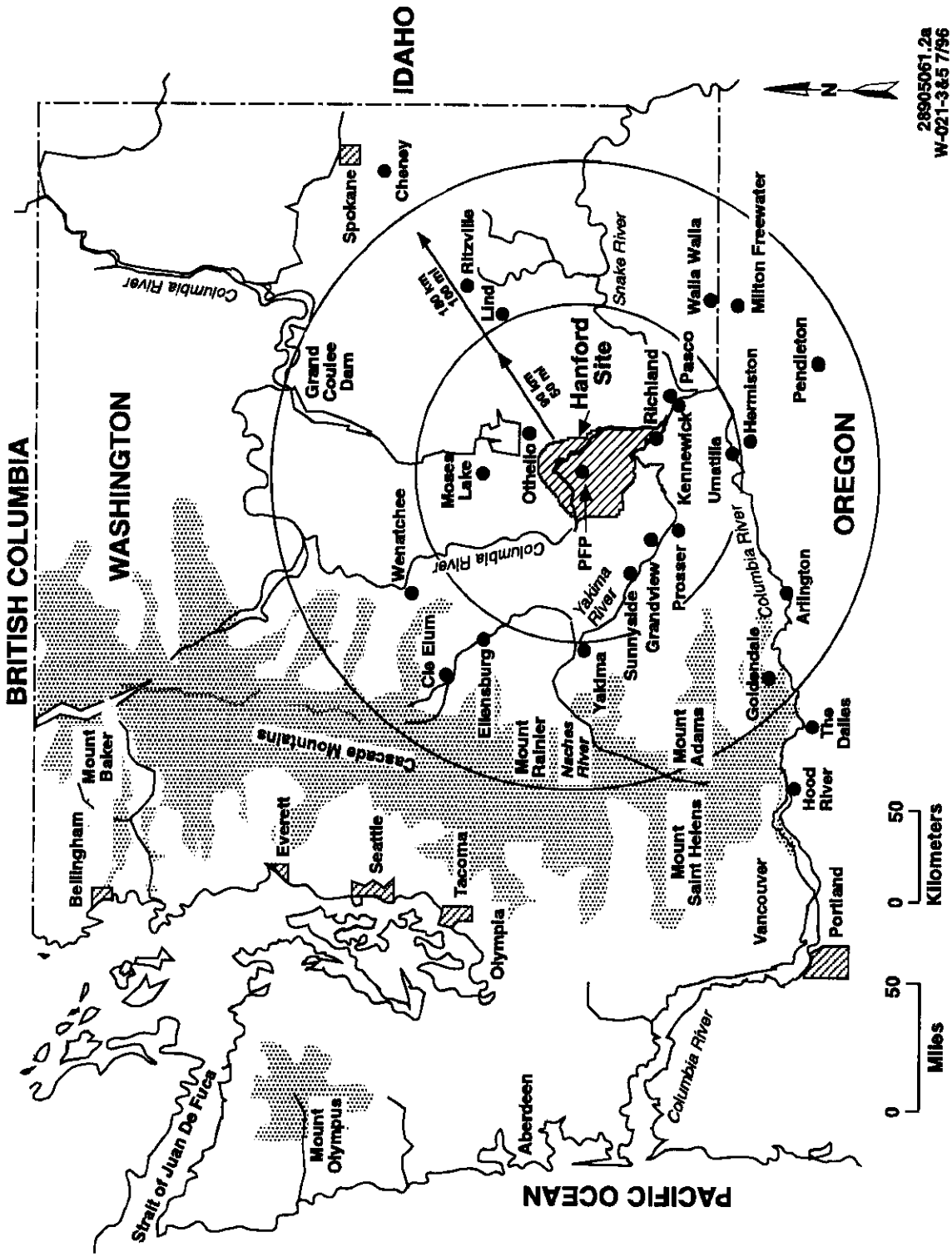
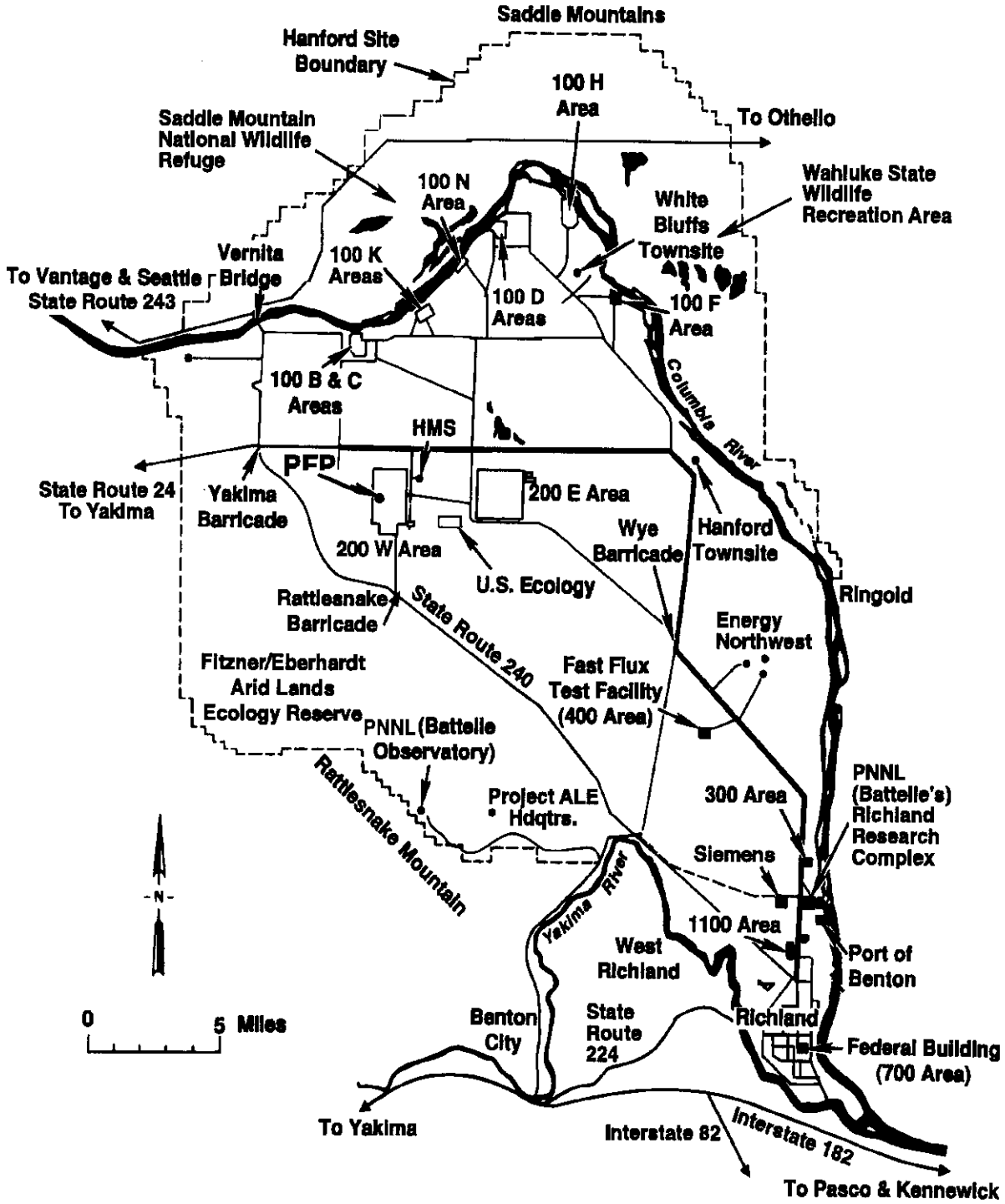


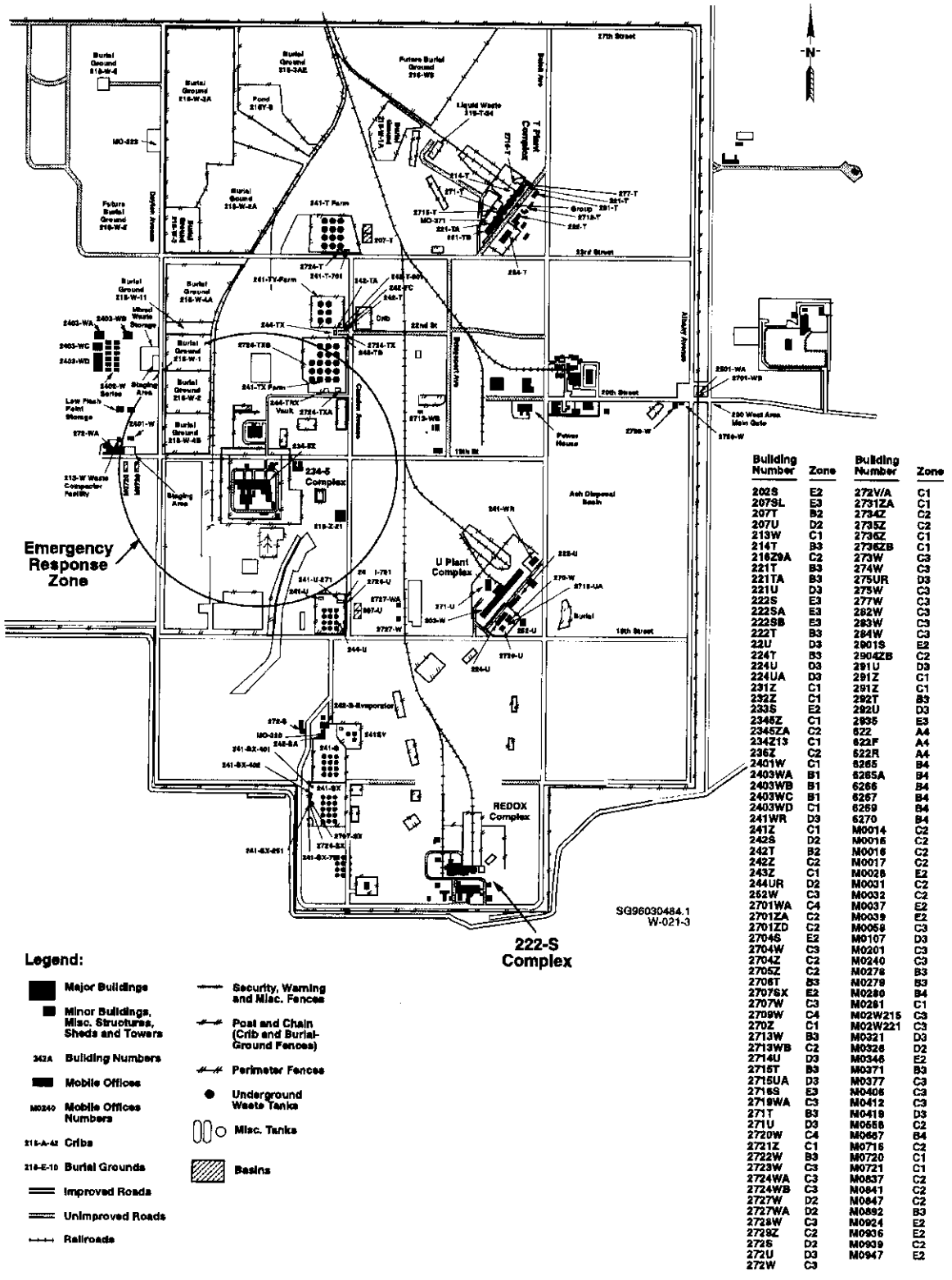
Figure 1-3. Hanford Site.



HMS - Hanford Meteorological Station
PNNL - Pacific Northwest National Laboratory
PFP - Plutonium Finishing Plant

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Figure 1-4. 200 West Area.



Building Number	Zone	Building Number	Zone
202S	E2	272V/A	C1
207SL	E3	2731ZA	C1
207T	B2	2734Z	C2
207U	D2	2735Z	C2
213W	C1	2736Z	C1
214T	B3	2736ZB	C1
216Z9A	C2	273W	C3
221T	B3	274W	C3
221TA	B3	275UR	D3
221U	D3	275W	C3
222S	E3	277W	C3
222SA	E3	282W	C3
222SB	E3	283W	C3
222T	B3	284W	C3
22U	D3	2901S	E2
224T	B3	2904ZB	C2
224U	D3	291U	D3
224UA	D3	291Z	C1
231Z	C1	291Z	C1
232Z	C1	292T	B3
233S	E2	292U	D3
2345Z	C1	2935	E3
2345ZA	C2	622	A4
234Z13	C1	622F	A4
236Z	C2	622R	A4
2401W	C1	6265	B4
2403WA	B1	6265A	B4
2403WB	B1	6266	B4
2403WC	B1	6267	B4
2403WD	C1	6269	B4
241WR	D3	6270	B4
241Z	C1	M0014	C2
242S	D2	M0015	C2
242T	B2	M0016	C2
242Z	C2	M0017	C2
243Z	C1	M0028	E2
244UR	D2	M0031	C2
252W	C3	M0032	C2
2701WA	C4	M0037	E2
2701ZA	C2	M0039	E2
2701ZD	C2	M0059	C3
2704S	E2	M0107	D3
2704W	C3	M0201	C3
2704Z	C2	M0240	C3
2705Z	C2	M0278	B3
2706T	B3	M0279	B3
2707SX	E2	M0280	B4
2707W	C3	M0281	C1
2709W	C4	M02W215	C3
270Z	C1	M02W221	C3
2713W	B3	M0321	D3
2713WB	C2	M0326	D2
2714U	D3	M0346	E2
2715T	B3	M0371	B3
2715UA	D3	M0377	C3
2716S	E3	M0406	C3
2719WA	C3	M0412	C3
271T	B3	M0419	D3
271U	D3	M0556	C2
2720W	C4	M0567	B4
2721Z	C1	M0716	C2
2722W	B3	M0720	C1
2723W	C3	M0721	C1
2724WA	C3	M0837	C2
2724WB	C3	M0841	C2
2727W	D2	M0847	C2
2727WA	D2	M0892	B3
2728W	C3	M0924	E2
2729Z	C2	M0936	E2
272S	D2	M0939	C2
272U	D3	M0947	E2
272W	C3		

Figure 1-5. Aerial View of the Plutonium Finishing Plant with Cutaway View of the 234-5Z Building.

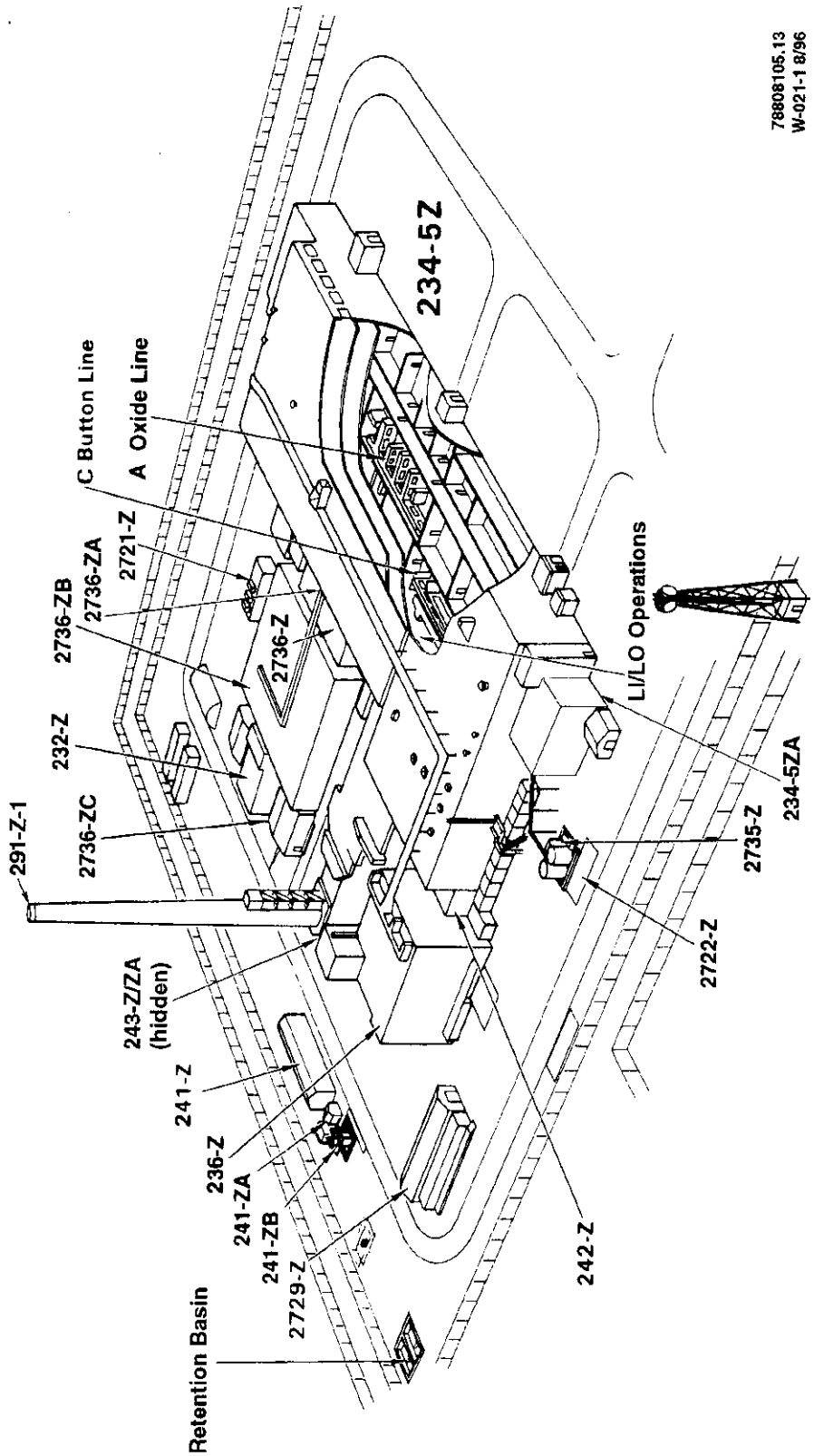


Figure 1-6. Cutaway View of the 236-Z Building.

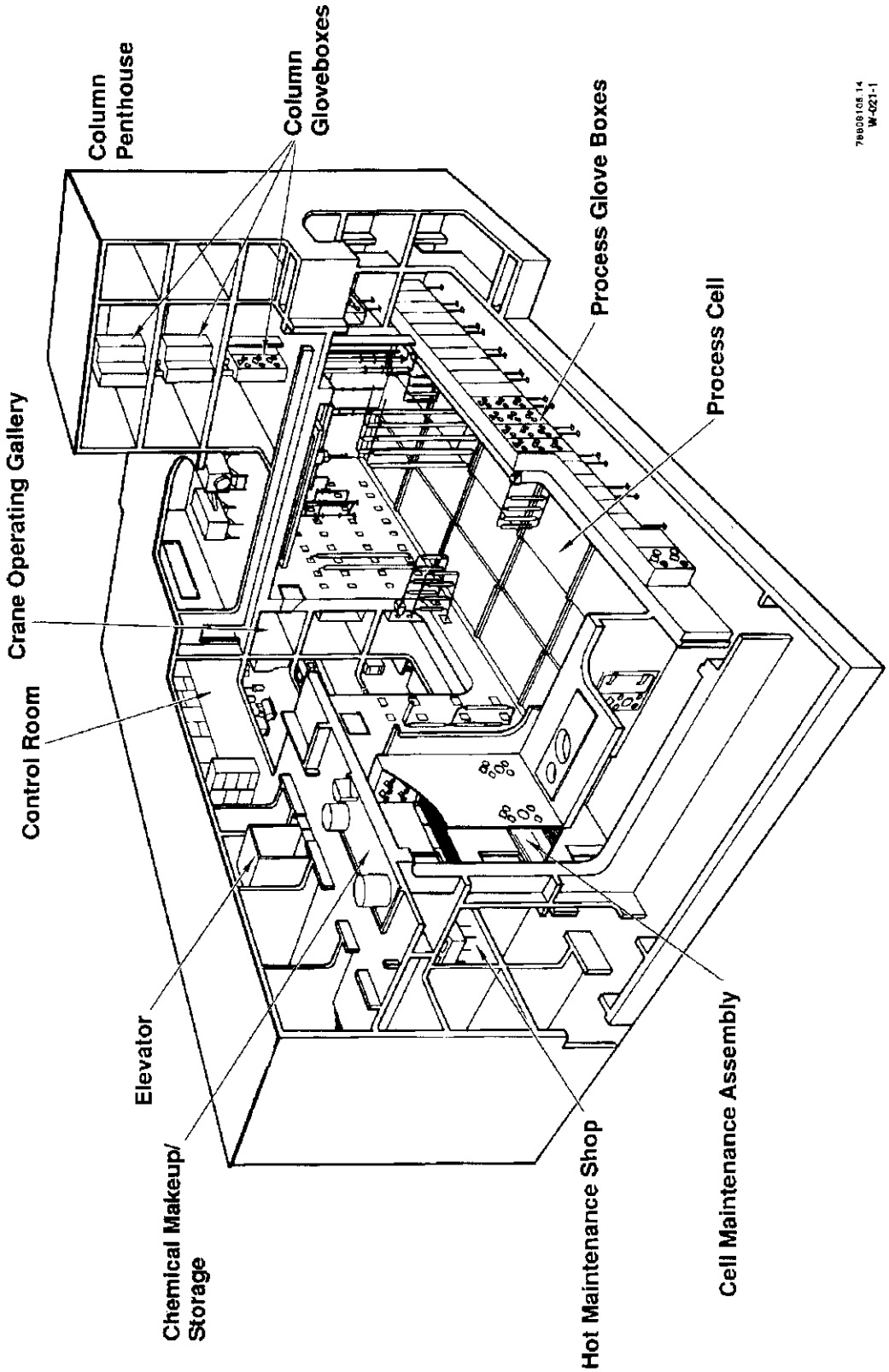


Figure 1-7. Cutaway View of the 232-Z Building.

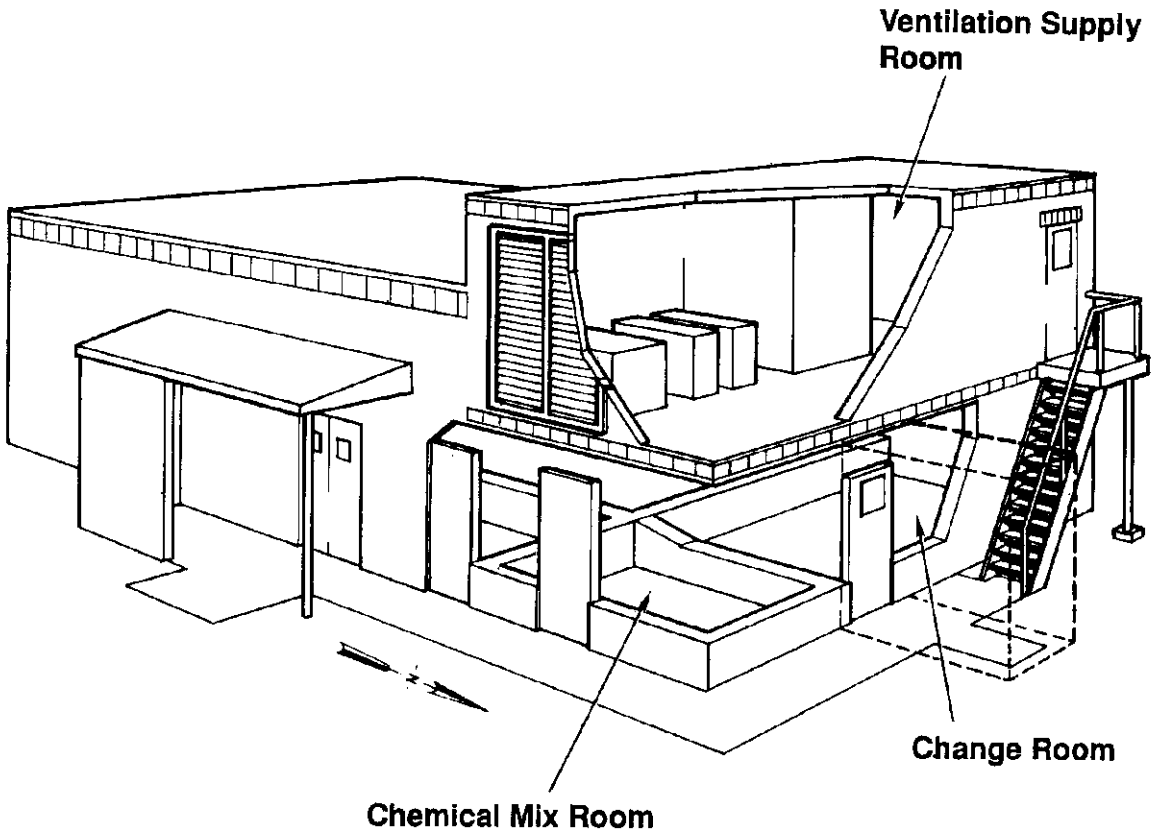


Figure 1-8. Cutaway View of the 241-Z Building.

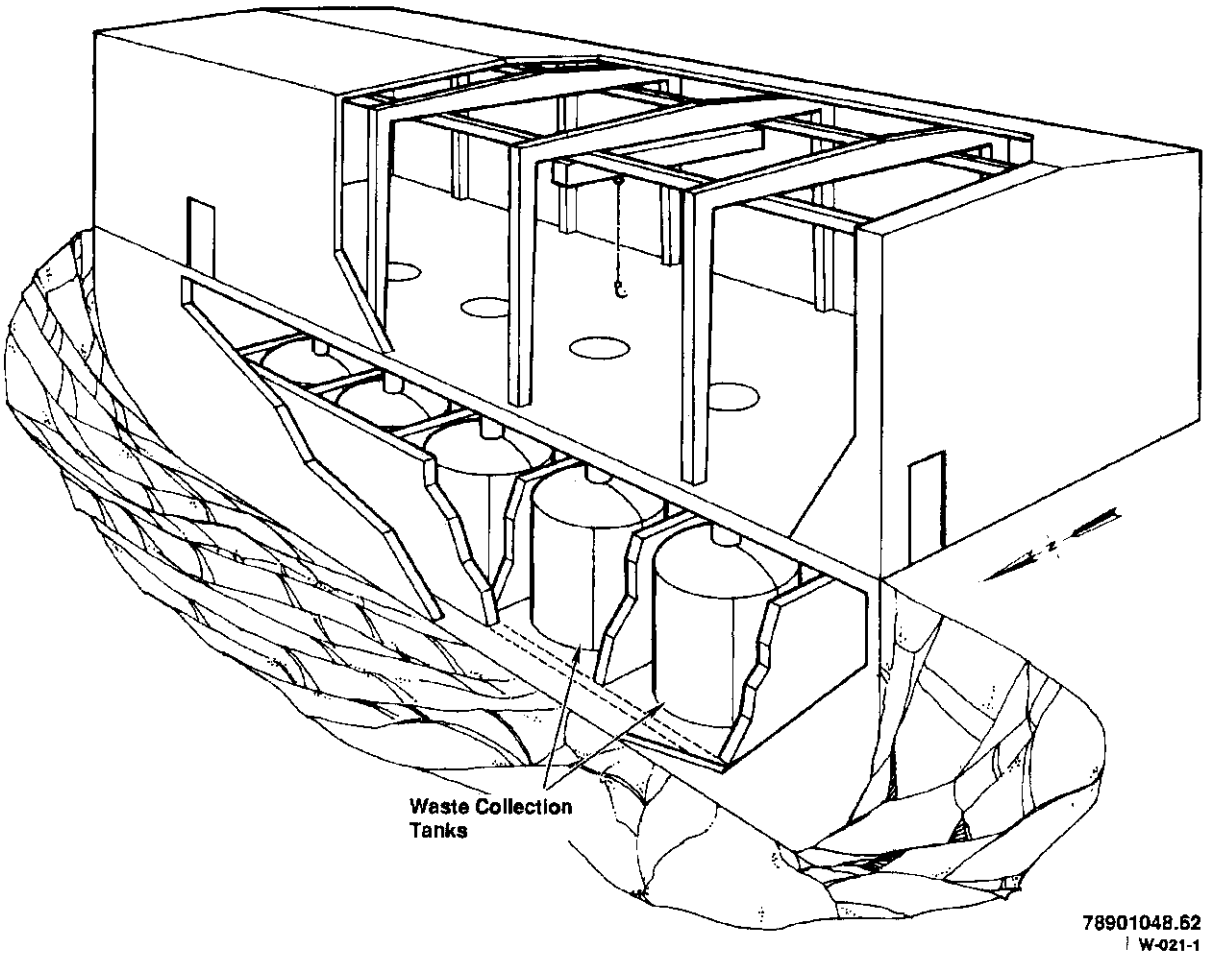


Figure 1-9. Cutaway View of the 242-Z Building.

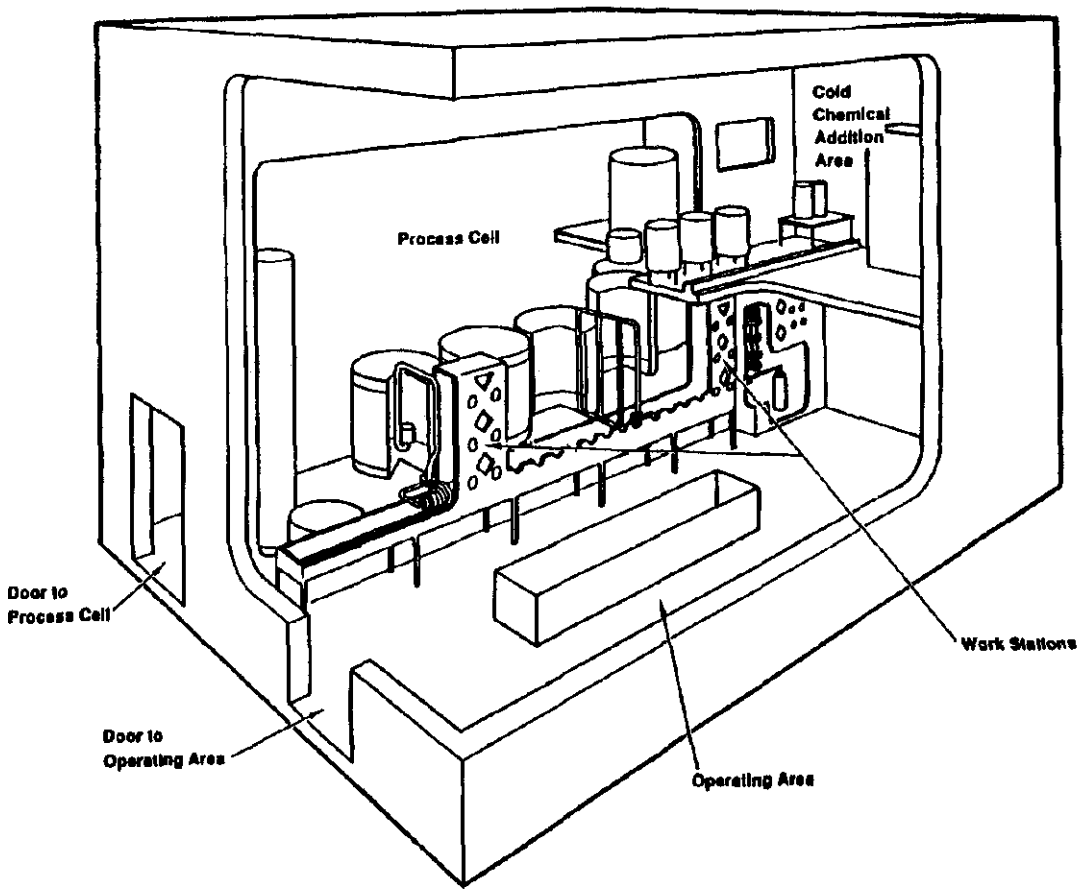


Figure 1-10. Cutaway View of the 291-Z Building.

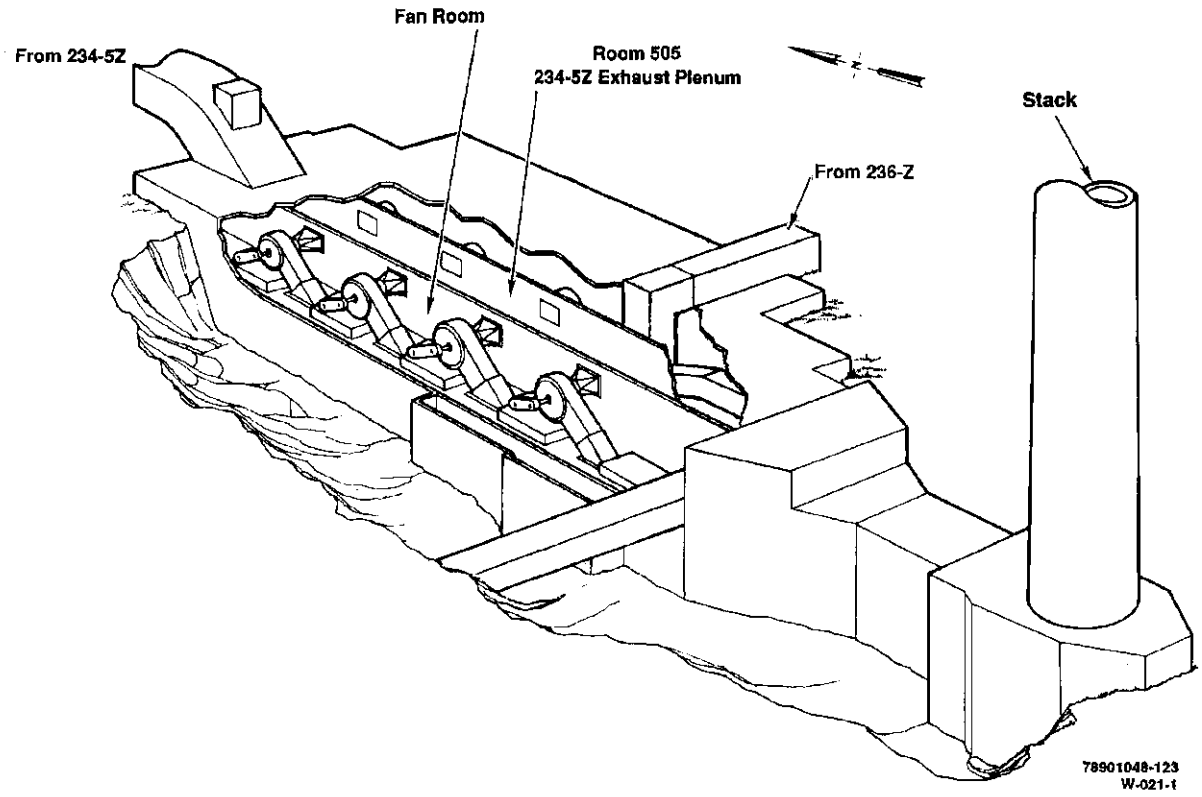


Figure 1-11. Cutaway View of the 2736-Z Building.

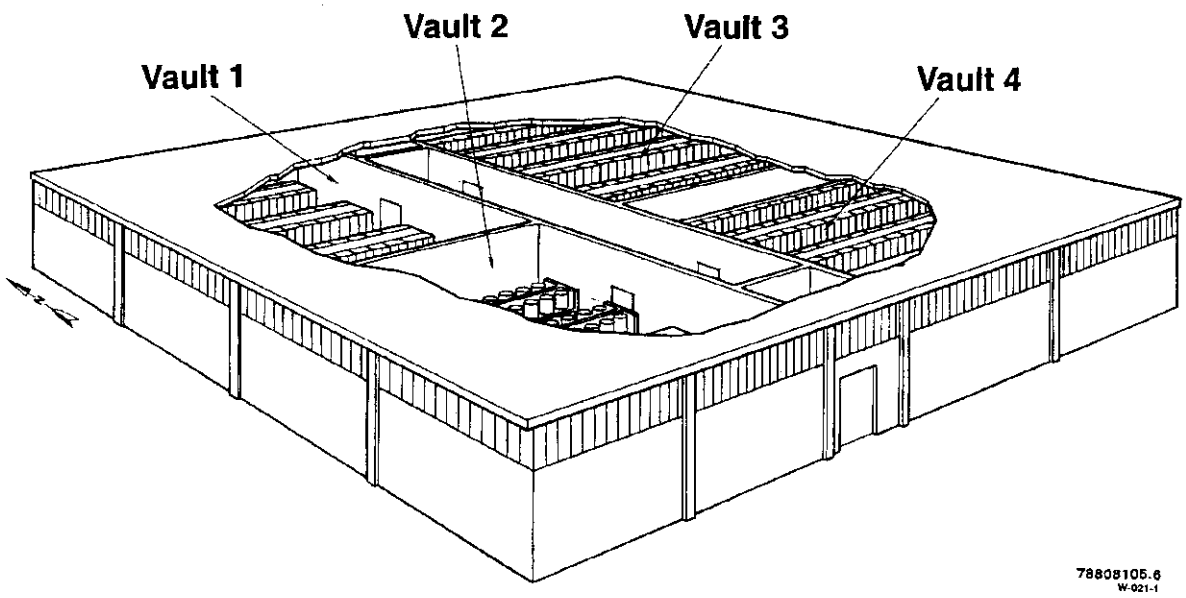
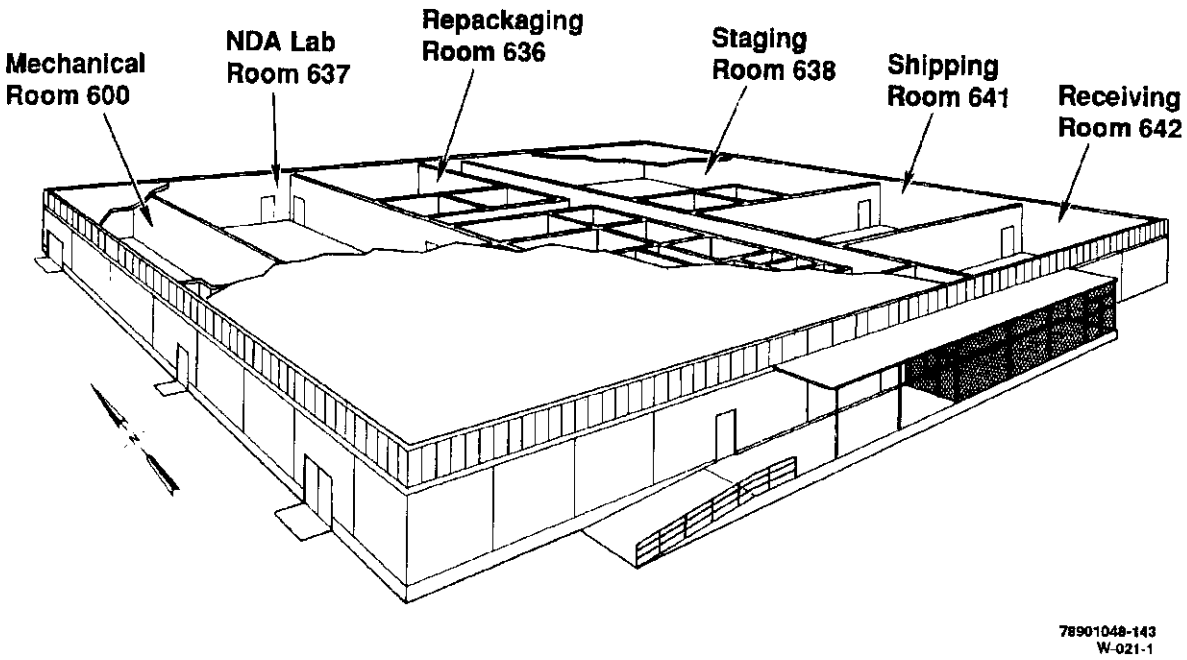


Figure 1-12. Cutaway View of the 2736-ZB Building.



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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 2.0

SUMMARY SAFETY ASSESSMENT

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 2.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) includes modifications for the following:

- Addition of the summary for a new abnormal event; Loss of Filtration
- Revision to the existing summary for the Reactive Plutonium-Bearing Material Stabilization to include HC-21C and HA-21I
- Revised dose consequence summary tables
- Incorporation of the Magnesium Hydroxide Precipitation Process
- Incorporation of the Bagless Transfer System

Other minor changes include editorial changes and clarifications.

It is noted that various sections of Chapter 2.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner located in the Plutonium Process Support Laboratories. Operation of either the production calciner or the laboratory calciner for solution stabilization is not authorized at this time and the related portions of Chapter 2.0 will be updated, if necessary, prior to initiation of operations.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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2.0 SUMMARY SAFETY ASSESSMENT

This chapter summarizes safety assessments presented in Chapters 3, 7, and 9 of this Final Safety Analysis Report (FSAR). Section 2.1 summarizes the detailed analyses of the Hanford Site and its potential impacts to the Plutonium Finishing Plant (PFP) as presented in Chapter 3.0, "Site Characteristics." Included, for example, are analyses of severe natural phenomenon and the effects of nearby industrial facilities.

Section 2.2 summarizes the radiological impact of normal operations. This impact is defined in terms of the quantities and characteristics of gaseous, liquid, and solid wastes generated by normal PFP operations as detailed in Chapter in 7.0, "Waste Management."

Section 2.3 summarizes analyses of abnormal operations, defined as events that occur from malfunctions of systems, operating conditions, or operator error. Examples include plutonium-bearing liquid and powder spills and ventilation system upsets. Detailed analyses of abnormal operations are presented in Section 9.1 of Chapter 9.0, "Accident Analysis."

Section 2.4 summarizes analyses of potential accidents presented in Chapter 9.0, Section 9.2. The analyses quantify the consequences and frequencies of potential accidents and compare the resultant values to risk acceptance guidelines. Conclusions are drawn in Section 2.5.

Many years of analysis have gone into assessing the ability of the PFP to serve the U.S. Department of Energy (DOE) environmental management mission. The FSAR documents that operations can be conducted safely and that the plant can continue its current mission with an acceptable level of risk. The following four items are provided in summary.

1. The PFP has been operating for 50 years with no significant radiological or toxicological impact to onsite (off plant) or offsite populations. The calculated offsite radiological exposure from normal operations is less than 0.005% of that received from natural background.

2. The PFP is located on the 560-mi^2 Hanford Site under the control of the DOE. The impact of severe site-specific natural phenomenon on the PFP has been analyzed and the associated risk found to be acceptable.

3. The PFP chemical processes are low energy and conducted in a sequential batch or campaign manner. The processes are fault tolerant, and a safe shutdown configuration can be accomplished in minutes.

4. The PFP process configuration is flexible and can be managed satisfactorily to safely perform current and future operations.

2.1 SITE ANALYSIS

The PFP is located within the 560-mi^2 Hanford Site. The closest public access to the PFP is State Route 240, 2.5 mi to the west, and the Columbia River approximately 7 mi to the north. Chapter 1, Section 1.2.1, "Site Characteristics," provides a summary description of the Hanford Site. A detailed description is provided in Chapter 3.

2.1.1 Natural Phenomena

Chapter 3.0 identifies and characterizes site-specific natural phenomena that could potentially impact the PFP. These phenomena include: flooding, strong wind (including wind-generated missiles), lightning, snow fall, earthquakes, and volcanic ash fall. The analysis identified only two forces, a sustained strong wind (and associated wind-generated missiles) and an earthquake, with the potential for initiating a release of radioactive or toxic materials.

2.1.1.1 Strong Wind. Hanford Site local meteorology has been recorded and studied for over 50 years. The U.S. Weather Bureau cooperative station records for precipitation date from 1912. Phenomena such as hurricanes and large tornadoes are inconsistent with the region. For analysis purposes, a sustained strong wind of 90 mi/h was used in accordance with Hanford Plant Standard SDC 4.1 (WHC 1991). The annual probability of this wind occurring is between 1.0×10^{-5} and 1.0×10^{-6}, which is within the credibility envelope used.

The wind-generated missile event is derived from UCRL 15910 (Kennedy et al. 1990) design and evaluation guidelines. The event consists of a strong wind driving a missile into the plant. Analysis and tests used a 12-ft 2 x 4 piece of lumber as the missile, being driven by the wind horizontally into the side of the facility. All facility side panels withstand the impact of the strike, with the exception of the 241-Z and 232-Z Buildings. Analysis of the combined probability of the sustained strong wind and a missile being driven into a critical portion of the plant was less than 1.0×10^{-6}, thus incredible. Outdoor hazardous material storage facilities are vulnerable to wind-generated missile strikes.

2.1.1.2 Earthquake. The primary earthquake-generating structures considered to be capable are the Rattlesnake-Wallula Alignment and the Gable Mountain/Gable Butte structure (see Section 3.6.1.2.1). The maximum acceleration at the Hanford Site from historical or instrumental earthquake data is estimated to have been 0.15 g. A peak acceleration of 0.20 g at ground surface has been assigned for the design basis earthquake (DBE) and is consistent with the Hanford Plant Standard SDC 4.1 (WHC 1991). The current seismic analysis for the PFP uses a 0.20-g seismic event as the DBE. Structural analyses conclude all significant process buildings, except the 232-Z Building resist DBE motion without collapse. Analyses of the 232-Z Building have shown it to survive seismic events up to 0.09 g in magnitude.

2.1.2 Safety Assessment

The PFP Complex is located in the 200 West Area of the Hanford Site. This remoteness, in conjunction with the ability to control access to the Hanford Site, enhances the margin of safety to the public of an existing, safe plant. Access control consists of three well-defined physical and administrative envelopes surrounding the PFP. These envelopes are as follows.

1. The DOE posts and controls access to the Hanford Site, including regular road patrols of State Route 240. This is equivalent to a 10 CFR 100 (NRC 1982) exclusion area.

2. The 200 West Area is a fenced area 2.5 mi from State Route 240. After entering the Hanford Site from one of the three controlled site entrances (Wye, Yakima, and Rattlesnake Barricades), there are three normally uncontrolled access gates to the 200 West Area.

3. The PFP is in the center of a secured restricted area inside 200 West Area. Access to the PFP is based upon the provisions of the *Atomic Energy Act of 1954*. The plant manager through the Hanford Patrol controls personnel and vehicular access. Authorized entry or exit is allowed only after satisfactory security inspection made by Hanford Patrol.

The location of the PFP, in relation to the prevailing winds and the rest of the Hanford Site, reduces the impact from any potential release to offsite personnel. The prevailing winds would direct the release plume away from areas of concentrated population.

2.1.3 Effects of Nearby Industrial, Transportation, and Military Facilities

There are no nearby industrial, transportation, or military facilities, other than those on the Hanford Site controlled by DOE, that can impact or be impacted by the PFP (see Section 3.2). The buildings within the PFP Emergency Response Envelope are located within the 200 West Area fence line.

The closest, routinely occupied onsite facility is the 272-WA Building, 0.6 km to the north northwest. Occupants of this building are defined as onsite receptors for Chapter 9.0 analysis purposes.

2.1.3.1 Industrial Facilities. The primary business in southeastern Washington is grazing and dry land or irrigated agriculture. No industrial facilities, nuclear facilities, gas pipeline, fuel or chemical storage sites, quarries or other such operations exist that would impact PFP. Bonneville Power Administration high-voltage transmission lines traverse the Hanford Site several miles from PFP.

2.1.3.2 Military Facilities. The U.S. Army Yakima Firing Range boundary is about 18 mi northwest of PFP. Live firing conducted has no impact on the Hanford Site. A military flight path (VR1350) is located 9 mi west of the PFP. This airway was analyzed and found to have no impact. There are no

other military operations that could conceivably be involved with the Hanford Site.

2.1.3.3 Transportation Facilities. Located 2.5 mi from PFP, State Route 240 is the closest transportation route to PFP. State Route 240 crosses the Hanford Site. This road along with other Hanford Site roads, are used for the commercial transport of fuel and common hazardous chemicals. There is no impact to PFP from these roadways and the PFP operations have no impact on these transport operations.

2.1.3.3.1 Aircraft Events. Hanford Site airspace is classified as uncontrolled airspace. Aircraft operators are requested by the Federal Aviation Administration to avoid flight below 2,400 ft mean sea level (msl) over the Hanford Site. There are three airports within 35 mi. A general aviation airport in Richland is closest, being 25 mi from the PFP. Three Federal Low Altitude Airways and one Military Training Route cross the Hanford Site.

Aircraft accident analysis based on NUREG-75/087 (NRC 1975) assessed the impact on the PFP. The annual probability of an accident resulting in consequences greater than 10 CFR 100 (NRC 1982) were less than 1.0×10^{-6}, and therefore considered incredible.

In addition to commercial and military air traffic, DOE-sponsored helicopter overflights of the Hanford Site have been performed for the purpose of gathering radiological survey data. These flights differ from those described above as the helicopters intentionally fly at low altitudes and in relatively close proximity to nuclear facilities. A helicopter crash into the PFP is judged to be an incredible event as long as the helicopters do not operate in the near proximity of the PFP (i.e., a 2,300 foot square centered on the 291-Z-1 stack).

2.1.3.4 Tall Structures. There are two tall structures associated with the plant, 291-Z-1 stack and the 50,000-gal elevated water tank. The 291-Z-1 stack is 200 ft tall and the release point for most gaseous effluents from PFP. Analysis confirmed that the stack will not fail in a DBE or strong wind. The elevated water tank will fail in the DBE. However, it is braced to control the mode of failure so that the building confinement boundary will not be breached. Tank failure will not impact the 270-Z Building.

2.2 RADIOLOGICAL IMPACT OF NORMAL OPERATIONS

Radioactive effluents generated during normal operations could potentially result in a significant radiological impact. Three radioactive effluent streams are generated; liquid, gaseous, and solid. Each effluent stream is individually managed based on radioactivity, toxicity, chemical and physical form. During normal operations, only the gaseous effluents result in a calculable offsite exposure.

2.2.1 Radioactive Gaseous Effluents

There are six gaseous effluent stacks for the PFP complex, five of which are routinely sampled and monitored. The effluents pass through one or two stages of high-efficiency particulate air (HEPA) filtration depending upon the area serviced. The principal isotopes present are $^{238,239,240,242}Pu$ and ^{241}Am. The activity released has historically been less than the regulatory-driven as low as reasonably achievable (ALARA) based emission control objectives. The associated offsite doses are a small fraction of that received from natural background radiation.

2.2.1.1 Quantity and Concentrations of Gaseous Effluent Streams. Five sampled and monitored gaseous effluent streams are associated with the PFP, 291-Z-1, 296-Z-3, 296-Z-5, 296-Z-6, and 296-Z-14 and one periodically sampled and unmonitored, 296-Z-15. Gaseous effluents from stack 291-Z-1, 200 ft tall, represent the majority of total exhaust from the PFP. The remaining five are minor stacks that release at an elevation of approximately 40 ft or less.

Gaseous effluent release data for 1990 through 1995 are provided in Table 2-1. The principle isotopes potentially released are $^{238,239,240,241}Pu$ and ^{241}Am. The release data in Chapter 7 demonstrates that the regulatory-driven ALARA based emission control objectives have been met.

2.2.1.2 Onsite and Offsite Receptors. Personnel located within the PFP Emergency Response Envelope, the PFP and associated buildings are defined as PFP facility workers and are not considered to be onsite personnel for consequence analysis purposes. The nearest onsite receptors occupy the 272-WA Building, 0.6 km north-northwest of the PFP.

To calculate consequences to the maximally exposed offsite individual, the offsite receptor is defined as the occupant at the nearest affected place just beyond the Hanford Site boundary. This individual is a hypothetical farmer living on the Hanford Site boundary at the point with the highest impact from the PFP plume. This farmer is 13.5 mi west-northwest from the PFP. An individual driving on State Route 240 or the recreational fisherman on the Columbia River is not considered as an offsite receptor as they are both judged to be within boundaries under the control of the DOE and could be evacuated in less than two hours.

2.2.1.3 Radiological Impact to Offsite Receptors. The GENII computer program (Napier et al. 1988) was used to calculate the doses to the maximally exposed offsite receptors and to the offsite population for gaseous effluent resulting from normal operations (Table 2-2). Two source locations were modeled: the 200 ft 291-Z-1 stack and a ground level release (for a release from any one of the three short stacks). The dose calculations for normal operations were based on the release data for the years 1989 through June of 1995. Using this data, the dose to the maximally exposed offsite individual is several orders of magnitude less than either the EPA limit (40 CFR 61, Subpart H) of 10 mrem/yr effective dose equivalent (EDE) (air pathway) or the DOE limit (DOE Order 5400.5) of 100 mrem/yr EDE continuous exposure over 5 years, 500 mrem/yr EDE occasional exposure.

2.2.2 Radioactive Liquid Wastes

There are three radioactive liquid waste (RLW) streams (one of which is currently being generated) discharged from the 236-Z and 234-5Z Buildings. The RLW is transferred to and stored temporarily in tanks at the 241-Z facility. There, it is treated to render it suitable for transport through underground pipelines to the Hanford Site tank farms for storage in double-shell tanks. The RLW streams are:

1. High-salt waste (HSW) from the Plutonium Reclamation Facility (PRF) in the 236-Z Building (the PRF is not authorized for production operation)

2. HSW from the Remote Mechanical C (RMC) Line in the 234-5Z Building (currently inactive)

3. Low-salt waste from laboratories and miscellaneous sources in the PFP.

These RLW streams are contained and isolated from the environment. During normal operations there is no impact to onsite or offsite receptors from these wastes.

Waste water with a radioactive interface includes cooling water, process steam condensate, and floor drains. The waste water, from drain lines D-1, D-2, and D-3 is sent to the Low-Level Waste Treatment Facility (LLWTF) (see Chapter 7). This stream was sent to the 216-Z-20 crib before the construction and operation of the Treated Effluent Disposal Facility (TEDF). The treatment at the LLWTF results in a decontamination factor of approximately 100 to 1. After treatment in the LLWTF, the stream meets the Derived Concentration Guides (DCGs) of DOE Order 5400.5, Chapter 3. The treated water from the LLWTF is routed to the TEDF for final disposal.

Steam condensate and floor drain discharges from the 291-Z Building are routed to French drains (see Chapter 7). Radiological inventories are not available for these streams, low-level radioactive contamination is not expected, but has been assumed.

2.2.2.1 Quantity and Concentrations of Liquid Effluent Streams. Currently there are two streams released to the environment (i.e., French drains 216-Z-13 and 216-Z-14). Prior to the construction and operation of the TEDF, waste water streams were also discharged to the 216-Z-20 crib.

2.2.2.1.1 French Drains. Three potentially contaminated French drains (216-Z-13, 216-Z-14, and 216-Z-15) are located at the PFP, only French drains 216-Z-13 and 216-Z-14 are in operation. The 291-Z Building evaporator cooler drainage, which was routed to French drain 216-Z-15, is now transferred to the LLWTF. The sources to the drains are not contaminated, but there is the potential for past radiological contamination. Radiological inventories are not available for these streams, low-level radioactive contamination is not expected, but has been assumed.

2.2.2.2 Radiological Impact on Offsite and Onsite Receptors. In the case of liquid effluents, the source term is retained on the soil column and not immediately available to any receptor. It is estimated that the source term is isolated from the groundwater by over 100 ft of soil column. Because the source term is immobilized, a complete analysis of this pathway was not performed. There is no scenario in which this source term would impact the current onsite or offsite population.

2.2.3 Radioactive Solid Wastes

Four categories of solid radioactive waste are generated by the PFP:

1. The LLW (or room waste)
2. The Waste Isolation Pilot Plant (WIPP) certifiable transuranic (TRU) waste (or hood waste)
3. Non-WIPP certifiable TRU waste
4. Polychlorinated biphenyl (PCB)/absorbed organic waste.

Room waste is potentially contaminated solid radioactive waste generated at the PFP, such as rags, paper, gloves, etc. The WIPP certifiable TRU waste is in excess of 100 nCi/g of plutonium and meets the acceptance requirements for transfer to WIPP. The non-WIPP certifiable waste contains aerosol cans. The TRU scrap with recoverable amounts of plutonium are stabilized and placed in storage.

2.2.3.1 Quantity and Types of Solid Waste Produced. Solid wastes are segregated based on ultimate disposal method. They are handled as WIPP waste, non-WIPP TRU solid waste transferred to 20-year retrievable storage and low-level solid wastes. The PCB/absorbed organic wastes are collected, sampled, and analyzed in accordance with U.S. Environmental Protection Agency (EPA) procedures. The PCB/absorbed organic wastes are stored according to applicable storage regulations for later transfer for processing.

The solid wastes are packaged based on the ultimate disposal option and are consistent with U.S. Department of Transportation regulations and Hanford contractor procedures. The outside containers of waste packages must be free of smearable contamination (20 dpm/100 cm^2 for alpha). The nominal solid waste volumes historically generated on an annual basis are shown in Table 2-3.

2.2.3.2 Radiological Impact on Offsite and Onsite Receptors. Within the scope of this FSAR there is no credible scenario in which solid waste generated would impact the onsite or offsite population. None of the waste has been transported offsite. Transportation of this material is addressed in appropriate packaging and shipping safety documentation.

2.3 RADIOLOGICAL IMPACT FROM ABNORMAL OPERATIONS

For the purposes of this FSAR, abnormal operations are defined as events that could occur from malfunctions of systems, operating conditions, or operator error. In general, the magnitude of the events discussed would not have a significant effect beyond the exclusion zone.

Chapter 9.0, Section 9.1, identifies and analyzes potential abnormal operations. The events presented are generic in nature and were developed, in part, from a composite of actual events recorded in the 50 years of PFP operating experience. The abnormal operations analyzed and their respective Chapter 9.0 section numbers are as follows:

- Radioisotope-Bearing Liquid Spills (Section 9.1.1)
- Radioisotope-Bearing Pressurized Liquid Container (Section 9.1.2)
- Radioisotope-Bearing Powder Spills (Section 9.1.3)
- Radioisotope-Bearing Pressurized Powder Container (Section 9.1.4)
- Stack Release Resulting from Filter Changes (Section 9.1.5)
- Ventilation System Upsets (Section 9.1.7)
  - Excessive Pressurization, 234-5Z Building (Section 9.1.7A)
  - Excessive Pressurization, 236-Z Building (Section 9.1.7B)
  - Excessive Pressurization, 2736-ZB Building (Section 9.1.7C)
  - Excessive Pressurization, 2736-Z Building (Section 9.1.7D)
  - Excessive Pressurization, 241-Z Building (Section 9.1.7E)
  - Excessive Depressurization — All PFP Operating Buildings (Section 9.1.7F)
- Loss of Ventilation (Section 9.1.8)
- Glovebox Glove Breach (Section 9.1.9).
- Pressurized Production Vertical Denitration Calciner (Section 9.1.10.1).
- Reactive Material Thermal Stabilization Process (Section 9.1.11).
- Laboratory Prototype Calciner (Section 9.1.12).
- Loss of Filtration (Section 9.1.13).
- Magnesium Hydroxide Precipitation Process (9.1.14).

- Bagless Transfer System (9.1.15).

The abnormal operations listed above are summarized in the following sections and in Table 2-4. In assessing the acceptance of certain abnormal operations, reference is made to risk acceptance guidelines. These guidelines, established for both radioactive and toxic materials, are presented in Chapter 9.0, Tables 9-49 and 9-50, respectively.

2.3.1 Radioisotope-Bearing Liquid Spills

Associated with the handling of almost any liquid at the PFP is the risk of a spill. The greatest likelihood of a spill, however, occurs during the handling of small plutonium-bearing laboratory samples. The composition of the spilled liquid could vary from slightly contaminated waste water to liquids containing significant amounts of radionuclides. All radionuclide-bearing liquids handled in the PFP are confined within protective systems that prevent or minimize a release to the environment resulting from the failure of a single system.

Although the spill of a laboratory sample is most probable, the worst case abnormal event conservatively assumes that the contents of a 10-L polyethylene or steel bottle containing concentrated plutonium nitrate solution are spilled from a height of 3 m onto the floor outside of a glovebox. As a result of the spill, it is estimated that 0.002% (by weight) of the plutonium nitrate solution with a 1,640 g/liter density, or 0.33 g (0.16 g Pu), becomes airborne as droplets. A single stage of HEPA filtration reduces the amount of Pu released to the environment to a level well below the risk acceptance guidelines for an event with a frequency of 1/yr.

2.3.2 Radioisotope-Bearing Pressurized Liquid Container

Containers of plutonium-bearing liquids, each having a small potential to become pressurized, are stored in the PFP in a variety of locations, quantities, and concentrations. Pressurization of containers can occur passively (e.g., chemical decomposition of the contained liquids and nuclear degradation of the primary container) or actively (e.g., external application of heat and physical crushing as a result of mishandling). It is assumed that the containers are handled using normal methods, including the performance of all venting and lid-removal procedures in open-faced hoods.

Pressurization of a container storing a liquid solution does not become an abnormal event until it results in failure of the primary container or causes a spill when an attempt is made to transfer the liquid. When an operator opens an overpack and determines that the primary container has failed due to overpressurization, the failure would, in most cases, be mitigated by the secondary container (overpack). If the pressure in a container has not been relieved due to plugging of the vent valve or improper venting before opening the container, the result could be personnel injury and contamination spread due to a rapid discharge of gases and liquids when the lid is removed.

The postulated event conservatively assumes that 5 L of a plutonium nitrate solution contained in a 10-L polyethylene bottle is ejected from the container and then spilled 3 m onto the floor outside of a glovebox. As a result of the spill, it is estimated that 0.002% (by weight) of the plutonium nitrate solution with a 1,640 g/liter density, or 0.16 g (0.08 g of Pu), may become airborne as droplets. A single stage of HEPA filtration reduces the amount of Pu released to the environment to a level well below the risk acceptance guidelines for an event having a frequency of 1/yr.

2.3.3 Radioisotope-Bearing Powder Spills

Associated with the handling of plutonium-bearing powders in the PFP is the risk of a spill occurring. Before removal from a glovebox the powder is placed in a metal slip-lid can, the lid is taped shut, and the can is placed in a plastic bag that is heat-sealed. After removal from the glovebox, the package is mechanically sealed into two successively larger cans. Tests have shown that slip-lid cans with untaped lids can withstand drops of 3 m without sustaining a loss of contents. Therefore, a series of errors must happen for a powder spill to occur.

The analysis conservatively assumes that 1 kg of PuO_2 powder (the maximum capacity of a slip-lid can) is spilled from a height of 3 m onto the floor outside of a glovebox. As a result of the free fall spill, it is estimated that 0.12% (by weight) of the PuO_2 powder, or 1.2 g, becomes airborne. Prior to release to the environment from the PFP stack, the 1.2 g of PuO_2 must pass through a single stage of HEPA filtration. Given a HEPA filter efficiency of 99.95%, only 6×10^{-4} g of Pu would reach the stack. The resultant dose is more than an order of magnitude lower than the risk acceptance guidelines for an event having a frequency of 1/yr.

2.3.4 Radioisotope-Bearing Pressurized Powder Container

The handling of a pressurized container of plutonium-bearing powder, both within and outside of process enclosures, has the potential to cause an abnormal event through the release of material. Plutonium powders are stored in a series of successively larger cans, providing head space to accommodate any expansion of the stored material. Pu-bearing material known to be capable of gas generation that could cause pressurization in a sealed container is stored in a vented configuration. The use of nested cans provides multiple confinement barriers, and the cans are stored in facilities with at least one stage of HEPA filtration.

The concentration of airborne radioactive material expected during abnormal occurrences is based on historical data from 1986 through 1988. The data shows that the concentrations of airborne radioactive material exceeding the operational plant limit of 2×10^{-12} μCi/mL (^{239}Pu) averaged 9.2×10^{-12} μCi/mL. Only two incidents resulted in concentrations as great as 10^{-10} μci/mL, with the highest concentration being 2.52×10^{-10} μCi/mL. A release at the highest concentration into a room would increase the stack concentration between 1.7×10^{-16} μCi/mL and 5.6×10^{-16} μCi/mL, concentrations

well below both the minimum detection level of 5 x 10^{-15} μCi/mL and the normal stack emission level of 4 x 10^{-14} μCi/mL.

2.3.5 Stack Release Resulting from Filter Changes

Ventilation exhaust from contaminated hoods, gloveboxes, process vessels, and potentially contaminated rooms around the gloveboxes is passed through a final, second stage of HEPA filtration in order to remove particulates prior to release. During the changeout of a secondary HEPA filter (the last barrier between contamination and the stack), it is possible for an error to occur (i.e., a filter is dropped) and result in a release to the environment via the 291-Z-1 stack.

The analysis assumes that a HEPA filter is dropped approximately 8 ft onto a concrete floor during a routine filter change in Room 309 or 310 of the 234-5Z Building resulting in the release of contaminated dust into the filter room. Nondestructive assays performed on HEPA filters removed from a filter room in the PFP after 14 years of service determined that the greatest loading on any a single filter tested was 3.7 x 10^{-3} g Pu. Assuming the dropped filter has the maximum Pu loading and assuming a safety factor of 2, the inventory at risk is 7.4 x 10^{-3} g. Given current plant operations are conducted on a smaller scale than when the assayed filters were in service, this value is appropriately conservative.

The analysis conservatively assumes that 1% of the inventory of a dropped HEPA filter would be released as respirable particles. Therefore, 7.4 x 10^{-5} g of respirable Pu powder would be released to the stack. The resultant dose is below the risk acceptance guidelines for an event having a frequency of 1/yr.

2.3.6 Ventilation System Upsets

2.3.6.1 Excessive Pressurization--All PFP Operating Buildings. All of the PFP operating buildings have been analyzed and there are no unacceptable consequences caused by excessive pressurization. The effects of pressurization on individual buildings are described below.

2.3.6.1.1 Excessive Pressurization, 234-5Z Building. Eight electric motor-driven supply fans furnish outside air to a supply plenum in the 234-5Z Building. The supply plenum also services the 236-Z Building. Nine electric motor-driven exhaust fans are located both in the 291-Z and 234-5Z Buildings. The ventilation is controlled by supply dampers A through F. Supply damper A feeds the office areas which are maintained at positive pressures with respect to all other areas. A failure of this damper would drive the zone additionally positive , which would have no effect on contamination control. Excessive building pressurization could occur from failure of supply dampers B, C, and D. These dampers feed air to rooms and corridors within the radiation zones of the 234-5Z Building. Pressure differentials of up to 1 in. w.g. between adjacent rooms could occur, but gloveboxes remain negative to room atmospheres. A small amount of the radioactive contamination free of confinement structures present in the building could be released by excessive

building pressurization. The amount of material released would be insignificant. The failure of damper E was not evaluated in detail as there are no unsealed sources of radioactive materials in the rooms that are supplied by this damper. In addition, the rooms would not be pressurized as the damper fails closed. Supply damper F services the 236-Z Building and is discussed in the next section.

2.3.6.1.2 Excessive Pressurization, 236-Z Building. The 236-Z Building is serviced by the same supply plenum and exhaust system that supports the 234-5Z Building. Failure to the open position of supply damper F could result in pressurization to 0.5 in. w.g. over normal. Were this to occur, the process cell and gloveboxes would remain negative to the surrounding rooms. If pressurization of the process cell occurs, the potential exists for a release to the environment via the airlock located at the south end of the cell. However, the airlock is equipped with a single stage of HEPA filtration resulting in an insignificant release.

2.3.6.1.3 Excessive Pressurization, 2736-ZB Building. A ventilation control failure could lead to a pressurization of 2 in. w.g. Such a pressurization is not expected to cause a breach of the building or release of material from the single glovebox located in the building.

2.3.6.1.4 Excessive Pressurization, 2736-Z Building. The 2736-Z Building could conceivably be pressurized close to the full 2 in. w.g. available in the supply plenum. The consequences of this action would be limited as there is no loose radioactive material stored in the facility.

2.3.6.1.5 Excessive Pressurization, 241-Z Building. There are no supply fans for the 241-Z Building. Therefore, there are no credible means of significantly pressurizing the structure.

2.3.6.2 Excessive Depressurization--All PFP Operating Buildings. All of the PFP operating buildings have been analyzed and there are no unacceptable consequences caused by excessive depressurization. The effects of depressurization on individual buildings are described below.

2.3.6.2.1 234-5Z Building. Depressurization could occur by valve adjustment errors or icing over of the humidifier pads on the supply unit air washers. In the case of a valve adjustment error, either the B or C supply plenum discharge damper could fail. Only certain parts of the building would be affected because the two dampers are tied to the same controller that has a single sensor in a room fed by both dampers. A failure of a supply damper would over pressurize the room housing the sensor, and the working damper would close down. The room served solely by the working damper will experience a drop in pressure. In general, intervening doors with adjoining rooms will open, and air from these rooms will flow into the rooms in an attempt to reestablish pressure. In the second case where there is a failure to sustain the supply air system, vacuum breakers on the supply plenum would open and limit the effect of the occurrence.

Depressurization by failure of supply damper B or C could result in airflow reversals. If doors are not securely latched, there would be a rush of air to the newly created low pressure rooms from the other rooms. If loose

radioactive materials were present from a separate event, the contamination could be spread by the depressurization. A depressurization of the building from a failure to sustain the supply air system would not result in a severe pressure differential. There may be a brief pressure reversal between zone 1 (frontside) and zone 3 (backside).

2.3.6.2.2 236-Z Building. This building is serviced by the same supply plenum and exhaust system that supports the 234-5Z Building. Accidental closure of supply damper F could result in depressurization to -6 in. w.g. This would be approximately equal to the 5.8 in. w.g. live load design of the roof. The sudden drop in pressure might cause personnel discomfort but would not compromise the structure nor affect the containment of radioactive material.

2.3.6.2.3 2736-ZB Building. No credible scenarios could result in significant depressurization of the building.

2.3.6.2.4 2736-Z Building. The radioactive materials in this building are either sealed in containers or are in containers with filtered vents. A pressure differential of a few inches of water would not cause leakage of the containers. A depressurization to -3 in. w.g. has occurred in the past in which no damage occurred.

2.3.6.2.5 241-Z Building. The simplicity and low flow rate of the system precludes any means to significantly depressurize the building.

2.3.7 Loss of Ventilation

A loss of ventilation would occur if both the supply fans and exhaust fans were to simultaneously lose power. This event would occur only during a simultaneous loss of two 13.8-kV electrical feeds and backup power from the diesel-generators located in Building 2721-Z. The supply fans and exhaust fans would coast to a stop. The supply fan dampers would open. Zone dampers B through E would open and dampers A and F would close. Zones 1 and 3B would be isolated from the rest of the system. The dampers to the exhaust fans would close except the dampers to the emergency exhaust fans, EM-1 and EM-2, that fail open.

Given a loss of ventilation, air in the facility would become essentially stagnant, except for natural circulation. The flow of air would be up the stack for most environmental conditions. Very slight reverse movement could be caused by specialized conditions of convection or differential pressures resulting from weather changes.

The generation of hydrogen gas from tanks containing plutonium solutions is a hazard under loss of ventilation conditions. Provided that solutions are present, calculations indicate it would take nearly four weeks to accumulate sufficient hydrogen to result in a structure-threatening deflagration.

Loss of ventilation would also result in increased temperatures and pressures for containers of plutonium stored in the vault. The storage cans would not burst under these conditions. There are no unacceptable

consequences resulting from loss of ventilation under the assumptions used in this analysis.

2.3.8 Glovebox Glove Breach

The handling and maintenance of glovebox gloves and the associated hand tools has the potential to breach a glove (i.e., breach of primary containment) resulting in the release of plutonium-bearing materials into an occupied area. Sources such as a hot surface, a sharp object, or deteriorated glove material can lead to glove failure. For a release to occur resulting from a glove breach, the event that breached the glove must also release contaminants, the negative glovebox differential pressure must be absent or reversed, or the event must create a reverse pressure pulse. While these events are considered to have the potential to expose individuals to radioactive material, the release would be small and the mitigating efforts of Radiological Control personnel would result in minimal health effects to workers. The consequences of a glovebox glove breach are bounded by the consequences of the spill of liquids and powders previously analyzed.

2.3.9 Pressurized Production Vertical Denitration Calciner

The production vertical denitration calciner (VDC) oxidizes plutonium nitrate solutions into plutonium oxide powder. Chapter 9.0, Section 9.1.10.1 analyzes pressurization of the VDC. A summary of the Chapter 9.0 analysis has not been prepared as VDC operation is not authorized at this time.

2.3.10 Reactive Material Thermal Stabilization Process

Chapter 9.0, Section 9.1.11 identified five event categories of abnormal operations associated with the reactive material thermal stabilization process. However, none of the abnormal operations in the categories were uniquely related to the stabilization process. Therefore, no additional analysis was performed for any of the events identified.

2.3.11 Laboratory Prototype Calciner

The Laboratory Prototype Calciner addendum to this FSAR identified six event categories of abnormal operations associated with the calciner operations. However, none of the abnormal operations in the categories were uniquely related to the operation of the calciner. Therefore, no additional analysis was performed for any of the events identified. It is noted that operation of the laboratory calciner is not currently authorized.

2.3.12 Loss of Filtration

Two buildings were evaluated to determine the potential consequences associated with a loss of filtration. The buildings evaluated are the 232-Z Building and the 241-Z Building. Both evaluations assume that filtration is

lost due to catastrophic breach in the HEPA filters or that a significant leak in the seals occur and the ventilation fans continue operating. Both exhaust systems are aerosol penetrant tested annually and releases from the individual exhaust stacks are continuously monitored. Section 9.1.13.1 describes the accident scenario and consequence calculations associated with an unfiltered release from Building 232-Z and Section 9.1.13.2 describes the accident scenario and calculated consequences associated with an unfiltered release from Building 241-Z.

2.3.13 Magnesium Hydroxide Precipitation Process

Abnormal operations associated with the Magnesium Hydroxide Precipitation Process are identified and evaluated in the related addendum (Carson 2000) to this FSAR.

2.3.14 Bagless Transfer System

Abnormal operations associated with the Bagless Transfer System are identified and evaluated in the related calculation notes (FH 2000).

2.4 ACCIDENTS

For the purposes of this FSAR, accidents are defined as situations where primary and/or secondary confinement may be credibly breached to the extent of releasing radioactive materials beyond the exclusion area or a quantity that could seriously endanger personnel within the exclusion and restricted areas. Included is consideration of industrial accidents that would not result in a release of radioactivity but could endanger onsite personnel.

The accident scenarios selected for analysis are hypothetical in nature and in many cases involve near incredible combinations of natural and operational conditions to achieve the worse case. The hypothetical events are deemed credible when their frequency exceeds 1.0×10^{-6}/yr. In some cases, analyses of incredible events were included because the public may deem them credible, as in the case of an aircraft accident. The accidents analyzed and their respective Chapter 9.0 section numbers are as follows:

- Explosions (Section 9.2.1)
  - Decomposition of Heavy Metal Nitrate-TBP Complexes (Section 9.2.1.2)
  - Flammable Gas Deflagration (Section 9.2.1F)
    - Slow Propane Releases (Section 9.2.1F.1.1)
    - Catastrophic Cylinder Failure (Section 9.2.1F.1.2)

- Fire (Section 9.2.2)
  - Remote Mechanical C Line and Remote Mechanical A Line Fire (Section 9.2.2A)
  - Hydraulic oil fire (Section 9.2.2B)
- Waste Drum Events (Section 9.2.2D)
  - Fire Release (Section 9.2.2D.2.1.1)
  - Mechanical Release (Section 9.2.2D.2.1.2)
  - Drum Explosion (9.2.2D.2.1.3)
- Criticality (Section 9.2.3)
- Seismic Event (Section 9.2.4)
- Strong Wind (Section 9.2.5)
- Aircraft Accident (Section 9.2.7)
- Toxic Chemical Release (Section 9.2.8).
- Accidents for the Plutonium-Bearing Solution Stabilization Process using the Production Vertical Denitration Calciner (VDC) (Section 9.2.9)
  - Flammable Gas Deflagration in the Production Vertical Denitration Calciner (Section 9.2.9.1)
  - Glovebox HC-230C-2 Fire (Section 9.2.9.2)
  - Compressed Air Cylinder Failure (Section 9.2.9.3)
  - Glovebox HC-230C-2 Seismic Release (Section 9.2.9.4)
  - Changes to the RMC Line Fire Analysis from Glovebox HC-230C-2 (Section 9.2.9.5)
- Accidents for Reactive Plutonium-Bearing Material Stabilization (Section 9.2.10)
  - Hydrogen Deflagration in Glovebox HC-21A from Opening Pressurized Containers (Section 9.2.10.1)
  - Deflagration in Glovebox HC-21C (Section 9.2.10.2)
  - Seismically Induced Deflagration in Glovebox HC-21C or HA-21I (Section 9.2.10.3)
  - Glovebox HC-21C or HA-21I Fire (Section 9.2.10.4)

- Seismically Induced Fire in Glovebox HC-21C or HA-21I (Section 9.2.10.5)
- Changes to the RMC Line Fire Analysis from Glovebox HC-21A and HC-21C (Section 9.2.10.6)

- Accidents for Plutonium-Bearing Solution Stabilization using the Laboratory Prototype Calciner (Section 9.2.11)
- Accidents for the Magnesium Hydroxide Precipitation Process (Section 9.2.12)
- Accidents for the Bagless Transfer System (Section 9.2.13)

The accidents listed above, with the exception of Plutonium-Bearing Solution Stabilization Process Accidents using either the Production VDC or the Laboratory Prototype Calciner, are summarized in the following sections and in Table 2-5. The solution stabilization accidents are not summarized as these processes are not currently authorized. The risk associated with each accident is defined by its associated probability and consequences as determined by the analysis. Probability estimates were derived from the accident scenarios by assigning equipment failure rates and human error probabilities to contributing factors. Radiological consequences are based on the source term and were calculated using the GXQ (Hey 1993) and GENII (Napier et al. 1988) computer codes. To determine risk acceptability, the probability and consequences for a given accident were compared to the risk acceptance guidelines (Chapter 9.0, Tables 9-49 and 9-50). These comparisons are shown in Figures 2-1 and 2-2 for onsite and offsite dose receptors, respectively. These comparisons are also made in Table 2-5. In all cases, the risk acceptance guidelines are met. In accordance with Hanford contractor procedure HNF-PRO-704, dose consequences to a receptor located at Highway 240 are provided in Table 2-5 for information only.

2.4.1 Explosions

The term explosion is used to identify any event which the general public would believe to be an explosion. This includes detonations, deflagrations, or overpressurizations due to gas generation. There are several systems within the PFP that have the potential to generate an explosion as a result of their operation. However, almost all of these systems are currently out of service. Two types of explosions, "red oil" and bottled flammable gas (i.e., propane) are summarized below. Additional flammable gas events (e.g., hydrogen) are summarized in Section 2.4.10.

2.4.1.1 Decomposition of Heavy Metal Nitrate-TBP Complexes. Red oil explosions result from the decomposition of heavy metal nitrate-tributyl phosphate (TBP) complexes. As discussed in Chapter 9.0, Section 9.2.1.2, heavy metal nitrate-TBP complexes decompose exothermically at elevated temperatures. If the rate of reaction is such that heat is generated faster than it can be removed, the reaction becomes autocatalytic. The rapid evolution of flammable gas (i.e., butene) may result in an explosion from (1) overpressurization of a process vessel or (2) ignition of the gas. Currently

authorized activities do not generate or process heavy metal nitrate-TBP complexes.

2.4.1.2 Flammable Gas Deflagration. The types and quantities of flammable gases used at the PFP were reviewed, and the greatest risk was determined to be presented by nominal 465 g (16.4 oz) U.S. Department of Transportation (DOT) 39 cylinders of liquid propane gas (LPG). Propane is used as needed at the PFP for a variety of maintenance activities. A preliminary hazards analysis identified the following hazards associated with the use of propane: fires, leaks, mechanical failures, and boiling liquid expanding vapor explosions. The hazards associated with the use of LPG in 465 g (16.4 oz) cylinders are divided into the general areas of slow leaks and catastrophic cylinder failures.

The former propane supply line in Bldg. 234-5Z is no longer in service and has been disconnected from a propane supply. The former supply header has been cut into segments, flushed, and capped. The line segments have been sampled and found not to contain explosive concentrations of propane (BWHC 1998). The segments of the former propane supply header will have vents installed in them to ensure propane concentrations in this header stay below the explosive limit (BWHC 1998a). Accordingly, deflagrations associated with the former propane header in Bldg 234-5Z have not been analyzed.

2.4.1.2.1 Slow Propane Releases. As discussed in Chapter 9.0, Section 9.2.1F.1.1, the slow discharge of propane from a 465 g (16.4 oz) DOT 39 LPG cylinder does not result in an explosion, but it could result in a deflagration.

Scenario. All DOT 39 cylinders are equipped with a safety relief valve that opens if the internal pressure exceeds 2,480-3,307 kPa (360-480 lb/in^2 [gauge]). This valve is significantly larger in size than valves used for normal gas consumption (i.e., 2.2 mm in diameter versus either 0.11 mm or 0.23 mm) such that an uncontrolled release would occur in a significantly shorter time (i.e., 20 seconds versus 20 hours and 6 hours, respectively). The worst-case discharge condition is therefore an uncontrolled discharge of propane from the 2.2-mm orifice.

Two release conditions are analyzed. In the first case, it is assumed that propane is released uncontrollably from the safety relief valve of a 465-g (16.4-oz) LPG cylinder into an unventilated 30-m^3 room (considerably smaller than any PFP process room). The propane is assumed to mix with the room air and deflagrate. In the second case, it is assumed that two cylinders simultaneous discharge via the safety relief valve into an unventilated 65-m^3 room. The propane is assumed to mix with room air and deflagrate.

Source Term. No radiological or toxicological source term was developed for this event as it was determined that the deflagration would not result in an uncontrolled release to the environment.

Probability. The frequency of safety relief valve failure was not estimated as it was determined that the risk would be acceptable at any event frequency.

Consequences. The worst-case deflagration results in peak pressures of 0.34 lb/in^2 and 0.35 lb/in^2 for the single-cylinder and two-cylinder events, respectively. These pressures are less than the 0.49 lb/in^2 required to fail the 234-5Z Building exterior wall panels. Accordingly, there is no release to the environment, and the associated risk is acceptable at any event frequency.

2.4.1.2.2 Catastrophic Cylinder Failure. As defined in Chapter 9.0, Section 9.2.1F.1.2, a catastrophic cylinder failure occurs when an LPG container ruptures and nearly all of the LPG instantaneously escapes.

Scenario. Possible mechanisms of a catastrophic cylinder failure include dropping, crushing, or an exposure to fire coincident with the failure of the safety relief valve.

- Dropping — The maximum potential drop height (based on the ceiling height of rooms in the 234-5Z Building) is 4.6 m (15 ft). A cylinder dropped from this height would deform but not rupture. If dropped onto a sharp object, the cylinder could be punctured, resulting in a slow release of propane (see Section 2.4.1.2.1); however, the puncture would not lead to a catastrophic cylinder failure.

- Crushing — Crushing-type accidents were investigated (e.g., mobile heavy equipment and falling heavy objects). No credible scenarios were identified.

- Exposure fire — The probability of a fire involving two DOT-39 cylinders and the coincident failure of the safety relief valves was investigated and found to be incredible.

Source Term. There is no radiological or toxicological source term for this event as no credible scenarios could be identified.

Probability. Dropping of cylinders does not lead to a catastrophic failure, therefore no probability was estimated. The potential for crushing-type accidents and a combined exposure fire/safety relief valve failure was analyzed through the development of event trees. The frequency of a crushing event leading to a catastrophic failure was determined to be 1.0×10^{-7}/yr. The frequency of a fire involving two cylinders occurring in combination with the failure of the safety relief valves was determined to be 4.14×10^{-7}/yr.

Consequences. There are no consequences for this event as no credible scenarios could be identified.

2.4.2 Fire

Fire is one of the accidents that has the potential for both breaching confinement and lofting radioactive materials. The scenarios summarized in this section are an RMC Line fire and a hydraulic oil fire on the top floor of the 234-5 Building. Additional fire analyses have been performed for waste drum storage (Section 2.4.3), a seismic event (2.4.5), vertical denitration calciner operations (Section 2.4.9), and thermal stabilization (2.4.10).

2.4.2.1 Remote Mechanical C Line and Remote Mechanical A Line Fire. The RMC Line and RMA Line were formerly used to produce plutonium metal from plutonium nitrate solutions. The majority of the RMC Line and RMA Line gloveboxes are now inactive. The RMC Line and RMA Line gloveboxes are constructed of polymethylmethracralate (PMMA) and polycarbonate panels on metal frames. These plastics represent a large fuel loading. The RMC/RMA Lines fire analysis is presented in Chapter 9.0, Section 9.2.2.A, and is summarized below.

Scenario. A fire is assumed to occur in a glovebox as a result of maintenance or retrofitting activities. It is assumed that the glovebox Halon fire suppression system does not extinguish the fire and that the Hanford Fire Department (HFD) fails to respond in normal time (i.e., approximately 15 minutes). The fire is assumed to be large enough to ignite the plastic glovebox panels. The fire could also start in Gloveboxes HC-21C or HA-21I as a result of operational of the high temperature furnaces.

The fire is assumed to propagate and involve all of the gloveboxes in Rooms 228A, B, and C and in Rooms 230-A, -B, -C, 232, 235A-1, A-2 and A-3, and 235-B and C. Although smoke loading could damage the in-line filterboxes servicing the glovebox (i.e., E-4) ventilation system, the final stage of E-4 HEPA filters would not be affected. The E-3 ventilation system servicing these rooms also provides one stage of HEPA filtration. The fire is assumed to be extinguished by the HFD after 40 minutes.

Source Term. To calculate the source term, it is assumed that all active gloveboxes are loaded with plutonium to their criticality prevention specification (CPS) limit. Applying the DOE-recommended airborne release fraction and respirable fraction to the inventory at risk for nonreactive compounds under thermal stress, the amount of respirable Pu made airborne is determined. Taking credit for one stage of HEPA filtration, the release from the 291-Z-1 stack is then determined.

Probability. The fire in the RMC/RMA Lines is assumed to be an anticipated event with an annual probability of 1×10^{-2}, without regard for the fire protection features. Taking credit for the failure of the fire protection system controls specified in Administrative Control 5.20 (HNF 2000) and the related fire protection features, is judged to lower the annual probability to 10^{-4} to 10^{-6}.

Consequences. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.2.2 Hydraulic Oil Fire in Room 321. The PFP Fire Hazards Analysis (FHA) analyzed an unmitigated, worst case fire involving a hydraulic oil spill in Room 321 of the 234-5Z Building. The hydraulic oil is used in the elevator hydraulic lift. The FHA analysis is discussed in Chapter 9, Section 9.2.2B, and is summarized below.

Scenario. The FHA assumes that 150 gallons of hydraulic oil is spilled in Room 321, spreads over a large area, and ignites. Within 2 to 5 minutes

the temperature of such a fire would exceed the single point and average temperatures used to determine the fire resistive properties of steel. Exposed steel columns and beams supporting the 234-5Z Building roof assembly are assumed to fail resulting in collapse of the roof.

In accordance with FHA recommendations, a containment berm has been constructed around the hydraulic elevator components. This berm limits the spread of the fire thereby limiting the number of steel columns exposed.

Source Term. Taking credit for the containment berm, the fire is limited to Room 321. There are no radioactive materials in this area of the 234-5Z Building.

Probability. Taking credit for the containment berm, a hydraulic oil fire resulting in collapse of 234-5Z Building roof assembly is judged to be incredible.

Consequences. Taking credit for the containment berm, there are no radiological consequences associated with a hydraulic oil fire in Room 321. The 234-5Z Building structure is a Safety Class SSC. Because the containment berm directly serves to protect the building structure, it too is a Safety Class SSC.

2.4.3 Waste Drum Events

Drums containing radioactive wastes from the PFP are stored within the fenced security area outside the PFP. Three different accidents are postulated: a drum fire, a mechanical release resulting from a forklift accident, and a drum explosion.

2.4.3.1 Fire Release. As discussed in Chapter 9.0, Section 9.2.2D.2.1.1, a vehicle crash with ensuing fire is judged to be the bounding fire event involving drum storage.

Scenario. For a fire release, the postulated event is a vehicle traveling within the fenced security area of the PFP that crashes into stored waste drums. Upon impact, the fuel tank of the vehicle ruptures and quickly releases its fuel. The fuel is ignited and burns as it spreads as a pool fire encompassing the storage containers breached by the crash. The fire lasts only a matter of minutes before the fuel is consumed. However, as the vehicle fuel burns, the contaminated, combustible material from the breached containers begins to burn and releases the contamination.

Source Term. It is conservatively assumed that the entire 3 kg inventory of Pu allowed in the yard is at risk. A fire could release 1.28 g of respirable plutonium oxide.

Probability. A vehicle crash into the waste containers with or without a fire requires the combination of a number of unlikely events. It is judged to be incredible for such an accident to involve the maximum allowed inventory of all containers. Applying a graded approach, it is simpler to use the risk acceptance guidelines for an unlikely event (1×10^{-2}/yr) than it is to

quantify the actual frequency of such an event. The frequency of a vehicle accident within the fenced area is much less than 1×10^{-2}/yr.

Consequences. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.3.2 Mechanical Release. As discussed in Chapter 9.0, Section 9.2.2D.2.1.2, the release of contaminants from a waste drum breached by mechanical forces (e.g., vehicle impact without fire, over-pressurization, falling, or forklift puncture) would be limited because the items in the containers are enclosed in multiple layers of plastic.

Scenario. For the mechanical release scenario it is assumed that a forklift punctures two drums containing the maximum amount of TRU.

Source Term. The maximum amount of Pu per drum is 15 g. Only 1.5×10^{-3} g of respirable plutonium nitrate would be dispersed in a mechanical release. The release amount is limited because of the relatively low amount of energy available for suspension of the Pu and because items in the drums are enclosed in multiple layers of plastic.

Probability. Although forklifts are operated by qualified operators, a forklift accident is an anticipated event (i.e., a frequency range of 1×10^{-2}/yr to 1/yr based on impacts to onsite receptor). The frequency of a forklift accident resulting in puncturing drums is bounded by 1×10^{-1}/yr.

Consequences. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.3.3 Drum Explosion. Many organic materials can decompose when exposed to radiation. Alpha radiolysis of organics in TRU waste can cause gas generation and possible drum pressurization. Flammable gas also can be generated in waste containers containing hydrogenous materials. For a closed, unvented waste container, the buildup of an explosive mixture of hydrogen and oxygen within the void space of the containers can be postulated.

Scenario. As analyzed in Chapter 9.0, Section 9.2.2D.2.1.3, a drum explosion is postulated to occur from the ignition of a flammable concentration of hydrogen. The accumulation of a flammable concentration would require (1) the absence or failure of the drum vent and (2) the absence or failure of the catalytic recombiner. The explosion is assumed to breach the container, scatter some of the contents of the containers, release some of the contaminants to the atmosphere, and ignite combustible material in the drum.

Source Term. Based on the release mechanism and the maximum of 15 g of Pu per drum, an explosion could release 0.015 g of respirable plutonium nitrate and 0.006 g of respirable plutonium oxide.

Probability. A drum explosion is conservatively assumed to be an unlikely event (i.e, having a frequency of 1 x 10^{-2}/yr to 1 x 10^{-4}/yr). For determining risk acceptance, the upper bound of the range is used (i.e., a frequency of 1 x 10^{-2}/yr).

Consequences. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.4 Criticality

Plutonium is present at the PFP in bare metal form, in powder form as PuF_4 and PuO_2, and in various liquid forms (primarily nitrates). The bare metal form of plutonium would reach criticality only in a compact, stacked, three-dimensional array. A criticality involving the powder form of plutonium would require a stacked array of powder pans to be moderated at a degree beyond that possible with normal powder densities. The majority of vessels storing or processing plutonium in a liquid form are constructed in a critically safe geometry. The exception is the 241-Z Building, which contains five 5,000-gal waste storage tanks. Gloveboxes cannot be of a critically safe geometry should they become flooded with water, but by enforcing strict administrative controls on mass, spacing, and form of materials, criticality can be prevented. The gloveboxes are also equipped with drains, where necessary, to prevent flooding.

Scenario. Chapter 9.0, Section 9.2.3 provides a detailed discussion of criticality safety as applied at the PFP to metal, powder, and liquid systems. Instead of developing detailed, PFP-specific criticality accident scenario, the design basis criticality from NRC Regulatory Guide 3.35 is used to assess consequences. This criticality produces an initial burst of 1 x 10^{18} fissions in 0.5 seconds followed successively, at 10 minute intervals, by 47 bursts of 1.9 x 10^{17} fissions for a total of 1 x 10^{19} fissions in 8 hours. The criticality is assumed to occur in a liquid system that is terminated by the evaporation of 100 L of solution.

Source Term. The amounts of radionuclides assumed to be produced by the criticality are presented in Chapter 9.0, Table 9-24. All of the noble gas fission products and 25% of the iodine radionuclides are released directly to a ventilated room with no holdup. The HEPA filter transmission factor for noble gas fission products and the iodine radionuclides is used as 1. The criticality is assumed to occur in a solution; therefore, an aerosol is assumed to be released due to evaporation directly into the room atmosphere. The aerosol is assumed to comprise 0.05% of the salt content of the solution that is evaporated or 1 mg PuO_2. No credit is given for holdup mechanisms in the room or duct work, but the filter system is assumed to be functional. The transmission factor for a single stage of HEPA filters is used as 5 x 10^{-4}.

Probability. In the approximately 50-year history of six major DOE sites, there have been six criticalities involving chemical processing. Thus, with overall raw statistics, the frequency of any one site suffering a criticality would be 6 in 240 years or 2.5 x 10^{-2}/yr.

Consequences. Two release models were used to evaluate a criticality accident. One model assumes the accident takes place in a building location ventilated via the 200-ft stack, and the other model assumes the accident takes place in a building location ventilated via a short stack. The two release models differ in the dose to onsite and offsite personnel due to differences in atmospheric dispersion and direct dose. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.5 Seismic Event

The response of the PFP facilities to an assumed seismic event and the resultant releases of radioactive and toxic materials are analyzed in Chapter 9.0, Section 9.2.4. The following analytical approach was used:

- Determine the structural response of each facility and glovebox to seismic loads (see Section 9.2.4.1)
- On a facility-by facility basis and glovebox-by-glovebox basis, identify the potential accidents resulting from the response to seismic loads (see Section 9.2.4.2)
- Determine for each potential accident the release of radioactive and toxic materials into the facility (see Sections 9.2.4.3, 9.2.4.4, 9.2.4.5, and 9.2.4.6)
- Calculate the fraction of material transported out of facilities (see Section 9.2.4.7)
- Calculate the doses resulting from the total release out of the facilities (see Section 9.2.4.8)
- Add the contributions to the seismic analysis from the Magnesium Hydroxide Precipitation Process and Bagless Transfer System (See Sections 9.2.4.10 and 9.2.4.11).
- Add the contribution to the seismic analysis from seismically induced fires initiated in Gloveboxes HA-21I and HC-21C by operation of the high temperature furnaces (See Section 9.2.4.2.12.F).

The specific PFP facilities analyzed are as follows:

- 234-5Z
- 236-Z
- 241-Z
- 242-Z
- 232-Z
- 291-Z
- 2736-Z, ZA, and ZB
- Outside tanks around 234-5Z and 236-Z.

2.4.5.1 Scenario. Due to the differing structural responses of PFP buildings to various ground accelerations, two seismic events of differing magnitude were evaluated.

2.4.5.1.1 Greater than 0.09-g Ground Acceleration. The 232-Z and 241-Z Buildings are susceptible to structural damage at horizontal ground accelerations greater than 0.09-g. Significant structural damage to other PFP buildings does not occur below 0.2-g.

Given an earthquake with a horizontal ground acceleration greater than 0.09 g, the analysis assumes that the inactive incinerator glovebox in the 232-Z Building topples and that the roof of the building collapses. The resultant forces are assumed to suspend plutonium contained in the incinerator glovebox and other process equipment and enclosures. Plutonium released into the 232-Z Building is assumed to be released directly to the environment.

For the 241-Z Building, the structure is assumed to fail and fall on the cover blocks over the underground tanks. The cover blocks are assumed to fail and fall onto the tanks which, in turn, fail. A portion of the plutonium solution in the tanks is assumed to be released directly to the environment.

2.4.5.1.2 0.2-g Ground Acceleration. The DBE for Safety Class structures, systems, components, and equipment is defined in Hanford Plant Standard SDC 4.1 (WHC 1991) as having a ground acceleration of 0.2-g. Assuming an earthquake of this magnitude, the PFP buildings, with the exception of the 232-Z and 241-Z Buildings, will remain standing. Building internals (e.g., gloveboxes and piping) and services and utilities (e.g., water and electrical power) will be affected. Scenarios are developed for plutonium and toxic material dispersal by mechanical means, a seismically induced criticality, and seismically induced fires.

Plutonium Dispersal. Plutonium dispersal by mechanical means is postulated to occur as a result of seismically induced containment and confinement system failures. Non-seismically qualified gloveboxes, hoods, and filterboxes are assumed to topple, non-seismically qualified tanks and piping are assumed to fail, and filters are assumed to fall from non-seismically qualified filter frames. As a result of these postulated failures, plutonium is released into facilities and subsequently transported to the environment.

Toxic Material Dispersal. The risk associated with seismically induced toxic material dispersal is bounded by analyses of nitric acid (HNO_3) in Chapter 9.0, Section 9.2.8.

2.4.5.2 Source Term.

2.4.5.2.1 Greater than 0.09-g Ground Acceleration. The high value for the total inventory of the 232-Z Building is 661 g of plutonium. The majority of this material (i.e., 405 g) is located in the incinerator. The remaining 256 g is located in a cyclone separator, a scrubber glovebox, and miscellaneous glovebox ventilation ducting. The bounding release from the incinerator glovebox is 2.6×10^{-2} g. The release to the building for the cyclone separator is 1.5×10^{-3} g. The release from the scrubber glovebox and

ducting is 1.7×10^{-1} g. Combining these values, the total release from the 232-Z Building is 2.0×10^{-1} g.

The release to the environment of plutonium-bearing solution from failure of Building 241-Z was determined to be 0.10 g of plutonium.

2.4.5.2.2 0.2-g Ground Acceleration.

Plutonium Dispersal. The plutonium inventory-at-risk in PFP gloveboxes and hoods (excluding the 232-Z Building) is assumed equal to established Criticality Prevention Specifications mass limits with the exception of the Analytical, Standards, and Plutonium Process Support Laboratories, and gloveboxes HC-227S and HC-227T for which more restrictive administrative mass limits have been established. Table 2-6 shows the total plutonium released into PFP facilities due to seismically induced mechanical dispersal.

The plutonium releases from the 232-Z Building, the 241-Z Buildingand the 291-Z Building are assumed to be released directly to the environment based on the extent of structural damage. The plutonium release to the environment from the remaining buildings, i.e., that released from the 234-5Z and 236-Z Buildings, is calculated for two cases. In the first case, it is assumed that the 234-5Z and 236-Z Buildings ventilation systems shut down (no ventilation case). In the second case, it is assumed that the supply fans have shut down but that the exhaust fans continue to operate (ventilation case). It is also assumed, in the second case, that the HEPA filters have totally failed and provide no filtration. Note that the releases from the 234-5Z, 236-Z and 291-Z Buildings in the second case are via the 200-ft stack, 291-Z-1.

In addition to the seismically induced mechanical dispersal of plutonium from the facilities, releases were also postulated from seismically initiated fires in the thermal stabilization gloveboxes, HA-21I and HC-21C, and from seismic effects on the BTS and the Magnesium Hydroxide Precipitation Process gloveboxes.

2.4.5.3 Probability.

2.4.5.3.1 Greater than 0.09-g Ground Acceleration. The frequency of an earthquake with a 0.09-g ground acceleration is 2×10^{-3}/yr.

2.4.5.3.2 0.2-g Ground Acceleration. The frequency of an earthquake with a 0.2-g ground acceleration is 1×10^{-4}/yr.

2.4.5.4 Consequences.

2.4.5.4.1 Greater than 0.09-g Ground Acceleration. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.5.4.2 0.2-g Ground Acceleration. For the "no ventilation" case, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

For the "ventilation" case, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.6 Strong Wind

The primary buildings and certain auxiliary structures of the PFP are analyzed in Chapter 9.0, Section 9.2.5, for potential damage due to the design basis wind, defined in the Hanford Plant Standard Architectural Civil Design Criteria SDC-4.1 (WHC 1991) as a wind speed of 90 mi/hr. In general, it was determined that either (1) the building/structure was capable of withstanding both the wind forces and the standard wind-generated missile or (2) the vulnerability of the building/structure to the wind forces (or wind-generated missile) did not lead to the release of hazardous materials. The exceptions were (1) the outside holding tanks, 2735-Z, for nitric acid (HNO_3) and aluminum nitrate nona-hydrate (ANN). Although the HNO_3 and ANN have been removed from the storage tanks, the analysis of HNO_3 in Chapter 9 has been retained.

2.4.6.1 HNO_3 Storage Tank Rupture.

Scenario. As analyzed in Chapter 9.0, Section 9.2.5.1, a steady 90-mi/h wind is assumed to generate a missile that breaches the transfer piping near the bottom of the HNO_3 storage tank in the 2735-Z area. The storage tank is assumed to contain 7,000 gal of 57% HNO_3 solution (maximum capacity) and the entire contents are assumed to spill into the surrounding retention basin. Ten percent (10%) of the solution is assumed to be immediately aerosolized as it exits the tank and the remaining 90% forms a pool with a surface area of 976 ft^2.

Source Term. The source term for the HNO_3 storage tank rupture has two components: the first results from the 10% of the tank contents which are aerosolized, and the second from the evaporation of the remaining 90% of the solution. Based on the peak mass flow rate of HNO_3 solution from the tank, the peak flow rate of HNO_3 vapor due to aerosolization is 0.3263 kg/s. Based on the wind speed, the spill area, and the volatility and temperature of the HNO_3, a conservative value for the steady state evaporation rate was empirically determined to be 0.046 kg/s. Thus, the peak mass release rate is 0.372 kg/s.

Probability. There are barriers around the HNO_3 storage tank, Building 234-5Z to the north and west, and various pipes, tanks, ladders, and walkways to the south, that serve to provide some protection against missile strikes. Considering the barriers and the annual frequency of a strong wind (10^{-5} to 10^{-6}/yr), a large HNO_3 spill is judged to be an incredible event.

Consequences. A simple straight-line Gaussian dispersion was found to be appropriate to determine the downwind concentration for this accident. The dispersion calculation, performed using conservative and very stable atmospheric conditions, determined the peak concentrations of HNO_3 experienced by the nearest onsite and offsite receptors which are summarized in Table 2-5.

The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.7 Aircraft Accident

Aircraft accidents involving the PFP are evaluated in Chapter 9.0, Section 9.2.7. Airspace above the Hanford Site is used by many types of aircraft, but typically only on a limited basis. There are no public, military, or high-volume airports within 20 mi of the PFP, and no federal airways pass directly over the PFP. It has been determined that an aircraft impact is an incredible event.

DOE-sponsored helicopter overflights of the Hanford Site have been performed for the purpose of gathering radiological survey data. For these flights helicopters intentionally fly at low altitudes and in relatively close proximity to nuclear facilities. A helicopter crash into the PFP is considered to be an incredible event as long as the helicopters do not operate in the near proximity of the PFP (i.e., a 2,300 foot square centered on the 291-Z-1 stack).

Scenario. In order for an aircraft accident to result in a release of radiological or toxicological material, the aircraft must impact a PFP building and breach the wall or roof in a critical area. An accident with commercial or military aircraft involving the PFP has been determined to be an incredible event. Boundaries imposed by an Unreview Safety Question (USQ) Evaluation prohibit DOE-sponsored helicopters from operating in the near proximity of the PFP (defined above) where a crash into the PFP would be a credible event. A detailed scenario was not developed because it was determined that there are no credible scenarios for these events.

Source Term. No radiological or toxicological source term was calculated as it was determined that any aircraft impact is an incredible event.

Probability. The frequency of a commercial or military aircraft accident involving the PFP was determined for several of the most credible or consequential categories of overflights. Using the available data, the frequency of a commercial or military aircraft accident involving the PFP has been determined to have a total value of less than 1×10^{-7}/yr, indicating that it is an incredible event.

A helicopter crash into the PFP is an incredible event as long as the helicopters do not operate in the area prohibited by the USQ Evaluation (i.e., a 2,300 foot square centered on the 291-Z-1 stack).

Consequences. No radiological or toxicological consequences were calculated as it was determined that any aircraft accident involving the PFP is an incredible event.

2.4.8 Toxic Chemical Release

A 7,000 gal tank used to store HNO_3 at the 2735-Z storage facility. Although the HNO_3 has been removed and the tank is not in service, the analysis in Chapter 9 has been retained. The potential onsite exposure for chemicals used at the PFP is bounded by the analysis done for the HNO_3 storage tank.

Scenario. As analyzed in Chapter 9.0, Section 9.2.8, the postulated event conservatively assumes that the outside HNO_3 storage tank fails and releases the maximum 7,000 gallons of 57% HNO_3 to the retention basin. The area of the retention basin which is irregularly shaped is 976 ft^2 (90.7 m^2) (see Drawing H-2-77439). A HNO_3 plume is formed by pool evaporation and moves downwind from the spill site.

Source Term. Based on the wind speed, spill area, and the volatility and temperature of the nitric acid, a conservative value for the steady-state evaporation rate is empirically determined to be 4.9×10^{-3} kg/s.

Probability. The most likely cause for a large spill and for lack of mitigating actions would be a seismic event. The frequency of a 0.2-g seismic event is 1×10^{-4}/yr.

Consequences. For this release the nitric acid vapor is considered a passive tracer, and the normal Gaussian dispersion model is appropriate. The peak concentrations of nitric acid vapor are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.9 Accidents for the Plutonium-Bearing Solution Stabilization Process Using the Production Vertical Denitration Calciner

The Production Vertical Denitration Calciner (VDC) oxidizes plutonium nitrate solutions into plutonium oxide powder. Chapter 9.0, Section 9.2.9.1 through 9.2.9.5 analyze potential VDC accidents. A summary of the Chapter 9.0 analyses has not been prepared as VDC operation is not authorized at this time.

2.4.10 Accidents for Reactive Plutonium-Bearing Material Stabilization

The following subsections summarize the subject accident analyses. Reactive plutonium-bearing material stabilization is performed in muffle furnaces located in gloveboxes HC-21C and HA-21I. Supporting activities (e.g., furnace charge preparation, sampling, interim storage) are performed in gloveboxes HC-21A, HC-18M, and HC-18BS.

2.4.10.1 Hydrogen Deflagration in Glovebox HC-21A from Opening Pressurized Containers. Plutonium oxide storage containers are opened in glovebox HC-21A. Flammable gasses, primarily hydrogen, may be present due to the thermal and radiolytic decomposition of plastic packaging materials and moisture.

Scenario. Plutonium oxide is stored in multiple overpack containers, the outer container of which is a 7-inch can. It is assumed that a 7-inch can pressurized to 30 psig is inadvertently sealed into glovebox HC-21A and is opened. At 30 psig, a 7-inch can would contain 0.10 moles of hydrogen. If this quantity was uniformly dispersed within the volume of the glovebox, the resultant hydrogen concentration would be 0.1%, significantly below the lower flammability limit of 4%.

As the hydrogen is released from the 7-inch can and mixes with the glovebox atmosphere, localized concentrations within the flammability range will exist for a short period of time. If all of the available hydrogen formed a stoichiometric cloud that was subsequently ignited, a hypothetical pressure increase of 0.4 psig can be calculated. The actual pressure increase would be significantly less because the efficiency of the burn would be less than 100% and because glovebox HC-21A is open to conveyor glovebox HC-2, i.e., glovebox HC-21A is not a sealed system. It is concluded that the pressure increase from burning hydrogen would not breach the glovebox.

Source Term. No source term was calculated as the glovebox is not breached by this event. The quantity of plutonium potentially suspended inside the glovebox is judged to be small relative to that suspended by normal operations (e.g., pouring oxide through a sieve).

Probability. The burning of flammable gas released from a 7-inch can pressurized to 30 psig is an unlikely event, defined as having an annual probability of 1×10^{-2} to 1×10^{-4}. This probability is based on the relatively small number of such cans at PFP and the fact that containers pressurized to 30 psig are visibly bulged.

Consequences. Onsite and offsite radiological consequences were not calculated for this accident based on the absence of a significant source term relative to normal operations.

2.4.10.2 Deflagration in Glovebox HC-21C or HA-21I. Thermal stabilization of plutonium oxide is accomplished by heating the material to 1,000 C in muffle furnaces. The potential exists for the presence of contaminants, primarily plastics, that can generate flammable gases when heated to high temperatures in the absence of oxygen.

Scenario. It is assumed that measures taken to prevent the introduction of contaminants are ineffective such that 10 g of plastic are assumed present in the plutonium oxide charged to the furnace. In addition, the furnace offgas system is assumed to fail such that the plastic pyrolizes forming flammable gases versus simply oxidizing and forming CO_2 gas and water.

The flammable gas formed by pyrolysis is assumed to be present in the furnace at a flammable concentration and to be ignited. The resultant pressure increase is sufficient to open the furnace door and is postulated to catastrophically fail the glovebox gloves directly opposite the furnace and disperse plutonium into the surrounding room.

Source Term. The deflagration is assumed to fill the volume of the room with respirable plutonium at a concentration of 10 mg/m^3. The room is

serviced by the E-3 ventilation system that provides one stage of testable HEPA filtration before release from the 291-Z-1 stack.

Probability. The annual probability of a flammable gas deflagration is 1×10^{-3} if the plastic contaminant is polyvinylchloride and 1×10^{-5} if it is polyethylene. The probability is lower for polyethylene because decomposition does not occur until the gas is at or above the autoignition temperature.

Consequences. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.10.3 Seismically Induced Deflagration in Glovebox HC-21C or HA-21I. A seismically induced deflagration in glovebox HC-21C or HA-21I is not considered a credible event based on (1) the seismic event probability, (2) the presumed presence of plastics, (3) the time sequencing of the seismic event relative to furnace operations, and (4) required pre-existing failures or very specific seismic induced failures. Although a deflagration is not credible, flammable gases can be generated and subsequently burn.

Scenario. Similar to the analysis summarized in Section 2.4.10.2, it is assumed that 10 g of plastic are present in the plutonium oxide charged to the furnace and that the furnace offgas system fails. The seismic event is assumed to cause the furnace door to open. Flammable gas exiting the furnace is assumed to be ignited and burn in a flashfire.

Source Term. The flashfire is calculated to result in the suspension of a very small quantity of respirable plutonium. The seismic event is also assumed to cause a panel to fall from the glovebox providing a release path into Room 230-A.

Probability. The annual probability of a seismically induced flash fire is assumed to be the same as the annual probability of the seismic event, i.e., 1×10^{-4}.

Consequences. The consequences of the small quantity of respirable plutonium released are insignificant relative to other seismic releases.

2.4.10.4 Glovebox HC-21C or HA-21I Fire. The potential for a fire exists whenever combustible materials coexist with a source of ignition. Although the quantities of combustible materials in glovebox HC-21C or HA-21I are small, the furnaces represent a significant ignition source.

Scenario. It is assumed that combustible materials are present in glovebox HC-21C or HA-21I and are ignited due to contact with hot surfaces of the furnace. The fire is assumed to burn the polycarbonate windows. The fire is assumed to be of sufficient magnitude and intensity to breach the glovebox via burned-out gloves or failed windows.

Source Term. The maximum inventory at risk in either glovebox is 8,000 g of plutonium based on the Glovebox HA-21I criticality prevention specification. Applying the DOE-recommended airborne release fraction and

respirable fraction for non-reactive compounds undergoing thermal stress, the respirable plutonium made airborne by the fire is determined. The airborne plutonium is exhausted via either the E-4 or E-3 ventilation system through one stage of testable HEPA filtration out of the 291-Z-1 stack.

Probability. The annual probability that a fire will breach Glovebox HC-21C and not be rapidly extinguished is less than 1×10^{-6}. This value is based on the probability of accumulating and igniting a large quantity of combustible material, failure of the glovebox Halon fire suppression system and the room wet pipe sprinkler system, and a delayed response by the Hanford Fire Department. Seismically induced fires in these gloveboxes are discussed in Section 2.4.10.5.

Consequences. For the accident as described above, the maximum onsite and offsite doses, expressed as rem EDE and rem to the bone surface, are summarized in Table 2-5. The risk acceptance guidelines applicable to this accident are also given in Table 2-5.

2.4.10.5 Seismically Induced Fires in Gloveboxes HC-21C and HA-21I. A seismic event can result in a fire in gloveboxes HC-21C and HA-21I as both combustible materials (e.g., PMMA and polycarbonate windows) and an ignition source (e.g., furnaces) are present.

Scenario. It is assumed that the seismic event causes gloveboxes HC-21C and HA-21I to topple. As a result, it is assumed that either the furnaces move such that hot surfaces come into contact with the combustible windows or that the furnace doors open and radiant heat ignites the windows. The inventory at risk and quantity of respirable plutonium made airborne by the fire are defined in Chapter 9.0, Sections 9.2.4.2.12.F and 9.2.4.8. A seismic event may or may not result in failure of the exhaust fans in the ventilation system. If the ventilation exhaust system continues to operate, airborne material within the facility is released out of the 291-Z-1 stack. If the exhaust system fails, the release from the fire in the RMC/RMA Line areas is through leak paths around doors and out of the facility in the same manner as other material is released from the facility in the "no ventilation" case (See Chapter 9.0, Section 9.2.4.7).

For the accident as described above, the maximum onsite and offsite doses are included in the totals for the seismic event discussed in Section 2.4.5.

2.4.10.6 Changes to the RMC/RMA Lines Fire Analysis from Gloveboxes HC-21A, HC-21C and HA-21I. Section 2.4.2.1 summarized a worst case glovebox fire which included Gloveboxes HC-21A, HC-21C and HA-21I. Therefore, all changes due to these gloveboxes have been incorporated in the analysis discussed in Section 2.4.2.1.

2.4.11 Accidents for the Laboratory Prototype Calciner

Accidents which have been postulated to potentially result from operation of the Laboratory Prototype Calciner are as follows:

- Hydrogen deflagration in Room 188 from opening drum

- Hydrogen deflagration in Glovebox 188-1 from opening bagged polybottle
- Flammable gas deflagration in the Laboratory Prototype Calciner
- Glovebox 188-1 fire
- Glovebox 188-1 seismic event.

Each of these accidents is discussed in detail in the Laboratory Prototype Calciner addendum to this FSAR. The accident analysis provides a description of the accident scenario, mitigation, probability, consequences and conclusions for each event analyzed. A summary of the accident analysis for the laboratory calciner has not been prepared since the calciner is not currently authorized for operation.

2.4.12 Accidents for the Magnesium Hydroxide Precipitation Process

Accidents associated with operation of the Magnesium Hydroxide Precipiation Process are identified and analyzed in the related addendum (Carson 2000) to this FSAR.

2.4.13 Accidents for the Bagless Transfer System

Accidents associated with the operation of the Bagless Transfer System are identified and analyzed in the related calculation notes (FH 2000).

2.5 CONCLUSIONS

The PFP has been operating for 50 years with no significant radiological or toxicological impacts to onsite or offsite populations. The processes involve low energy reactions and the quantities of reagent involved are small. The remodeling and upgrades of process lines have increasingly compartmentalized the operations and added additional levels of safety. The separation of processes and the campaign operations reduce the probability of a combination of natural and human events resulting in an event with unacceptable radiological or toxicological impact.

The analysis of accident scenarios consistently shows that the risk associated with the current DOE authorized PFP mission and operations are within the risk acceptance guidelines.

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Table 2-1. Radioactive Releases (annual average concentrations in μCi/mL). (3 sheets)

Year	Location	Radionuclide	Airborne release (Ci)	Average concentrations (μCi/mL)
1990	291-Z-1	^{238}Pu	8.1 E-06	2.2 E-15
		$^{239, 240}Pu$	2.2 E-04	6.0 E-14
		^{241}Pu	1.2 E-03	3.2 E-13
		^{241}Am	6.1 E-05	1.7 E-14
		Total flow (L)		3.7 E+12
	296-Z-3	$^{239, 240}Pu$	5.8 E-06	2.1 E-13
		^{241}Am	4.6 E-07	1.7 E-14
		Total flow (L)		2.7 E+10
	296-Z-5	$^{239, 240}Pu$	ND	<1.3 E-15
		^{241}Am	ND	<2.6 E-15
		Total flow (L)		1.6 E+11
	296-Z-6	Total flow (L)		1.7 E+11
	296-Z-14	Total flow (L)		1.1 E+09
1991	296-Z-1	$^{239, 240}Pu$	2.4 E-04	6.3 E-14
		^{241}Pu	1.8 E-03	4.6 E-13
		^{241}Am	5.7 E-05	1.5 E-14
		Total flow (L)		3.9 E+12
	296-Z-3	$^{239, 240}Pu$	3.5 E-06	1.4 E-13
		^{241}Am	4.4 E-07	1.7 E-14
		Total flow (L)		2.6 E+10
	296-Z-5	$^{239, 240}Pu$	ND	<2.9 E-15
		^{241}Am	ND	<5.8 E-15
		Total flow (L)		1.6 E+11
	296-Z-6	Total flow (L)		1.4 E+11
	296-Z-14	Total flow (L)		2.4 E+10

Table 2-1. Radioactive Releases (annual average concentrations in μCi/mL). (3 sheets)

Year	Location	Radionuclide	Airborne release (Ci)	Average concentrations (μCi/mL)
1992	291-Z-1	$^{239,\ 240}Pu$	4.2 E-04	7.9 E-14
		^{241}Pu	2.9 E-03	5.5 E-13
		^{241}Am	7.2 E-05	1.4 E-14
		Total flow (L)		3.7 E+12
	296-Z-3	$^{239,\ 240}Pu$	1.0 E-06	2.0 E-14
		^{241}Am	8.8 E-07	1.7 E-14
		Total flow (L)		3.6 E+10
	296-Z-5	$^{239,\ 240}Pu$	ND	<7.5 E-16
		^{241}Am	ND	<1.9 E-15
		Total flow (L)		1.2 E+11
	296-Z-6	Total flow (L)		1.5 E+11
	296-Z-14	Total flow (L)		2.5 E+10
1993	291-Z-1	^{238}Pu	ND	<1.2 E-14
		$^{239,\ 240}Pu$	5.1 E-04	1.4 E-13
		^{241}Pu	3.4 E-03	9.4 E-13
		^{241}Am	9.3 E-05	2.5 E-14
		Total flow (L)		3.7 E+12
	296-Z-3	$^{239,\ 240}Pu$	4.4 E-07	1.6 E-14
		^{241}Am	1.9 E-07	7.1 E-15
		Total flow (L)		2.7 E+10
	296-Z-5	$^{239,\ 240}Pu$	ND	<9.7 E-16
		^{241}Am	7.9 E-07	5.3 E-15
		Total flow (L)		1.5 E+11
	296-Z-6	Total flow (L)		1.4 E+11
	296-Z-14	Total flow (L)		2.5 E+10

Table 2-1. Radioactive Releases (annual average concentrations in μCi/mL). (3 sheets)

Year	Location	Radionuclide	Airborne release (Ci)	Average concentrations (μCi/mL)
1994	291-Z-1	^{238}Pu	1.5 E-05	4.3 E-15
		$^{239, 240}Pu$	3.0 E-04	8.6 E-14
		^{241}Pu	2.0 E-03	5.7 E-13
		^{241}Am	5.5 E-05	1.6 E-14
		Total flow (L)		3.5 E+12
	296-Z-3	^{238}Pu	9.0 E-08	4.7 E-15
		$^{239, 240}Pu$	1.1 E-07	5.8 E-15
		^{241}Am	ND	ND
		Total flow (L)		1.9 E+10
	296-Z-5	$^{239, 240}Pu$	ND	ND
		^{241}Am	ND	ND
		Total flow (L)		1.2 E+11
	296-Z-6	Total flow (L)		1.3 E+11
	296-Z-14	Total flow (L)		2.3 E+10
1995	291-Z-1	^{238}Pu	2.3 E-06	6.2 E-16
		$^{239, 240}Pu$	7.6 E-05	2.0 E-14
		^{241}Pu	2.0 E-04	5.4 E-14
		^{241}Am	1.5 E-05	4.0 E-15
		Total flow (L)		3.6 E+12
	296-Z-3	^{238}Pu	3.5 E-08	2.5 E-15
		$^{239, 240}Pu$	3.1 E-08	2.2 E-15
		^{241}Pu	3.1 E-06	2.2 E-13
		^{241}Am	1.5 E-08	1.0 E-15
		Total flow (L)		1.3 E+10
	296-Z-5	Total flow (L)		1.3 E+11
	296-Z-6	Total flow (L)		1.3 E+11
	296-Z-14	Total flow (L)		2.9 E+10
	296-Z-15	Total flow (L)		2.3 E+10

SOURCE: Environmental Releases for Calendar Year, WHC-EP-0527
ND - No data.

Table 2-2. Offsite Doses for Ground and Stack Level Releases from PFP Based on Annual X/Qs (Chronic release).

Release Type	EDE		Max. Organ[a]
Maximum Individual	(rem)		(rem)
Ground Level	3.0 E-08		5.5 E-07
Stack Level	1.0 E-06		1.9 E-05
Population	(person-rem)	Health Effect (LCF)[b]	(person-rem)
Ground Level	8.0 E-04	4.0 E-07	1.5 E-02
Stack Level	4.4 E-02	2.2 E-05	8.2 E-01

[a]The maximum organ for all cases is the bone surface.
[b]Latent Cancer Fatality.

Table 2-3. Historical Solid Waste Generation Volume Summary.

Radioactive waste	ft^3/yr	Drums/yr
TRU waste to WIPP		
Contaminated plastic, cloth, rubber, and glass	3,400	460
Burial box mixed waste (lead panels and leaded glass windows)	75	--
TRU waste to 20-year retrievable storage		
8 in. x 8 in. HEPA filters	15	2
Leaded glovebox gloves	75	10
Burial box waste (waste too large for drums)	7,000	--
Low-level radioactive solid waste		
Nonhazardous, aerosol cans	15	2
Nonhazardous, Zone 3 waste	10,870	1,478
Nonhazardous, low-level burial box waste	100	--
Nonhazardous, 24" x 24" HEPA filters	600	--
Hazardous lead, alkaline dry cell batteries, and wet cell batteries	8	1
Hazardous fluorescent lamps (now recycled)	4	0.5
PCB-contaminated and -absorbed waste		
TRU Absorbed organics (if the PRF was in operation)	52	7
TRU PCB-contaminated solid waste	30	4
TRU PCB-contaminated burial box waste	50	--
TRU PCB Hydraulic fluids, etc.	50	7
Low-level waste		
Low-level absorbed organics	50	--
Low-level PCB hydraulic fluid	66	90

HEPA = High-efficiency particulate air (filter).
PCB = Polychlorinated biphenyl.
TRU = Transuranic.
WIPP = Waste Isolation Pilot Plant.

Table 2-4. Abnormal Operations. (2 sheets)

Number	Title	Synopsis
2.3.1	Radioisotope-Bearing Liquid Spills	A spill involving the entire contents of a 10-L bottle of plutonium solution is the bounding event. The event releases 0.16 g Pu into the building. Such a release, even without reduction by HEPA filtration, is well below the risk acceptance guidelines for an event with a frequency of 1/yr.
2.3.2	Radioisotope-Bearing Pressurized Liquid Container	A pressurized 10-L container is assumed to release half of its contents to a room. The resultant airborne release is 0.08 g Pu. Such a release, even without reduction by HEPA filtration, is well below the risk acceptance guidelines for an event with a frequency of 1/yr.
2.3.3	Radioisotope-Bearing Powder Spills	A powder spill is assumed that requires a series of errors to achieve. After one stage of HEPA filtration the release out of the stack (6.6 E-04 g) is more than an order of magnitude below the risk acceptance guidelines for an event with a frequency of 1/yr.
2.3.4	Radioisotope-Bearing Pressurized Powder Container	Plutonium stored in closed containers may be released if pressurization results in a container breach. Chemical reactions or radiolysis of hydrogenous material can lead to pressurization. The analysis shows storage room air concentrations to be on the order of 2.5×10^{-10} µCi/ml. Such a room concentration would be undetectable at the stack.
2.3.5	Stack Release Resulting from Filter Changes	During a final-stage HEPA filter change, Pu could be released if a filter is mishandled. If such an event occurred, the resulting dose (from the release of 7.4 E-05 g) would be well below the risk acceptance guidelines for an event with a frequency of 1/yr.
2.3.6	Ventilation System Upsets	Properly functioning ventilation systems provide a vital part of the equipment that makes it possible to handle plutonium safely. The following subsections detail the most important of the failure modes. In no case does upset directly result in a release of radioactive materials. Such events, in conjunction with loss of containment events, could, however, exacerbate the spread of contamination within a building. For most events within Buildings 234-5Z, 242-Z, and 236-Z, no automatic recovery systems would be available. However, operating procedures include instructions addressing the required operator response to abnormal operations.
2.3.6.1.1	Excessive Pressurization, 234-5Z Building	Excessive building pressurization can occur from failure of control dampers. Supply dampers B, C, D, and E each feed air to rooms and corridors within the radiation zones of the 234-5Z Building. A number of separate scenarios are presented under this heading. Pressure differentials of up to 1 in. w.g. between adjacent rooms will occur but gloveboxes remain negative to room atmospheres.
2.3.6.1.2	Excessive Pressurization, 236-Z Building	The 236-Z Building receives air from 234-5Z Building through Supply Damper F. Failure to the open position can cause pressurization of up to 0.5 in. w.g. over normal. As with the damper failures within the 234-5Z Building, the process cell and gloveboxes remain negative to the rooms.
2.3.6.1.3	Excessive Pressurization, 2736-ZB Building	A ventilation control failure could lead to a pressurization of ~2 in. w.g. Such a pressurization is not expected to cause a breach of the building or release of material from the single glovebox located in the building.
2.3.6.1.4	Excessive Pressurization, 2736-Z Building	A pressurization of the 2736-Z Building is not expected to cause any release of radioactive material into the building or to the outside as all materials stored in this facility are double or triple canned in metal cans or drums. The building could be pressurized to 2 in. w.g.
2.3.6.1.5	Excessive Pressurization, 241-Z Building	No building pressurization would happen as there are no supply fans.
2.3.6.2	Excessive Depressurization - All PFP Operating buildings	
2.3.6.2.1	234-5Z Building	Significant depressurization of the 234-5Z Building is prevented by a pair of gravity-operated supply relief dampers on the supply plenum and by control on the exhaust fans.

Table 2-4. Abnormal Operations. (2 sheets)

Number	Title	Synopsis
2.3.6.2.2	236-Z Building	Accidental closure of Supply Damper F could result in depressurization to -6 in. w.g. Such a depressurization is approximately equal to the 5.8 in. w.g. (30 lb/ft^2) live load of the roof. During such an event the pressure inside and outside gloveboxes would be the same but there would be no force to release radioactive materials to the rooms. There would be no release to the environment.
2.3.6.2.3	2736-ZB Building	No credible scenario was found.
2.3.6.2.4	2736-Z Building	An actual event once depressurized the building to ≈3 in. w.g. with no adverse effect.
2.3.6.2.5	241-Z Building	There is no way to significantly depressurize this building.
2.3.7	Loss of Ventilation	This section contains a number of events that result from loss of ventilation--none of which result in a significant spread of plutonium. The topics include air reversals due to convection and weather changes, radiolytic hydrogen accumulation, and spread of contamination in vaults due to container rupture from heat rise.
2.3.8	Glovebox Glove Breach	The most vulnerable part of the plutonium confinement system is the glove system. This section discusses various release mechanisms and concludes that the hazard to operating personnel is not great.
2.3.9	Pressurized Production Vertical Denitration Calciner	The VDC is assumed to pressurize due to a loss of vacuum. The pressurized calciner is estimated to release 127 mg of Pu to the HC-230C-2 glovebox atmosphere. Two testable stages of HEPA filtration within the E-4 ventilation system limit the release out the exhaust stack to an insignificant value. (A third testable stage of HEPA filters exists in the exhaust system but was not credited in the analysis).
2.3.10	Reactive Material Thermal Stabilization Process	No unique abnormal operations were identified that were associated with operation of the thermal stabilization process.
2.3.11	Laboratory Prototype Calciner	No unique abnormal operations were identified that were associated with operation of the Laboratory Prototype Calciner.
2.3.12	Loss of Filtration	Release due to a loss of filtration (catastrophic failure of the HEPA filters) result in releases roughly equivalent to filtered releases from the 291-Z stack.
2.3.13	Magnesium Hydroxide Precipitation Process	Abnormal operations associated with the Magnesium Hydroxide Precipitation Process are identified and evaluated in the related addendum (Carson 2000) to this FSAR.
2.3.14	Bagless Transfer System (BTS)	Abnormal operations associated with the BTS are identified and evaluated in the related calculation notes (FH 2000).

HEPA = High-efficiency particulate air (filter)

Table 2-5. Summary of Accident Analysis Consequences. (3 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
2.4.1.2	Flammable gas deflagration	Flammable gas deflagration resulting from: 1) slow leak of propane gas or 2) catastrophic failure of propane cylinder	Slow leak: 1.0 assumed Catastrophic Failure: Incredible (<1.0 E-06)	The slow leak event was found to have acceptable consequences even with an assumed probability of 1.0. For the event with a <1 E-06 probability, no consequence was calculated since the event is incredible.	The overpressure resulting from the deflagration is not large enough to breach any PFP wall panels.	N/A
2.4.2.1	RMC/RMA Lines Fire	Fire in trash igniting RMC/RMA Lines and adjacent rooms	10^{-4} to 10^{-6}	Onsite EDE = 0.012 Offsite EDE = 4.3 E-03 Onsite bone = 0.21 Offsite bone = 0.074	Onsite EDE: 25 Offsite EDE: 4 Onsite Bone: 250 Offsite Bone: 40	0.01
2.4.2.2	Hydraulic oil fire, Room 231 234-5Z	Roof collapse due to failed structural members	Incredible (<1.0 E-06)	None calculated as probability <1.0 E-06 and low source term	Not applicable	N/A
2.4.3	Waste Drum Events					
2.4.3.1	Fire Release	Vehicle crash with ensuing fire	<<1.0 E-02	Onsite EDE = 2.2 Offsite EDE = 0.04 Onsite Bone = 32.8 Offsite Bone = 0.64	(Probability = 1.0 E-02) Onsite EDE: 5 Offsite EDE: 0.5 Onsite Bone: 50 Offsite Bone: 5	0.06
2.4.3.2	Mechanical Release	Forklift Punctures two drums	1.0 E-01	Onsite EDE = 0.12 Offsite EDE = 2 E-03 Onsite Bone = 2.2 Offsite Bone = 0.03	Onsite EDE: 1 Offsite EDE: 0.1 Onsite Bone: 10 Offsite Bone: 1.0	8 E-3
2.4.3.3	Drum Explosion	Ignition of flammable concentration of hydrogen	<<1.0 E-02	Onsite EDE = 1.65 Offsite EDE = 0.02 Onsite Bone = 28.7 Offsite Bone = 0.38	(Probability = 1.0 E-02) Onsite EDE: 5 Offsite EDE: 0.5 Onsite Bone: 50 Offsite Bone: 5	0.08
2.4.4	Criticality	The generic criticality from Regulatory Guide 3.35 used	2.5 E-02	Ground release: Onsite EDE total = 0.73 Offsite EDE total = 0.053 Onsite thyroid = 2.4 Offsite thyroid = 1.6 Stack release: Onsite EDE total = 0.16 Offsite EDE total = 0.032 Onsite thyroid = 0.27 Offsite thyroid = 0.97	 Onsite EDE: 2 Offsite EDE: 0.2 Onsite Thyroid: 20 Offsite Thyroid: 2 Onsite EDE: 2 Offsite EDE: 0.2 Onsite Thyroid: 20 Offsite Thyroid: 2	2.15 E-1 7.55 E-2
2.4.5[1]	Seismic Event[1]	no ventilation case	1.0 E-04	Onsite EDE = 17.71 Offsite EDE = 0.37 Onsite Bone = 256 Offsite Bone = 5.26	Onsite EDE: 25 Offsite EDE: 4 Onsite Bone: 250 Offsite Bone: 40	1.44

Table 2-5. Summary of Accident Analysis Consequences. (3 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
		ventilation case	1.0 E-04	Onsite EDE = 11.49 Offsite EDE = 2.53 Onsite Bone = 178 Offsite Bone = 38	Onsite EDE: 25 Offsite EDE: 4 Onsite Bone: 250 Offsite Bone: 40	5.97
		Small earthquake with release from Building 232-Z only	2.0 E-03	Onsite EDE = 4.57 Offsite EDE = 0.09 Onsite Bone = 73 Offsite Bone = 1.36	Onsite EDE: 8.5 Offsite EDE: 1.0 Onsite Bone: 85 Offsite Bone: 10	0.37
2.4.6	Strong wind and missile strike	Wind driven missile breaches transfer line at the bottom of the outside HNO_3 storage tank causing a large pool and release of HNO_3 vapors	<1.0 E-02	HNO_3 Onsite = 18 ppm HNO_3 Offsite = 0.29 ppm	HNO_3 Onsite: 19 ppm HNO_3 Offsite: 3.9 ppm	0.92 ppm
2.4.7	Aircraft accident	Airplane crash into building	Incredible (<1.0 E-06)	Not calculated; probability <1.0 E-06	N/A	N/A
2.4.8	Toxic chemical release	7000 gal outside HNO_3 storage tank failure caused by seismic event; HNO_3 vapor release from spilled solution surface	1.0 E-04	Onsite: 1.8 ppm Offsite: 0.032 ppm	Onsite 24 ppm Offsite 7.7 ppm	0.13 ppm
2.4.9	Accidents for the Plutonium-Bearing Solution Stabilization Process Using the Production Vertical Denitration Calciner (not summarized as this process is not currently authorized)					
2.4.10	Accidents for Reactive Plutonium-Bearing Material Stabilization Operations in Gloveboxes HC-21C and HA-21I.					
2.4.10.1	Hydrogen Deflagration in Glovebox HC-21A from Opening Pressurized Containers	Deflagration	1.0 E-02 to 1.0 E-04	Negligible	NA	N/A
2.4.10.2	Deflagration in Glovebox HC-21C or HA-21I	Deflagration	1.0 E-04 to 1.0 E-06 for PE or PC 1.0 E-02 to 1.0 E-04 for PVC and PS	Onsite EDE 2.1 E-03 Offsite EDE 7.4 E-04 Onsite Bone 0.03 Offsite Bone 0.01	(Probability 1.0 E-02) Onsite EDE = 5.0 Offsite EDE = 0.5 Onsite Bone = 50 Offsite Bone = 5	1.7 E-3

Table 2-5. Summary of Accident Analysis Consequences. (3 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
2.4.10.3	Seismically Induced Deflagration in Glovebox HC-21C or HA-21I	Deflagration Flash Fire	Not credible 1.0 E-04 to 1.0 E-06	NA Negligible	NA	N/A
2.4.10.4	Glovebox HC-21C or HA-21I Fire	Fire	Not credible	Onsite EDE 2.2 E-04 Offsite EDE 7.7 E-05 Onsite Bone 3.5 E-03 Offsite Bone 1.2 E-03 Also included in Section 2.4.2.1	See 2.4.2.1	1.82 E-4
2.4.10.5	Seismically Induced Fire in Glovebox HC-21C and HA-21I	Fire	1.0 E-04	Included in total for Seismic Event, Section 2.4.5	See 2.4.5	
2.4.10.6	Changes to the RMC/RMA Lines Fire Analysis from Gloveboxes HC-21A, HC-21C, and HA-21I	All changes have been incorporated into the RMC/RMA Lines fire analysis in Section 9.2.2A and 2.4.2.1.				
2.4.11	Accidents for the Laboratory Prototype Calciner	Accidents for solution stabilization using the Laboratory Prototype Calciner are not summarized as this process is not currently authorized.				
2.4.12	Accidents for the Magnesium Hydroxide Precipitation Process	Refer to the Magnesium Hydroxide Precipitation Process addendum (Carson 2000) to this FSAR for information on analyzed accidents.				
2.4.13	Accidents for the Bagless Transfer System	Refer to the calculation notes for the Bagless Transfer System (FH 2000) for information on analyzed accidents.				

EDE = Effective dose equivalent.
LPG = Liquid propane gas.
PFP = Plutonium Finishing Plant.
RMC = Remote Mechanical C.

Note: 1. The consequences for the seismic event exclude the seismic analysis related to the laboratory Prototype Calciner shown in the Laboratory Prototype Calciner addendum to this FSAR since the calciner is not authorized for operation. Similarly, the seismic event consequences do not include the seismic releases associated with the Production Vertical Denitration Calciner since it is not authorized for operation.

Table 2-6. Releases into Plutonium Finishing Plant Facilities For Seismic Event: 1 x 10^{-4} Probability.

Facility	Room, Glovebox (or Hood)	Release into Facility (g Pu)	% ^{240}Pu	Reference Subsection
234-5Z[3]	131-157, (Analytical Lab) 179-187, (PPSL) 221-C, D, and E (Standards Lab)	0.79[1]	< 10 > 10	9.2.4.6.3.1.A
	166, South Hood	0.01[2]	> 10	9.2.4.6.3.1.H
	227, HC-227S/T	0.96[2]	> 10	9.2.4.6.3.1.M
	228-B, HC-13MD	0.38	> 10	9.2.4.6.3.1.O
	228-C, HC-18M	1.5	> 10	9.2.4.6.3.1.P
	230-A, HC-21C	0.75	> 10	9.2.4.6.3.1.Q
	230-B, HC-21A	1.07	> 10	9.2.4.6.3.1.R
	235-B, HA-20MB	1.50	> 10	9.2.4.6.3.1.U
	235-B, HA-21I	1.20	> 10	9.2.4.6.3.1.U
	235-B, HA-23S	3.30	> 10	9.2.4.6.3.1.U
	235-B, HA-28	0.38	> 10	9.2.4.6.3.1.U
	235-C, 235-B-2	0.38	> 10	9.2.4.6.3.1.V
	Duct Level: E-4 Ducting	1.15	< 10	9.2.4.6.3.1.W
	Duct Level: Filterbox 7A and 9A	0.83	< 10	9.2.4.6.3.1.W
	Filter Rooms	0.07	< 10	9.2.4.6.3.1.X
236-Z	Canyon	0.40[2]	> 10	9.2.4.6.3.2.A.c
	Pipe Chase	0.15[2]	> 10	9.2.4.6.3.2.A.g
	Transfer Line	0.02[2]	> 10	9.2.4.6.3.2.A.h
	27, PH and maintenance	0.83	> 10	9.2.4.6.3.2.C.d
2736-Z, -ZA, -ZB	--	Negligible	--	9.2.4.6.3.6
241-Z	--	0.10[2]	>10	9.2.4.6.3.8
242-Z	--	Negligible	--	9.2.4.6.3.7
291-Z	--	0.01	< 10	9.2.4.6.3.9
232-Z	--	0.20	< 10	9.2.4.6.3.10
Total into Facilities		15.56[1]		

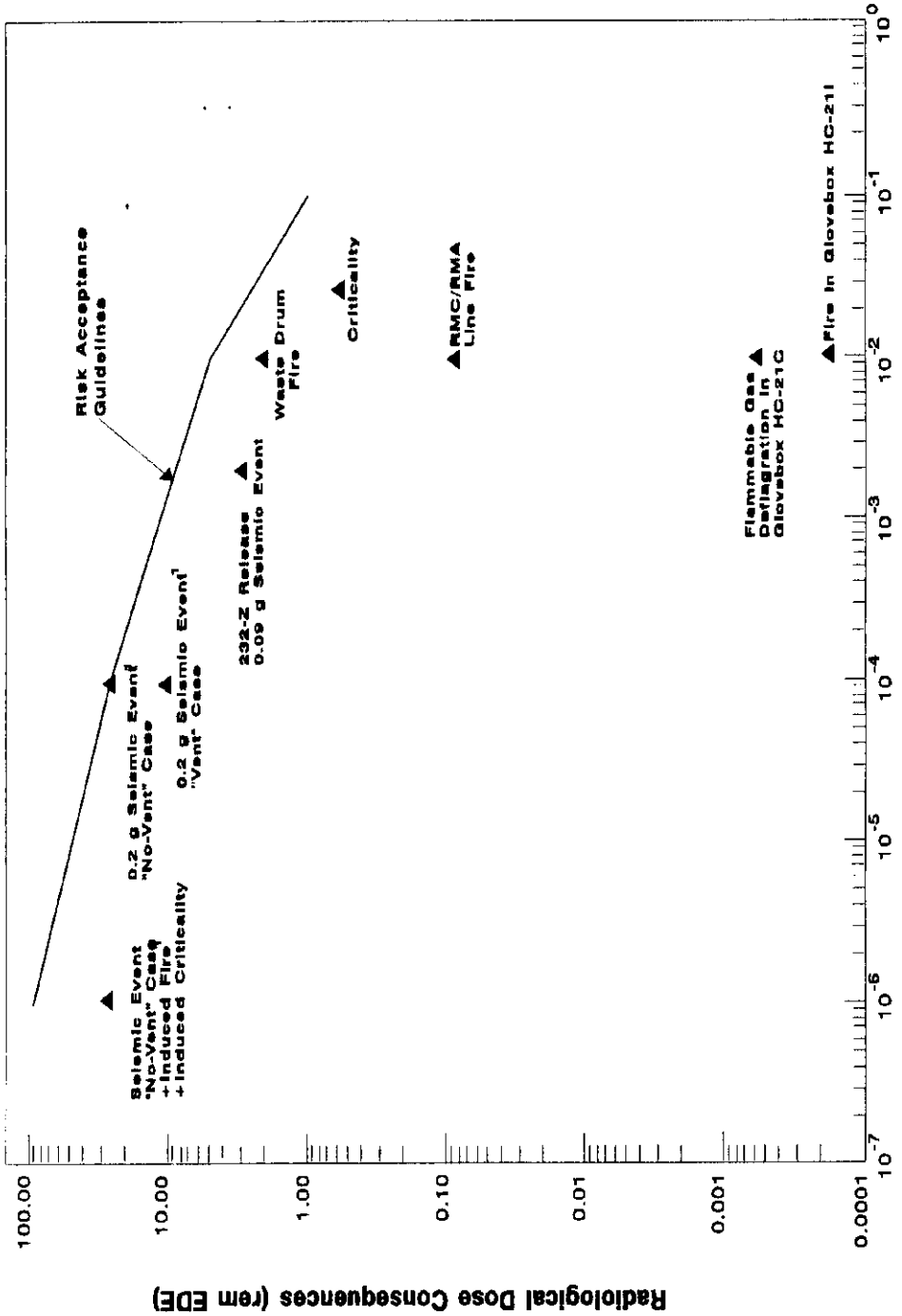
Notes: 1. The release values for the laboratories exclude the Laboratory Prototype Calciner in Room 188 of the PPSL since the calciner is not currently authorized for operation.

2. Denotes solution.

3. The releases from the Magnesium Hydroxide Precipitation Process and Bagless Transfer System gloveboxes are not shown in the table but are included in the releases from the facility due to a seismic event (See Section 2.4.5).

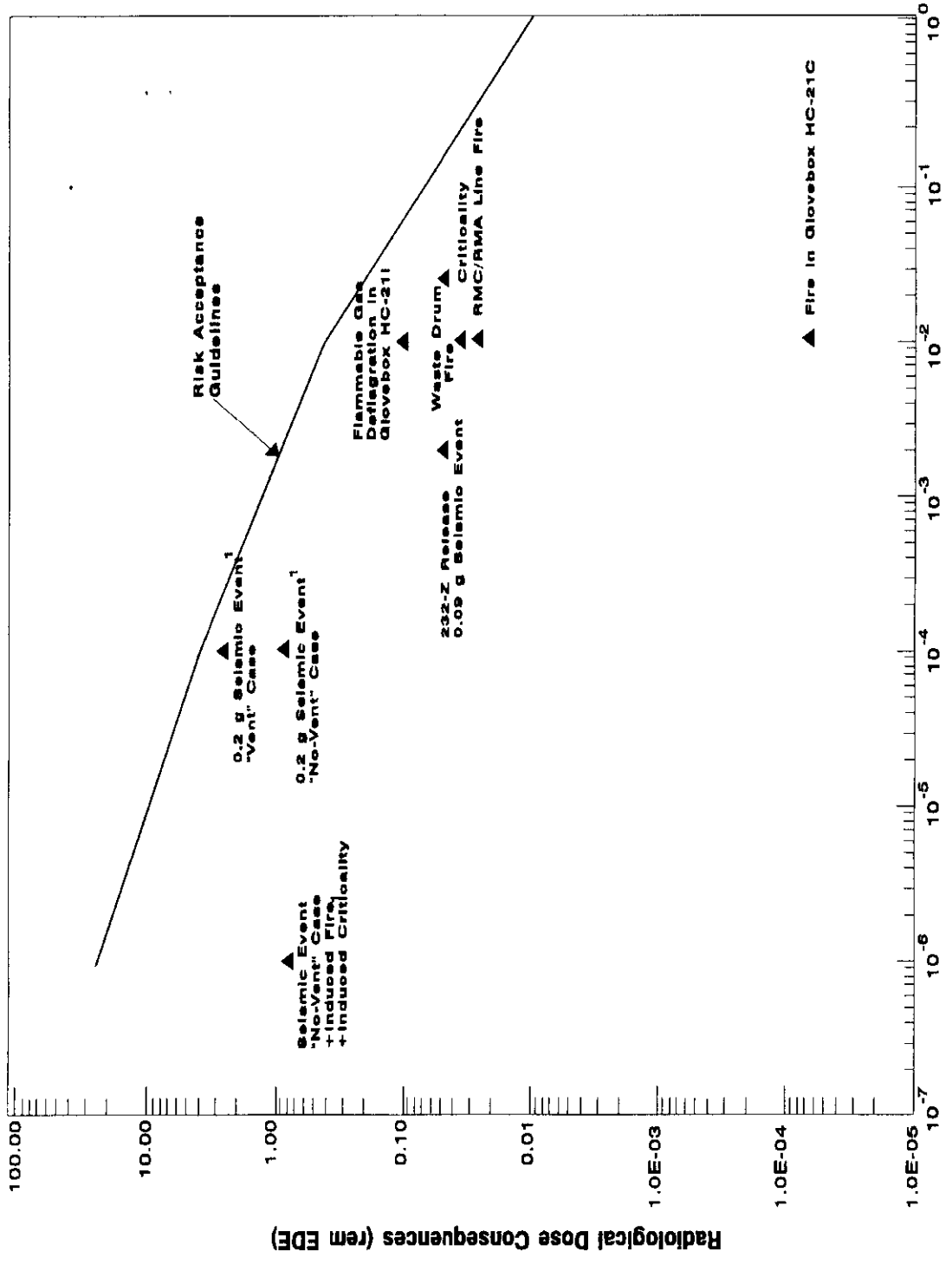
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Figure 2-1. Onsite Receptor Risk Acceptance Comparison.



Note 1: The consequences due to the various seismic event accident analyses include the seismic contributions from the Laboratory Prototype Calciner. Details of the Laboratory Prototype Calciner are found in the Laboratory Prototype Calciner addendum to this FSAR. Other accident analyses related tot he Laboratory Prototype Calciner are not on this figure but are discussed in the Laboratory Prototype Calciner addendum.

Figure 2-2. Offsite Receptor Risk Acceptance Comparison.



Note 1: The consequences due to the various seismic event accident analyses include the seismic contributions from the Laboratory Prototype Calciner. Details of the Laboratory Prototype Calciner are found in the Laboratory Prototype Calciner addendum to this FSAR. Other accident analyses related tot he Laboratory Prototype Calciner are not on this figure but are discussed in the Laboratory Prototype Calciner addendum.

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F3-45	2	1/01
F3-46	2	1/01
F3-47	2	1/01
F3-48	2	1/01
F3-49	2	1/01
F3-50	2	1/01

PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 3.0

SITE CHARACTERISTICS

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 3.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) incorporates the following:

- Recent data on the elevation of the water table below the PFP

Other minor changes include editorial changes and addtional clarifications.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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3.0 SITE CHARACTERISTICS

3.1 GEOGRAPHY AND DEMOGRAPHY OF SITE

A description of the Plutonium Finishing Plant (PFP) site, its location, nearby population, and land usage is provided in the following subsections.

3.1.1 Plant Site Location

The PFP is located within the U.S. Department of Energy (DOE) Hanford Site. The Hanford Site is a 560-mi^2 area with limited access for reasons of national security in addition to health and safety considerations. Figure 3-1 shows the location of the Hanford Site in the State of Washington.

The 200 West Area is a 2,000-acre area near the center of the Hanford Site. Figures 3-2 and 3-3 are detailed maps of the Hanford Site and the 200 West Area, respectively.

The PFP is situated in Section 1, Township 12 North, Range 25 East, Willamette Meridian in Benton County. The coordinates of the PFP are 46°33'02.345" N. and 119°37'54.982" W. The North American Datum Lambert coordinates (NAD83) are N. 135670.830 and E. 566565.639.

3.1.2 Plant Site Description

The PFP is located in the 200 West Area within a protected area defined by a fence around the PFP complex, as shown in Figure 3-4. The elevation of the PFP is 676 ft above mean sea level (msl).

In general, the relief is gently sloping from the 200 West Area toward the Columbia River.

The vegetation mosaic of the Hanford Site, found in *Final Environmental Statement, Waste Management Operations, Hanford Site*, ERDA-1538 (ERDA 1975), consists of eight major kinds of shrub-steppe communities identified by the most conspicuous or most abundant plant species:

- Sagebrush/bluebunch wheatgrass
- Sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass
- Sagebrush-bitterbrush/cheatgrass
- Greasewood/cheatgrass-saltgrass
- Winterfat/Sandberg's bluegrass
- Thyme buckwheat/Sandberg's bluegrass
- Cheatgrass-tumble mustard
- Willow.

The most broadly distributed vegetation type on the Hanford Site is the sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass association. This vegetation occurs as a broad zone surrounding the PFP and is between the sagebrush/bluebunch wheatgrass-type and the sagebrush-bitterbrush/cheatgrass type. It differs from the sagebrush/bluebunch wheatgrass, because sagebrush plants tend to be larger in size and provide more ground cover. Spiny hopsage

and rabbitbrush may be intermingled with sagebrush shrubs. Fire can burn through this kind of vegetation, killing sagebrush, but hopsage and rabbitbrush survive burning, sending out new growth during the growing season following the fire. The general paucity of herbaceous cover also tends to favor invasion by tumbleweed, with or without fire. The sagebrush/cheatgrass and sagebrush/Sandberg's bluegrass communities provide very limited forage for wildlife.

Vegetation is removed routinely within the PFP site fence and adjacent to it for security purposes, which also reduces the fire hazard. A discussion of the impact on the PFP from loss of power due to potential range fires or other accidents may be found in Chapter 9.0, Section 9.2.

The PFP site is blanketed by a thin layer of windblown sediments. These sediments, called eolian sediment (ERDA 1975), range from fine sands and silt, which in some places blanket coarse gravel and basalt bedrock, to coarse sands, which are moved only short distances.

Water erosion on the plateau around the PFP is minor because of the minimal precipitation, high soil porosity, and lack of sufficient relief to initiate runoff.

Winds are of substantial importance because they can erode the mobile surfaces. Erodible soils (ERDA 1975), mainly Rupert Sand and Burbank Loamy Sand, exist on the plateau. The shear stress of the wind at the Earth's surface determines whether sufficient force exists to move sand grains. Where vegetation exists, the shear stress is reduced sharply and erosion is minimized. However, if the vegetation is removed by fire, construction, plowing, or other means, strong winds will erode the sandy soil (ERDA 1975). Winds are also a factor in the tumbleweed nuisance, which requires removal of accumulated tumbleweeds along fences and buildings for safety and security reasons.

Traffic routes are shown on Figure 3-2. The only road used by the general public is State Route (SR) 240, which passes within 2.5 mi of the PFP. A four-strand barbed wire fence separates the highway right-of-way and the Hanford Site. The Hanford Site is traversed by SR 240 and by the Columbia River, also shown on Figure 3-2.

There are no residents within the Hanford Site boundary. Within this boundary, only DOE personnel and contractor personnel, or other authorized personnel, are allowed to travel in areas beyond the Rattlesnake Barricade, Wye Barricade, and the Yakima Barricade (see Figure 3-2). This restriction of access allows some measure of control over exposure to offsite individuals from Hanford Site activities.

3.1.3 Population, Distribution, and Trends

The 1990 estimate of population living within a 50-mi radius of the Hanford Meteorological Station (HMS) is 376,000 (Beck et al. 1991). The HMS is used as the population reference point for the PFP because of the availability of data and its proximity: 2 mi northeast of the PFP. Figure 3-5 shows the 1990 U.S. Census populations of nearby communities with the circle of a 50-mi radius from the HMS superimposed. Population estimates

were made through the year 2040 based on 1990 census information, current birthrate trends, and an estimate of net migration into or out of the state as economic and employment opportunities change over the forecast period. The forecast does not reflect the population expansion that would result from the creation of a nuclear park or a more intensive use of nuclear energy for power generation and other purposes. It was assumed that the Hanford Site would remain under the control of the DOE and that no persons would reside within the site boundaries. The population residing in the unincorporated areas was calculated on the basis of population density in the portion of a specific census district, which lies within the area. This assumed an even distribution of population throughout the unincorporated areas of each census district. It was further assumed that the rate of population growth was the same for both incorporated and unincorporated areas. Figure 3-6 shows the distribution of population within a 50-mi radius of HMS projected by decades until the year 2040.

A seasonal increase of an estimated 2,800 migratory farm workers occurs annually in the agricultural region east of the Columbia River (Franklin County). The peak periods are May and June and during the fall harvest. Some of these workers are permanent Tri-Cities residents and most live in Pasco (Herborn 1989). See Figure 3-7 for distribution of transient populations (Supply System 1988).

3.1.4 Uses of Nearby Land and Waters

The nature and extent of present land use is presented here on the basis of arcs from the HMS. The Hanford Site vicinity map with sectors overlaid is shown in Figure 3-8. Starting from a line directly north of the HMS, the 0- to 10-mi zone between the 0° and 150° radials is a limited access area under DOE control. Land north of the river is controlled by the U.S. Fish and Wildlife Service as the Saddle Mountain National Wildlife Refuge and the Washington State Department of Game as the Wahluke Wildlife Recreation Area. Most of the zone between the 150° and 270° radials consists of the Fitzner/Eberhardt Arid Lands Ecology Reserve, which also is limited access DOE land under the control of the Pacific Northwest National Laboratory. Between the 270° radial and the starting radial, land south of the Columbia River is DOE-controlled limited access, and land north of the river is the Saddle Mountain National Wildlife Refuge. See Figure 3-9 for locations of recreational areas and refuges/reserves at the Hanford Site.

Again, starting from the 0° radial, the 10- to 20-mi zone is a continuation of the Saddle Mountain National Wildlife Refuge. Farther north, this zone includes the easternmost portion of the Wahluke Slope and the Saddle Mountains. Between the Wahluke Branch Canal and the Columbia River, the zone consists of lands in the Columbia Basin Project that are irrigated or being developed for irrigation. The area west of the river is a limited access area (the Hanford Site). There are no private industrial facilities located within the 10- to 20-mi radius of the PFP. From the 140° to the 360° radial and within the 10- to 20-mi radius, the area outside the Hanford Site is available for residential living or farming. This area is mainly unirrigated and used for grazing cattle and sheep. South and west of the Columbia River, in the vicinity of the Priest Rapids Dam, are 411 mi^2 of undeveloped and unpopulated land used for the U.S. Army Yakima Firing Range.

Northeast of Priest Rapids Dam and Reservoir is the Wahluke Slope portion of the Columbia Basin Project.

The 20- to 30-mi zone on the 0° radial is north of the Saddle Mountains and is irrigated farmland, part of the Columbia Basin Project. The area from lower Crab Creek to northwest Othello generally is undeveloped. From Othello south to the Columbia River, the land is irrigated farmland. On the west side of the river is the city of Richland. West from Richland, the 20- to 30-mi zone includes the Yakima River and the towns of Prosser, Sunnyside, Grandview, and Mabton. Land along the Yakima River is primarily in orchard use. Higher land away from the valley floor is used primarily for grazing livestock, with some land used for grain crops. At about the 270° radial, the U.S. Army Yakima Firing Range is again encountered. At 320° is the Ginkgo Petrified Forest, a state park and national landmark.

At the 0° radial, the 30- to 40-mi zone consists of undeveloped area of sagebrush and sand dunes. At 20°, the Potholes Reservoir, a recreation area surrounded by sand dunes, is located south of Moses Lake. Between 30° and 50°, this zone encompasses a major portion of the U.S. Water and Power Resources Service Columbia Basin Irrigation Project. At about the 130° radial, the Columbia River is encountered, with the city of Pasco on the north side and the city of Kennewick on the south side. South and west of Kennewick, the 30- to 40-mi zone runs south of the Horse Heaven Hills. Although this land is used primarily for dryland wheat farming, there are about 88 sections (56,320 acres) where permits have been granted for private irrigation development. Crossing the Horse Heaven Hills, the 220° to 260° zone includes part of the Yakima Valley, containing the towns of Granger, Toppenish, Zillah, and Wapato. This land is largely in orchards and truck crops, with livestock grazing at the higher elevations. Northeast of Yakima is the U.S. Army Yakima Firing Range, east of which lies irrigated farmland of the Columbia Basin Project.

At the 0° radial, in the 40- to 50-mi radius, the land is primarily rangeland with some irrigated farmland. The town of Moses Lake is in this zone at about the 20° radial. Between the 20° and 90° radials is a large portion of land planned for irrigation development as part of the Columbia Basin Project. At about 70°, between the 40- and 50-mi radius, the land is used for dryland wheat production. Between the 90° and 120° radials and extending to the 50-mi radius, the land is used for dryland wheat production. An exception is the area at the confluence of the Snake and Columbia Rivers, where private irrigation projects are under way. Land on both sides of the Columbia River below McNary Dam supports private irrigation projects totaling about 345 sections (220,800 acres). Between the 200° and 260° radials, the terrain is very rugged and, for the most part, undeveloped. At the 260° radial, the Yakima Valley commences with the city of Yakima at 270°. This is an area of both irrigated and dryland farming and cattle production. At 330°, a portion of the Wenatchee National Forest is encountered.

Recreationists, consisting of hunters, fishermen, boaters, and off-road sports enthusiasts, enjoy activities throughout various parts of the area. The primary fishing season is from June through November; the main hunting season is October through January. The heaviest use of the Columbia River area by recreationists is on weekends and holidays, usually in the early morning hours. On an average, 50 fishermen and 10 hunters are present during the weekdays east of the Columbia River. These numbers increase to about

100 fishermen and 50 hunters on weekends and holidays. Recreationists also use the Yakima River, with an estimated maximum of 50 at any time in this area. Additionally, there could be as many as 1,500 recreationists at the Horn Rapids Off-Road Vehicle Park for any given event. During peak fishing, hunting, or sports events, up to 2,550 recreationists may be located within the area. See Figure 3-7 for distribution of transient populations (Supply System 1988).

Annually, on the last weekend in July, about 30,000 to 40,000 visitors attend the Tri-Cities Water Follies, of which the major event is the Columbia Cup hydroplane boat races on the Columbia River. This event is held at Columbia Park, which is more than 25 mi southeast of the PFP.

An estimated 200,000 acre-ft of water may be taken annually for irrigation from the Columbia River in the Hanford Site vicinity (DOE 1987). This estimate is based on the best data available from the Washington State Department of Ecology. These are "paper water rights" (legal permits to limit usage) and are estimated to be twice the actual pumpage, even though not all withdrawals of water are listed. Water rights received after 1969 are not reflected, and not everyone who withdraws water has applied to the State of Washington for water rights. However, the data given are an adequate upper limit for current water usage to 40 mi downstream from the 200 East and West Areas (Rockwell 1986).

Downstream from the Hanford Site private irrigation development is extensive on both sides of the river.

3.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

The PFP is located near the center of the Hanford Site in the 200 West Area. A commercial facility, U.S. Ecology, is located on land leased from the State of Washington. The U.S. Ecology site is within 5 mi of the PFP and handles radioactive low-level wastes (LLW). The nearest military facility is the U.S. Army Yakima Firing Range, located just northwest of the Hanford Site western boundary. All facilities on the Hanford Site are controlled or licensed by the DOE or the U.S. Nuclear Regulatory Commission (NRC) (see Figure 3-10).

Roads near the PFP include SR 24 and SR 240 (see Figure 3-10). These highways and the Hanford Site roads are used by many types of vehicles, including commercial trucks for deliveries of gas, diesel fuel, chemicals, and reagents. However, the separation of the roads from the PFP is such that no adverse effects from highway accidents are projected for the PFP operations.

There are no private or commercial airports within a distance of 20 mi from the PFP. The Richland Airport, nearest to the Hanford Site, is a small, general utility airport, and Kennewick's Vista Field, also a small airport, is located farther out from the site. The Tri-Cities Airport at Pasco, used by local carriers, is 33 mi from the Hanford Site. Federal and military airways within close proximity to the PFP are shown on Figure 3-41. The probability of aircraft affecting the PFP is remote and is discussed in Chapter 9.0.

There are no refineries, major oil storage facilities, munitions, or explosive storage facilities close to the PFP. The nearest natural gas

transmission pipeline is approximately 35 mi away. The considerable distance of these facilities eliminates the potential hazards to the PFP from fires and explosions.

A partial tabulation of the active nuclear areas on the Hanford Site and their location relative to the PFP is presented in Table 3-1. The SARs for the facilities identified in Table 3-1 were reviewed to determine the possible accidents at these facilities and the potential effects of such accidents on the safe operation of the PFP. It was determined that the distances of these areas and related facilities from the PFP and the engineered safeguards built into each facility provide adequate assurance that releases resulting from postulated accidents would not present a significant risk to the PFP or operating personnel.

3.3 METEOROLOGY

The following sections describe the meteorological conditions that influence the operations of the PFP.

3.3.1 Climatology

The Cascade Mountain Range to the west greatly affects the climate of the Hanford Site area. Storm tracks generally move from the Pacific Ocean across the Cascade Mountain Range and then across the Hanford Site. The orographic effect of this range helps create the moderate winters, hot summers, and the relative dryness of the Hanford Site area (Rockwell 1986).

3.3.1.1 Precipitation. Average annual precipitation is 6.26 in.; 54% of the annual precipitation occurs during November through February, whereas only 10% occurs in July, August, and September. The driest month is July with 0.15 in. and the wettest month is December with 1.03 in. (Hoitink and Burk 1995).

Total annual precipitation at the Hanford Site and the probability that the precipitation will not exceed a given amount is shown in Figure 3-11. Precipitation of 1.56 in. in a 24-hour period can be expected to occur at the Hanford Site at least once in 25 years. At the other extreme, there have been 102 consecutive days without measurable precipitation during the summer of 1919 and 172 d with only 0.32 in. (February 24 to August 13, 1968) (Stone et al. 1983).

3.3.1.1.1 Design Criteria. There is currently no specific rainfall design criteria for facilities at the Hanford Site (see Chapter 4.0, Section 4.3.11, for discussion of general design criteria utilized at the Hanford Site).

3.3.1.2 Snowfall. About 38% of all precipitation from December through February is in the form of snow. The average number of days during which there is an accumulation of as much as 6 in. of snow is four, although the 1964/1965 winter had 35, 32 of which were consecutive. Total annual snowfall, which includes all frozen precipitation, has varied from a low of 0.31 in. (1957-1958) to a high of more than 56.1 in. (1992-1993) (Hoitink and Burk 1995). The average annual snowfall is 13.2 in. The largest depth of snow on the ground at any one time was 24.5 in. in February 1916. Table 3-2 provides

snowfall statistics from 1946 through 1994. There is about a 30% probability that the depth of snow on the ground will exceed 6 in. during the winter season (see Figure 3-12).

3.3.1.2.1 Design Criteria. Facility design criteria at the Hanford Site for snowfall loading is discussed in Chapter 4.0, Section 4.3.6 and 4.3.9.

3.3.1.3 Hail and Ice. The HMS has recorded hailstones ranging in size from 0.2-in. to 0.4-in. in diameter, though hail occurs twice a year at most. Glaze ice occurs on an average of six times a year, between November and March. Rime ice occurs at higher elevations in the hills or along the banks of the Columbia River (Stone et al. 1983).

3.3.1.3.1 Design Criteria. There are currently no specific hail and ice design criteria for facilities at the Hanford Site (see Chapter 4.0, Section 4.3.11, for discussion of general design criteria utilized at the Hanford Site).

3.3.1.4 Wind. The Cascade Mountain Range serves as a source of cool air, especially during the summer months, and has a considerable effect on the Hanford Site wind regime. The drainage (gravity) wind, plus topographic channeling, causes a considerable diurnal range of speeds during the summer (see Table 3-3).

While gravity winds occur with regularity in the summer, these are seldom strong unless reinforced by frontal activity. In June, the month of highest average speed, there are fewer instances of hourly averages exceeding 31 mi/h than in December, the month of lowest average speed (see Figure 3-13 and Table 3-3).

Light winds at the Hanford Site in winter cause considerable atmospheric stagnation. December, for example, has an average of 10 days with a peak gust under 13 mi/h. By contrast, only once in 7 years does June have even one such day. During the winter, about 28% of hourly average wind speeds are less than 4 mi/h. Wind speeds are less than 4 mi/h during 19% of the year (Stone et al. 1983).

3.3.1.4.1 Design Criteria. Facility design criteria at the Hanford Site for wind loading and missile protection is discussed in Chapter 4.0, Section 4.3.1 and 4.3.4, respectively.

3.3.1.5 Fog. Episodes of fog are typically associated with low wind speeds. Wind speeds exceed 4 mi/h during only 27 of the hours in which fog is present (Stone et al. 1983).

3.3.1.5.1 Design Criteria. There is currently no specific design criteria for fog for facilities at the Hanford Site (see Chapter 4.0, Section 4.3.11, for discussion of general design criteria utilized at the Hanford Site).

3.3.1.6 Dust. This phenomena is recorded at the HMS when the visibility is restricted to 6.2 mi or less by either dust or blowing dust. The dry sand and soil of the Pasco Basin, in addition with local construction and agricultural activities, combine to generate all sources of airborne dust at the Hanford Site. Blowing dust at the Hanford Site occurs with strong winds of greater

than 18 mi/h. An average of 5 days per year has dust or blowing dust. These dust storms last an average of just over 3 hours but have lasted as long as 18 hours. Dust storms occur most frequently from March through May and also in September. The spring dust storms occur when soil is disturbed by spring agricultural activity and winds. September dust storms are related to ground breaking for winter wheat in the eastern and central part of the Pasco Basin (north and northeast of the Hanford Site). Dust storms are least frequent in August, November, and December (Stone et al. 1983).

3.3.1.6.1 Design Criteria. There is currently no specific design criteria for dust for facilities at the Hanford Site (see Chapter 4.0, Section 4.3.11, for discussion of general design criteria utilized at the Hanford Site).

3.3.1.7 Temperature. The average maximum temperatures in January and July are 38.4 °F and 91.4 °F, respectively. The average minimum temperatures for the same months are 24.0 °F and 60.9 °F, respectively. The average monthly relative humidity varies from a low of 33.2% in July to a high of 80.2% in December. The lowest winter season daily minimum temperatures range from -23 °F to 20 °F; the highest summer season daily maximum temperatures vary from 100 °F to 113 °F (Hoitink and Burk 1995).

Temperatures at the Hanford Site are colder in winter and warmer in summer than would be the case without the Cascade Mountain Range. However, other mountain ranges shield the area from arctic outbreaks, and half of all winters are free of temperatures below 0 °F. However, two winters in 50 years of record have contributed a total of 6 days with temperatures of -20 °F or below; in January through February, 1950, there were four consecutive such days. There are 6 days recorded when the maximum temperature failed to get above 0 °F. At the other extreme, in the winter of 1966-1967, the lowest temperature all season was 20 °F. Although daytime temperatures reach 90 °F or above for an average of 51 days per year, night time temperatures of 70 °F or above occur only an average of 7 days per year. The cool nights are a result of the gravity winds mentioned earlier.

3.3.1.7.1 Design Criteria. There is currently no specific temperature design criteria for facilities at the Hanford Site (see Chapter 4.0, Section 4.3.11, for discussion of general design criteria utilized at the Hanford Site).

3.3.1.8 Thunderstorms. Thunderstorms occur in every month of the year, except January and November. The thunderstorm season is essentially from April through September. The average number of thunderstorm days per year is 10; however, the total varies from a low of 3 in 1949 to a high of 23 in 1948. The largest number of thunderstorms in any single month was 8 in June 1972, July 1983, and August 1953 (Hoitink and Burk 1995). Although severe thunderstorms are rare, the Hanford Site is vulnerable to lightning strikes causing grass fires; the most notable occurrences were in August 1961, July 1963, July 1970, August 1973, and August 1984 (Rockwell 1986).

3.3.1.8.1 Design Criteria. There is currently no specific thunderstorm design criteria for facilities at the Hanford Site (see Chapter 4.0, Section 4.3.11, for discussion of general design criteria utilized at the Hanford Site).

3.3.1.9 Tornados. The formation of a severe tornado of the Midwest-type is highly unlikely under the climatologic and orographic conditions of the Pacific Northwest. There have been only two tornado funnel clouds and one small tornado (June 16, 1948) observed on the Hanford Site in the 34-year period 1945 through 1978. Although one of these touched ground, it caused no damage. The nearest reported tornado damage was in Yakima (April 30, 1957), about 45 mi to the west, and at Wallula Junction (June 26, 1958), about 50 mi to the southeast (Rockwell 1986). Only minor damage was noted.

3.3.1.9.1 Design Criteria. Design criteria for tornado winds at the Hanford Site is discussed in Chapter 4.0, Section 4.3.2.

3.3.1.10 Ashfall. Ashfall and design criteria for ashfall loading at the Hanford Site is discussed in Section 3.6.6.4.

3.3.1.11 Data Sources. The principal source of climatologic data for the Hanford Site is the HMS, with its 410-ft tower, located between the 200 East and 200 West Areas (see Figure 3-2). Elevation of the station is 733 ft above msl. This meteorological station has been collecting data since 1944. From 1912 through 1942, weather records were kept at a U.S. Weather Bureau cooperative station near the old Hanford townsite.

Wind and temperature measurements are taken at the HMS tower levels shown in Table 3-4.

Surface observations of dew point temperatures and ambient air temperature are taken every fifteen minutes about 0.25 mi east of the tower at the HMS building. Also near the building is a precipitation gauge and a pyranometer used to measure solar radiation.

3.3.1.12 Normal and Extreme Values of Meteorological Parameters. These data are given in Table 3-5.

3.3.2 Onsite Weather Forecasting and Climatology Capability

Meteorological and climatological services available from the HMS include the following:

- Emergency Response Capability--In an accidental release of radioactive material, the forecaster on duty would immediately compute a short term wind forecast for the release location. To do this, one uses wind data automatically reported every fifteen minutes by a network of 30 wind stations. Wind data are used to construct airflow charts over the Hanford Site every 15 minutes. The wind data are also continuously sent to the Unified Dose Assessment Center (UDAC). The next duty of the forecaster is to incorporate the wind data and stability category with an interactive mesoscale diffusion and transport computer model to produce computer printouts of plume positions and movement over the Hanford Site. These calculations are made for two situations: once a month as a practice run, and on request. This service can be requested 24 hours per day except on the weekend and holidays when the service is only available on the day shift. A backup generator at the HMS is available to support this forecasting capability. A manually

started backup generator is also available at the transmitter. In the case of a loss of power at the transmitter, the Hanford Patrol would be contacted to manually activate the backup generator.

- Adverse Weather Advisories--This service is provided to facilitate safe and efficient operation of the Hanford Site plants. These advisories consist primarily of winds in excess of 35 mi/h and thunderstorms; however, occasional warnings are required for drifting snow and freezing rain. Although tornadoes are seldom seen in the Hanford Site, if conditions were such that a tornado could be produced, a warning to that effect would be issued over the emergency warning system. People designated by each Hanford Site contractor are notified to take appropriate action.

- General Weather Forecasts--General weather forecasts are prepared and recorded at 0700 and 1500 hours each day. The forecasts are tailored to the requirements of the DOE and Hanford Site contractors for general work scheduling.

- Climatology--Climatologic data and analyses for the Hanford Site are provided to assess energy demands for preliminary site assessments and for the design and construction of facilities in which environmental control is essential.

One of the functions of the HMS is to monitor and record the wind speed and direction and stability data from the HMS tower. Joint frequency distribution of wind speed, wind direction (at ground and stack height 32 ft and 200 ft, respectively), and stability data (based on vertical temperature gradients; ΔT at 200 ft to 230 ft), are given in Tables 3-6 and 3-7 for the period 1983 through 1991 and is considered to be representative for the Hanford Site.

Atmospheric stability refers to the degree of turbulence in the air; when the atmosphere is thermally stable, turbulent motions are suppressed and less mixing and dilution of airborne contaminants can occur.

Figure 3-14 Sheet 1, presents an example of a wind rose for all stability classes combined. Figure 3-14 (Sheet 2) presents the wind rose pattern broken down to individual areas in the Hanford Site.

3.3.3 Short-Term and Long-Term (Routine) Dispersion Estimates

Straight-line Gaussian plume models are widely accepted and used for atmospheric dispersion estimates related to radiological and toxicological releases. These models are appropriate if the following conditions can be assumed.

- The distance from the source to the point analyzed is large compared to the size of the source. Most Gaussian plume models assume the source to be a point of zero size so that results too close to the source overestimate plume concentrations. Simple Gaussian plume models generally are not considered valid if less than about 100 ft from the source.

- The terrain is relatively flat and surface and meteorological conditions are uniform in all directions and are constant in time. The conditions at the time and place of the release completely determine subsequent transport and diffusion.

- The release rate is constant and is of relatively long duration so the plume is long enough that diffusion in the direction of travel can be neglected (i.e., transport is dominated by bulk movement of the air). This yields a continuous (not-time-dependent) model, which is not valid for short releases such as explosions or tank ruptures. A continuous model will tend to overestimate greatly air concentrations for such short release times.

The basic Gaussian plume model for atmospheric releases to onsite personnel and offsite individuals (as utilized in analyses in Chapters 8.0 and 9.0) is given by:

$$\overline{X} = Q' F_{(y)} G_{(z)} / (2\pi\sigma_y\sigma_z U)$$

where:
- $\overline{X}/Q'$ = Concentration at the receptor
- Q' = Release rate
- σ_y = Horizontal diffusion coefficient
- σ_z = Vertical diffusion coefficient
- U = Average wind speed
- $F_{(y)}$ = Horizontal off-axis correction
- $G_{(z)}$ = Vertical off-axis correction.

The x direction is downwind in the direction of transport, the y direction is transverse to the direction of transport horizontally, and the z direction is transverse to the direction of transport vertically.

The off-axis correction factors describe the decrease in concentration with increasing distance from the plume centerline. These factors are defined as follows:

$$F_{(y)} = \exp[-0.5(y/\sigma_y)^2]$$

$$G_{(z)} = \exp\{-0.5[(z-h_e)/\sigma_z]^2\}$$

where y and z are the horizontal and vertical distances to the plume axis, respectively, and h_e is the effective release height. The plume is usually assumed to be reflected by the ground. This reflection is accounted for by

placing a mirror image virtual source below the ground, producing a vertical off-axis correction of the following form:

$$G_{(z)} = \exp\{-0.5[(z-h_e)/\sigma_z]^2\} + \exp\{-0.5[(-z-h_e)/\sigma_z]^2\}$$

Two special cases are of primary interest:

1. Release at ground level and receptor at ground level on plume centerline. Therefore, $y = 0$, $z = 0$, and $h_e = 0$ leading to:

$$F_{(y)} = 1.0$$

$$G_{(z)} = 2.0$$

$$\overline{X}/Q' = 1/(\pi\sigma_y\sigma_z U)$$

2. Elevated release with receptor at ground level. Therefore $y = 0$, $z = 0$, and h_e the effective stack height leading to:

$$F_{(y)} = 1.0$$

$$G_{(z)} = 2.0 \exp[-0.5(h_e/\sigma_z)_2]$$

$$\overline{X}/Q' = \exp[-0.5(h_e/\sigma_z)^2]/(\pi\sigma_y\sigma_z U)$$

The horizontal and vertical diffusion coefficients, σ_y and σ_z, are functions of x (the transport distance to the receptor) and the atmospheric stability class (Randerson 1984) and are evaluated using empirical formulas of the form (Napier et al. 1988):

$$\sigma = Ax^B + C$$

The dispersion coefficients ($\overline{\chi}/Q'$) used in this document for calculating the population dose due to atmospheric releases were derived by the GXQ Code (Hey 1993a, 1993b). These coefficients are based on site-specific meteorology records in the form of joint frequency tables (see Tables 3-6 and 3-7) where, for each of 16 directional sectors, frequencies of occurrence of the various atmospheric stabilities as a function of wind speed are tabulated (wind data used to generate the joint frequency data presented in this chapter was collected in the 200 Areas between 1983 and 1991 at the HMS [Schreckhise et al. 1993]). For a given direction, two $\overline{\chi}/Q'$ values (for both ground level and stack level releases) are calculated for each stability and wind speed

category and weighted according to its frequency of occurrence. For acute releases from the PFP, the 99.5th percentile $\bar{\chi}/Q'$ in the direction and distance of interest is determined, while for chronic releases an annual average $\bar{\chi}/Q'$ value is determined.

The onsite and offsite $\bar{\chi}/Q'$ values for the acute ground level releases (used in the accident analyses in Chapter 9) were then adjusted to account for building wake and plume meander effects in accordance with NRC Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants* (NRC 1982a). Wake correction factors for the onsite and offsite locations were calculated to be 0.25 and 0.80, respectively.

For free-standing stacks (i.e., stacks at least 2.5 times the height of nearby buildings), the effective release height is defined by:

$$h_e = h_s + h_r + h_d$$

where: h_s = The physical stack height
h_r = Plume rise resulting from momentum and buoyancy
h_d = Downwash resulting from air movement around the stack.

Ground concentrations near an elevated release point (i.e., within about three hundred feet) tend to be unstable with slight changes in conditions giving large changes in the ground-level concentration. For this reason, calculated doses near an acute elevated release should be viewed as approximate estimates. To allow for this, usually no credit is taken for plume rise effects for acute elevated releases, because the conditions during such a release cannot be ensured. Average conditions over a year, however, are well known from historical data, permitting the use of a plume rise correction for calculation of chronic doses. As expected, the solutions for ground-level and elevated releases converge as the receptor distance increases and become relatively insensitive to moderate changes in effective release height beyond 1 or 2 km (about 0.6 to 1.2 mi).

3.3.3.1 Maximally Exposed Individual. The onsite maximally exposed individual (MEI) is located in the nearest normally occupied facility with the highest dose outside the PFP emergency response area. The potential offsite MEI is the hypothesized receptor at the Hanford Site boundary location that receives the highest radionuclide concentration. For long-lived isotopes (such as plutonium), these are the equivalent to the onsite and offsite locations having the greatest $\bar{\chi}/Q'$ values.

Dose consequences to the MEI are calculated for use in determining the risk (e.g., risk = consequence x probability) associated with routine and accidental releases. The chronic dose releases to onsite and offsite individuals (see Chapter 8.0, Section 8.4) utilize the dispersion coefficients ($\bar{\chi}/Q'$) calculated from joint frequency data provided by the HMS. Acute dose releases to onsite and offsite individuals are presented in the accident analyses of Chapter 9.

3.3.3.2 Population. For purposes of estimating annual population doses as a result of chronic releases (as presented in Chapter 8.0), calculations are carried out for a series of rings at varying distances from the point of release in each directional sector. The rings corresponding to the transport distances evaluated are shown in Table 3-8. The directions evaluated are the midpoints of 16 sectors, each 22.5° wide. The directional sectors are defined in Table 3-9. The sectors having the largest scaled dispersion coefficients ($\bar{\chi}/Q'$) are given in Table 3-10 for the 200 West Area. These values were chosen as the worst case for exposure (Nguyen 1995).

These dispersion coefficients are used in conjunction with a similar grid showing population within each segment (one sector of one ring) to calculate annual total, or chronic, average population doses within a 50-mi radius of the release point. Calculations of chronic dose releases to offsite population (see Chapter 8.0, Section 8.6) utilize the dispersion coefficients ($\bar{\chi}/Q'$) calculated from joint frequency data provided by the HMS. Acute dose releases to offsite population are presented in the accident analyses of Chapter 9.

3.4 SURFACE HYDROLOGY

3.4.1 Hydrologic Description

The surface water located within the boundaries of the Hanford Site consists of the Columbia River, various ditches, ponds, and trenches in and near the 100 Areas, 200 East and West Areas, and 300 Area. These are shown in Figure 3-15. Two ephemeral streams just west of the Hanford Site, Cold and Dry Creeks, may flow for a short period after a heavy rainfall or snowmelt. The Yakima River borders part of the southern boundary of the Hanford Site.

The surface hydrology of the Hanford Site has been studied extensively (Rockwell 1988). These studies include an analysis of the Columbia and Yakima Rivers, as well as extensive investigations as to the nature of a number of human-made ditches and ponds used for the disposal of low-level radioactive liquid waste, certain industrial waste, and cooling waters from various processes. *Annual Report of RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1994* (DOE-RL 1995), provides a listing of ditches, ponds, and trenches and their chemical and radiological inventories.

3.4.2 Floods

3.4.2.1 Flood History. The Columbia River, which flows through the northern part of the Hanford Site and along the eastern boundary, and the Yakima River, which flows along the southern boundary, are the dominant streams in the area. Both streams are important sources of industrial, agricultural, and domestic water for the region. The average annual Columbia River flow in the Hanford reach, based on 65 years of records, is about 120,000 ft^3/s (USGS 1985). High flowrates ranging from 250,000 ft^3/s to 450,000 ft^3/s have been recorded. During low-flow periods, flowrates typically average 60,000 ft^3/s (USGS 1985). For 57 years of records, the average annual flow of the Yakima River has been about 3,672 ft^3/s, with monthly maximum and minimum flows of 17,300 and 162 ft^3/s, respectively. Maximum Columbia River floods of historical record

occurred in 1894 and 1948, with flows of 800,000 and 740,000 ft^3/s, respectively (Wood 1954). The likelihood of floods of this magnitude recurring has been reduced by the construction of several flood control/water storage dams upstream of the Hanford Site. Normal river elevations within the Hanford Site range from 394 ft where the river enters the Hanford Site near Vernita to 341 ft where it leaves the Hanford Site near the 300 Area. The ground elevation at the PFP is 676 ft above msl.

Since 1902, there have been fewer than 20 major floods on the Yakima River. The most severe of these occurred in November 1906, December 1933, May 1948, and February 1996. Discharge magnitudes at Kiona, Washington, were 66,000, 67,689, 37,000 ft^3/s, and approximately 45,500 ft^3/s, respectively (Supply System 1981 and U.S. Army Corps of Engineers 1996). The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively.

3.4.2.2 Flood Considerations. The Columbia River probable maximum flood (PMF) (the flood discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions reasonably possible in the region) would produce a flow of 1,440,000 ft^3/s; flood elevations would be about 423 ft at 100-N Area and 384 ft at the 300 Area (ERDA 1976). This flood would not affect the central part of the Hanford Site (the plateau of the 200 East and West Areas), where most of the transuranic wastes and high-level wastes are now stored and which has an elevation greater than 499 ft. Similarly, waters of a 100-yr flood (459,000 ft^3/s) would have no effect on the PFP and waste disposal sites (ERDA 1975).

3.4.2.2.1 Design Criteria. PFP facilities are not required to be designed nor analyzed for flood loads, as the PFP is located outside of the PMF flood-affected zone of the Columbia River [see Chapter 4.0, Section 4.2.3, for discussion of the flood design criteria for safety class and safety significant structures, systems, and components (SSCs)].

3.4.2.3 Effects of Local Intense Precipitation on Flooding. The probable maximum precipitation (PMP) has been estimated as 11 in. in 24 hours at least once in a million years (ERDA 1975). Potential flooding of the 200 West Area has been analyzed on a local and regional basis (Skaggs and Walters 1981). The referenced analysis provides a detailed evaluation of the potential for flooding in Cold Creek. (The PFP is located within the Cold Creek Watershed.) Using procedures of the U.S. Weather Bureau (1966), maximum total precipitation was computed to be 12.43 in. over a 3-d period having a maximum 6 h rainfall of 4.52 in. (Skaggs and Walters 1981). The results of the Skaggs and Walters study show the flood would reach a maximum elevation of 645 ft above msl. The PFP, at 676 ft above msl, is above this maximum elevation for which flood protection is required.

The PFP is not within a flood plain. The area adjacent to the PFP drains to low ground, which extends in a north-to-south direction (Figure 3-16). Plant buildings are located on high ground (elevation 676 ft above msl) to the west of the low ground.

3.4.3 Probable Maximum Flood on Streams and Rivers

3.4.3.1 Precipitation Losses. For the Pasco Basin (see Figure 3-17) water balance estimates indicate precipitation of 756,000 acre-ft/yr, zero runoff and groundwater recharge of 6,000 acre-ft/yr (less than 1%) (Leonhart 1979).

3.4.3.2 Runoff Model. The total annual precipitation over the Pasco Basin is estimated at 7.6×10^5 acre-ft, averaging less than 8 in./yr. The mean annual runoff from the basin is estimated to be less than 2.5×10^4 acre-ft/yr, or approximately 3% of the total precipitation. The runoff coefficient is zero, for all practical purposes. The bulk of the remaining precipitation is assumed to be lost through evapotranspiration, with perhaps less than 1% recharging the groundwater system (Leonhart 1979).

Surface runoff from the Hanford Site to the Columbia and Yakima Rivers contributes negligibly to total gauged flows. About two-thirds of the Hanford Site drains into the Columbia River; the remaining one-third (in the western and southern portions of the site) drains into the Yakima River. The drainage divide between the Columbia and Yakima River watersheds is shown in Figure 3-18, which illustrates that the divide lies between the 200 East and 200 West Areas.

3.4.3.3 Probable Maximum Flood Flow, Water Level Determinations, and Coincident Wind Wave Activity. The Columbia River PMF, resulting in a maximum water level of 423 ft above msl, would not affect the PFP, which is at elevation 676 ft above msl.

The development of irrigation reservoirs within the Yakima River Basin has considerably reduced flood potential of the river. For example, the December 1933 flood was reduced from 84,700 to 52,965 ft^3/s at Yakima, Washington, by management of upstream reservoir storage facilities. A flood in December 1959, if it had been uncontrolled, could have reached a magnitude of 56,496 ft^3/s at Yakima, was held at 27,542 ft^3/s by the reservoir system.

Lands susceptible to a 100-year flood on the Yakima River are shown in Figure 3-19. Flooded areas near Horn Rapids could extend into the southern section of the Hanford Site; however, these waters would not reach the PFP. The Yakima River upstream from Horn Rapids is physically separated from the Hanford Site by Rattlesnake Mountain. This topographic barrier prevents potential flooding of the Yakima River from reaching the PFP.

The potential for flash flooding from the Cold Creek was discussed in Section 3.4.2.3. The maximum elevation of the flood was estimated to be 645 ft above msl. The elevation at the PFP is 676 ft above msl.

PFP facilities are not required to be designed nor analyzed for flood loads, as the PFP is located outside of the flood-affected zones of the Columbia and Yakima rivers, and of the Cold Creek (see Chapter 4.0, Section 4.2.3, for discussion of the flood design criteria for safety class and safety significant SSCs).

Any coincident wind wave activity that a flood might induce would not affect the 200 West Area, as the flood would not reach this point.

3.4.4 Potential Dam Failures (Seismically Induced)

Grand Coulee Dam has been recognized as being the only upstream dam with a storage capacity great enough to cause a flood in the event of dam failure. A study concluded that seismic damage to Grand Coulee Dam would not produce a flowrate in excess of the PMF (ERDA 1976).

3.4.5 Probable Maximum Surge and Seiche Flooding

Surge and seiche flooding (causally related to hurricane, typhoon, or similar storms) are not possible in this region. Hurricanes and typhoons are not characteristic of the Hanford Site location meteorology.

3.4.6 Probable Maximum Tsunami Flooding

Tsunami flooding is not possible in this region because of the separation and elevation of the Hanford Site location from the Pacific Ocean.

3.4.7 Ice Flooding

The Snake and Columbia Rivers occasionally have been subjected to surface freezing; however, the flow channel has remained open since the flood control dams have been in place. No effects caused by this phenomenon will influence the PFP site.

The Yakima River has been subject to ice dam flooding; however, the riverbed is at approximately the same elevation as the Columbia River, and its flood capacity is such that it cannot cause the water level to rise enough to affect the PFP site.

3.4.8 Water Canals and Reservoirs

Water canals are not located in the vicinity of the PFP. No reservoirs are directly associated with the PFP; however, until 1982, liquid discharges of cooling and rainwater were carried from the plant by the open 216-Z-19 Ditch. This ditch was located on the southeast side of the PFP and carried liquid effluents to the 216-U-10 Pond. Subsequently, liquid discharges from the PFP were routed to the 216-Z-20 Crib for disposal. Use of the ditch, pond, and 216-Z-20 Crib have been discontinued. Potentially contaminated aqueous streams from the PFP are now treated at the Low-Level Waste Treatment Facility (LLWTF) (the 243-Z/ZA Complex). These streams leave the LLWTF and go to the Treated Effluent Disposal Facility (TEDF) in the 200 East Area for discharge to the environment (see Chapter 7.0, Section 7.3.2).

3.4.9 Channel Diversion

Flow diversions in the central Washington area have occurred historically several times. The causes were (1) glacier advances and recessions, and (2) major rock slides into the Columbia River bed. The areas where these

events occurred are 60 mi north of the Hanford Site. The rock slides have caused only temporary changes in flow and no permanent flow path changes.

Flow blockage downstream caused by volcanic activity could conceivably occur. However, a blockage of over 500 ft in height would be required to affect the PFP site.

3.4.10 Flooding Protection Requirements

Because of the natural drainage capabilities of the soil and the site elevation compared with the surrounding area, no flooding protection requirements are imposed on the PFP.

Specific effects on facility structures and equipment as a result of local, intense rainfall have not been identified. Flooding of the 291-Z Building because of the maximum rainfall, for example, has not been evaluated as of 1995, but analyses of loss of ventilation for any reason indicate no radiological concerns (see Chapter 9.0).

3.4.11 Low Water Considerations

Process and sanitary water is used at the PFP and supplied by the Hanford Site Utilities Services. Water is pumped from the Columbia River through a treatment process and then to the holding tanks located in the 200 West Area at the powerhouse. Under the most extreme cases of interruption in water flow, the plant may be placed in an orderly shutdown mode in accordance with the Building Emergency Procedures. While low-water conditions may affect plant performance, they do not present an imminent threat to the plant.

3.4.12 Environmental Acceptance of Effluents

The sediments beneath the PFP site consist of a thin mantle of windblown silts and sands, which cover layers of sand and gravel up to 200 ft thick deposited by catastrophic Pleistocene floods. These sedimentary deposits have the capacity to absorb and retain radioactive contaminants from the waste streams and from accidental spills or leaks.

Because of the mild, dry climate, precipitation and evapotranspiration influence the sediment moisture content mostly in the surface 6 to 7 ft, with measurable changes occurring as deep as 40 ft (Rockwell 1978b). Even though the sorption capacity of the sediments is low, the total sorption capacity of the sediment column between waste release point and the water table is high because of the long length of the column (up to about 320 ft in the 200 East and West Areas). The high column sorption capacity and low precipitation provide excellent conditions for maximum sorption of radionuclides released to the sediments. The soil column contains gravel, silt, and sand with some clays. The clays make good filter beds, and the soil columns exhibit cation exchange capabilities of 2.5 to 10 meq/100 g of soil (ERDA 1975).

3.4.13 Chemical and Biological Composition of Adjacent Water Sources

There are no water sources immediately adjacent to the PFP.

3.5 SUBSURFACE HYDROLOGY

3.5.1 Regional and Area Hydrological Characteristics

The Hanford Site lies within the Pasco Basin, a structural and topographic low within the Columbia Plateau physiographic province. The Pasco Basin (Figure 3-20) is bound by the Saddle Mountains to the north, the Umtanum and Yakima Ridges to the west, the Rattlesnake and Horse Heaven Hills to the south, and a broad regional monocline (known locally as the Jackass Mountain monocline) to the east.

The regional geology of the Hanford Site has been extensively studied and documented (Rockwell 1979a). From a hydrologic standpoint, the area is composed of a series of confined aquifers (primarily sedimentary interbeds of the Ellensburg Formation and interflow zones within the Columbia River Basalt Group) overlain by an unconfined aquifer in the upper and middle Ringold Formation and overlying sediments of the Hanford formation. The geologic and hydrologic characteristics of the various stratigraphic horizons are summarized in Table 3-11.

Based on interpretations from available geologic data, numerous lava extrusions flowed out from extensive fissure systems and flowed across the Columbia Plateau during the late Tertiary Period. The highly fluid lavas covered the developing Pasco Basin. As basining continued, thick sections of basalt accumulated within these low regions. Because of the geometry of the flows and the erosion or deposition of various sediments between the flows within these rock units, several artesian aquifers exist (e.g., the Mabton-Priest Rapids aquifer in the Cold Creek area and the Frenchman Springs aquifer in the Quincy-Odessa area). Water recharged these aquifers about 14,000 yr ago, based on radiogenic age-dating using the radioactive ^{14}C technique.

During the late Tertiary Period (Pliocene Epoch), the number and size of fissure eruptions decreased markedly and finally ceased. Even though volcanic activity ceased, basining continued and was accompanied by a regional north-south compression. As a result of these compressional forces acting on the basalt rocks, several east-west-trending anticlinal ridges (e.g., Saddle Mountains, see Figure 3-20) were formed in the western part of the Columbia Plateau. The formation of these ridges had a significant impact on the course of the Columbia River. Where the Columbia River was able to erode the basalt at least as quickly as the anticlinal ridges formed, little change in the course of the Columbia River occurred. Where the ridges rose faster than the water was able to erode, the river was temporarily halted and lakes were formed. As basining continued, lacustrine and fluvial deposits continued to fill the Pasco Basin and covered previously deposited basalts. These sedimentary deposits comprise the Ringold Formation. The White Bluffs just east of the Columbia River and north of Richland, Washington, represent the upper portion of the Ringold Formation.

The total thickness of the Ringold Formation in the Pasco Basin is about 1,200 ft. It is characterized by clay, silt, and fine sand with some gravel lenses in the lower section, cemented gravel in the middle, and silts and sands in the upperpart of the section. The Ringold sediments are well-to-poorly sorted and show a wide range of cementation. Locally, the coarse silts, sands, and gravel possess high hydraulic conductivities and are capable of storing vast quantities of groundwater. The silty clay and silty very fine sand beds have very high porosity but yield little or no water. These deposits are considered to be impermeable under hydraulic gradients of normal magnitude. The water table over the western portion of the Hanford Site occurs near the top of the Ringold Formation. In the eastern half of the Hanford Site, the water table rises well above the Ringold Formation and saturates the lower portion of the overlying Hanford Formation.

The gravel zones in the basal and lower units of the Ringold Formation tend to form a local confined aquifer system. The upperpart of the Ringold Formation and the overlying Hanford Formation constitute the major unconfined aquifer beneath the Hanford Site.

The extent of the Columbia River downcutting that took place primarily during the Pleistocene is an influential factor in the unconfined aquifer. Significant paleochannels of high hydraulic conductivity were formed as a result of this downcutting. The nature and location of the paleochannels have been studied using data from about 3,000 wells drilled on the Hanford Site and from a gravity survey (Deju and Richard 1975).

3.5.1.1 Uppermost Confined Aquifers. The uppermost confined aquifers consist of the lower and basal units of the Ringold Formation and the uppermost sedimentary interbeds and interflow zones (ARCHO 1976). From a water supply standpoint, the only significant confined aquifer is in the Priest Rapids member of the Columbia River Basalt Group. The aquifer is about 975 ft below the surface in the 200 East and West Areas.

The Rattlesnake Ridge interbed is the uppermost confined aquifer within the basalt aquifer system. The shape of the potentiometric surface of the uppermost confined aquifer is used to obtain an approximate picture of the regional flow system (Figure 3-21). Flow lines are perpendicular to contours of equal hydrostatic head contours. Recharge into the aquifer appears to occur within the ridges and plateaus fringing the Pasco Basin, with discharge being toward the Columbia River. The eastern portion of the Hanford Site appears to be a regional discharge area for the uppermost confined aquifer.

The uppermost confined aquifer is interconnected in places to the overlying unconfined aquifer. This occurs in areas where the confining layer has been eroded or subjected to extensive warping and deformation, such as along the anticlinal axis that runs from Umtanum Ridge to Gable Mountain.

3.5.1.2 Unconfined Aquifer. The unconfined aquifer consists of sand and gravel deposits of both the Hanford and Ringold Formations. Since these materials are very heterogeneous, greater lithologic differences appear more often within a given bed than between beds. The water table represents the top of the unconfined aquifer at any given time (Figure 3-22). The aquifer bottom is either basalt bedrock or silt and clay zones of the Ringold Formation. The aquifer bottom has been determined using information from hundreds of wells drilled at the Hanford Site.

The hydraulic characteristics of the unconfined aquifer are quite variable and are summarized in Tables 3-12 and 3-13 (Rockwell 1986). The storage coefficient is not sufficiently known to plot its areal distribution; however, as a result of extensive pump testing and geologic studies, a map was developed (ARCHO 1976) from the vertically averaged hydraulic conductivity distribution for the unconfined aquifer system (Figure 3-23). A zone of high hydraulic conductivity is situated between Gable Butte and Gable Mountain and continues through the middle of the Hanford Site.

The Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge to the west and southwest (Figure 3-24) are impermeable boundaries. Gable Mountain and Gable Butte, as well as other small areas of basalt, rise above the water table, distorting the groundwater flow. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids to Richland. The Columbia River represents a hydraulic discharge boundary for the aquifer. Groundwater flow and bank storage are affected by seasonal river stage fluctuations of the Columbia River.

The flow pattern that originally prevailed in the unconfined aquifer before waste discharges was primarily to the east and northeast with discharge into the Columbia River (ERDA 1975). Natural recharge occurs in the Cold Creek and Dry Creek valleys along the margin of the Rattlesnake Hills and Yakima Ridge. Groundwater flow appears to be distorted by a buried extension of Yakima Ridge, which parallels the Rattlesnake Hills for a distance of about 2 mi.

Before waste water disposal at the Hanford Site, unconfined groundwater flowed west to east across the Pasco Basin to the Columbia River. Artificial recharge has created significant perturbations in groundwater flow. The elevation of the water table beneath most of the 200 Area Plateau declined from June 1993 through June 1994. The largest change occurred in the 200 West Area where the water table dropped 3.84 ft. The declining water table in this area is caused by continued dissipation of the mound from the decommissioned U Pond. The maximum elevation of this mound, which occurred in 1984, was approximately 485 ft above mean sea level. The residual mound from U Pond appears to have shifted northward because of continuing waste water disposal to the Z-Plant Cribs (Dirkes and Hanf 1995). The water table map for the Hanford Site and outlying areas indicates that the groundwater mound beneath the 200 West Area has influenced regional groundwater flow. It contributes to steep hydraulic gradients to the east of the 200 West Area. The groundwater mound from U Pond has also increased the gradient in the gap between Umtanum Ridge and Gable Butte. However, the steep gradient in this area also results from recharge coming from the Cold Creek Valley and from the small width and shallow sediments in the gap (Dirkes and Hanf 1995).

3.5.1.2.1 Design Criteria. Facility design criteria for subsurface hydrostatic loading at the Hanford Site is discussed in Chapter 4.0, Section 4.3.10.

3.5.1.3 Unsaturated Zone. On the Hanford Site, the thickness of the unsaturated zone varies from 0 to 350 ft.

During the period August 1, 1973, through July 31, 1974, the Hanford Site experienced 170% of normal rainfall. At a field test site located south of the 200 East Area, where rainfall moisture penetration is measured routinely,

this excessive rainfall penetrated about 8 ft into the sediments. Moisture from rainfall during this period appears to have evaporated to the atmosphere. The data indicate that the loss of moisture by evaporation is greater than that gained through precipitation, forming a desiccated zone at the near-surface during the summer months (ARCHO 1975). The Hanford Site sediments, below a depth of about 30 ft, are essentially dry.

3.5.2 Plutonium Finishing Plant Site Hydrogeological Characteristics

Four major stratigraphic units underlie the PFP (discussed in Section 3.6): (1) the basalt of the Columbia River, which forms the bedrock beneath the area; (2) semiconsolidated sediments of the Ringold Formation, which directly overlie the bedrock; (3) unconsolidated eolian silt; and (4) unconsolidated sand, silt, and gravel (collectively termed glaciofluvial sediments) which directly overlie the eolian silt.

The surface of the Columbia River Basalt beneath the PFP lies at an elevation of 145 ft above msl. Beneath the PFP, both the lower and upper Ringold units are missing. The middle Ringold unit is approximately 415 ft thick. Although the middle Ringold unit consists predominantly of pebbles and cobbles, it contains a few sand lenses up to 20 ft thick. Early Palouse soil (wind-deposited silt) occurs beneath the PFP between elevations of 560 and 585 ft above msl. They are overlain by 90 ft of a coarse-to-medium glaciofluvial sand.

The water table is found beneath the PFP in the middle Ringold Formation. Initially the water table beneath the PFP was at 400 ft above msl. The elevation of the water table surface in this area has been influenced by water discharged to surface ponds and cribs since the startup of the Hanford Site project. After deactivation of the Reduction Oxidation (REDOX) Chemical Processing Plant, the rise in the water table stopped and it began to recede. The elevation of the water table rose again with the start of cooling water discharge from the 242-S Waste Evaporator-Crystallizer, which is currently shut down. The water table beneath PFP currently ranges from approximately 454 to 456 ft above msl (Hartman et al. 2000).

Figure 3-25 shows the locations of test wells used for monitoring water levels in the 200 West Area and around the PFP. There are no wells at the PFP in use as a source of drinking water. Figure 3-26 shows a sample hydrograph for a typical well structure near the PFP. Chemical monitoring of the groundwater is performed near the PFP [see *Hanford Site Groundwater Monitoring for 1994* (Dresel et al. 1995) for details and results of groundwater monitoring for chemicals and radionuclides in the Hanford Site]. As a result of this monitoring effort, it has been discovered that CCl_4 is present in the groundwater around the plant. Figure 3-27 shows sample results of the available data for this compound (Dirkes and Hanf 1995). During the Plutonium Reclamation Facility (PRF) operation, CCl_4 was a component of the solvent for the extraction columns. The current processes active at the PFP do not use CCl_4, and all of the drums of CCl_4 have been removed. Groundwater remediation activities on the CCl_4 began in 1992 and are continuing.

The only potential pathways for groundwater contamination to enter the unconfined aquifer from the PFP are indirect washing of potentially contaminated soils in the french drains by non-contaminated steam condensate

discharges and/or accidental releases. Located under the PFP, this aquifer has a low transmissivity and a low hydraulic conductivity. As a consequence, migration of radionuclides (such as those from past disposal practices) to the water table would be slow. The total hydrological load resulting from operating PFP from 1977 to 1985 amounted to 72 x 10^8 gal. The 216-Z-20 Crib stream formerly serviced the PFP to collect waste water. A radionuclide inventory of the crib is provided in *Westinghouse Hanford Company Environmental Surveillance Annual Report 200/600 Areas*, Calendar Year 1988 (Elder et al. 1989). For a discussion of current waste discharges from the PFP, see Chapter 7.0.

Wells are currently sampled in the vicinity of PFP according to the *Environmental Monitoring Plan*, DOE/RL-91-50 (DOE-RL 1997).

The 216-Z-21 Basin received demister and cooling water from the PFP. Environmental surveillance results for the basin are shown in (Elder et al. 1989).

Wastewater streams from the PFP no longer flow to the 216-Z-20 Crib or 216-Z-21 Basin but are now directed to the LLWTF and/or the TEDF. For discussions of the LLWTF and the TEDF, refer to Chapter 7.0. For discussions of wastewater streams, refer to Chapter 5.0.

3.5.3 Contaminant Transport Analysis

There are no normal or consequential off-normal radiological events caused by the PFP that would burden the groundwater. Laboratory sorption studies and the observed depth distribution of plutonium beneath various cribs, ditches, and ponds at the Hanford Site indicate that there is very little mobility in Hanford soils and sediments. However, mobile forms of plutonium have been reported at other DOE sites. Infrequent and low amounts of precipitation, the fact that the majority of plutonium is in a dry powder form, and the hazardous spill reporting and cleanup policies of the Hanford contractors toward plutonium spills, reduces the probability of current releases of plutonium from reaching the groundwater.

Kasper describes the distribution of plutonium in sediments beneath the 216-Z-12 Crib, which was used to support operations at the PFP (Kasper 1982). Plutonium activity decreased rapidly with depth, and was essentially equal to background (less than 1 ρCi/g) at 10 m (about 30 ft) below the crib. Groundwater in nearby wells showed no detectable alpha activity (less than 0.017 ρCi/mL). If plutonium from the PFP were spilled on the ground, the contaminated soil would be removed and taken to an appropriate disposal site. Soil removal is the standard decontamination procedure for such spills.

Spills of hazardous materials, such as coolants and acids, may occur at the PFP, however, these spills can be minimized by operator or maintenance personnel actions. These spills also would be removed with contaminated soil. Implementation of the hazardous spill reporting and cleanup policies of the Hanford contractors inhibits spills of small volumes of hazardous materials from affecting groundwater. Solid Waste Handling Operations personnel are trained and responsible for hazardous spill cleanup involving such things as coolants and acids. Reporting requirements for spills are followed in accordance with DOE Orders 232.1 (DOE 1995b) and 5400.1 (DOE 1990), and

Reporting Occurrences and Processing Operations Information, HNF-PRO-060, and *Identifying and Resolving Unreviewed Safety Questions*, HNF-PRO-062.

3.6 GEOLOGY AND SEISMOLOGY

3.6.1 Basic Geologic and Seismic Information

The geology of the Hanford Site region is well documented (Supply System 1981; JABE 1970, 1971; DOE 1988; NRC 1982c). The PFP site is located on the glaciofluvial deposits at an elevation of 676 ft above msl. The glaciofluvial deposits at the PFP site are underlain by sediment of the Ringold Formation from about 550 ft above msl to basalt at about 125 ft above msl.

The thickness of the basalt exceeds 10,000 ft on Rattlesnake Mountain; however, the total thickness at the PFP site is unknown but assumed to be roughly the same.

Seismic investigations and evaluations for the PFP and other Hanford Site activities have been summarized and reported by John A. Blume and Associates (JABE 1970) and others (Supply System 1981, Rockwell 1979b).

Two of the largest historical earthquakes in the region were the Umatilla, Oregon, earthquake in 1893, with estimated Modified Mercalli (MM) intensity VII, located 33 mi southeast of the Hanford Site, and the Milton-Freewater, Oregon, earthquake of 1936, with estimated MM intensity VII, located 57 mi southeast of the Hanford Site (JABE 1970). Calculations indicate that the Umatilla earthquake produced a maximum ground acceleration of approximately 0.03 g at the Hanford Site (JABE 1970).

A large earthquake that reportedly occurred on December 15, 1872, in the Northern Cascades-Okanogan area was the subject of a detailed investigation by the Supply System (Supply System 1977a). The results of the investigation did not pinpoint the epicenter but located it in the Northern Cascades-Okanogan area, over 94 mi from the PFP site. The earthquake was estimated to be at an MM intensity VIII, which was estimated to have produced an MM intensity at the PFP site of IV to V.

The primary earthquake-generating structures considered to be capable are the Rattlesnake-Wallula Alignment and the Gable Mountain/Gable Butte structure (Section 3.6.1.2.1).

Evaluation of the earthquake frequency and magnitude data presented within this chapter resulted in the design response spectra presented in the site-wide standard, SDC 4.1, Revision 12, *Standard Design Criteria Architectural-Civil, Design Loads for Facilities* (DOE-RL 1993). The design response spectra for the design-basis earthquake (DBE) is then applied to the design of safety class and safety significant SSCs. See Chapter 4.0, Section 4.2.5, for detailed discussions of the seismic design criteria.

3.6.1.1 Local Topography. Contours within a 50-mi radius of the PFP are shown in Figure 3-28. The topography around the PFP basically slopes downward to

the north, south, and west and slopes slightly up to the east. Cross sections showing profiles of the ground surface are presented in Figure 3-29.

3.6.1.2 Regional Geology. The Hanford Site is situated within the Columbia Plateau physiographic province, characterized by the occurrence of a thick sequence of tholeitic basalts varying significantly in topographic expression as well as structure. The Columbia Plateau physiographic province is bordered by the Northern Rocky Mountains physiographic province to the north and east, the Basin and Range physiographic province to the south, and the Cascade physiographic province to the west (Figure 3-30).

The regional geology is dominated by Cenozoic volcanic rocks and structures. A generalized geologic map of the region is shown in Figure 3-31. A regional tectonic map is shown in Figure 3-32. The major regional geologic provinces are described in the following subsections.

3.6.1.2.1 Columbia Plateau Physiographic Province. The Columbia Plateau physiographic province can be subdivided into several smaller physiographic subprovinces: Columbia Basin subprovince (sometimes referred to as the Columbia Plateau), the Blue Mountains subprovince, and the Harney-Snake River Plateau subprovince (Dowden et al. 1975).

Columbia Basin Subprovince. The interior lowland portion of the Columbia Plateau, represented by a broad geologic and structural basin, is referred to as the Columbia Basin physiographic subprovince.

The major topographic relief forms are several east-to-southeast-trending ridges on the western side. The Frenchman Hills, Saddle Mountains, Horse Heaven Hills, Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge are surface expressions of anticlinal folds of Tertiary Columbia River basalts and sedimentary interbeds. Within the Hanford Site, Rattlesnake Mountain, Yakima Ridge, and Umtanum-Gable Mountain Ridge represent an eastward-to-southeastward continuation of the ridge system.

The PFP is in the Pasco Basin, one of several structural subbasins within the Columbia Basin (Figure 3-33). The Columbia Basin contains the Channeled Scablands formed during Pleistocene glaciation.

The Cordilleran Ice Sheet extended into northern Washington, but its maximum extent was north of the Hanford Site. Ice-dammed lakes formed in northern Idaho and western Montana when ice lobes filled major drainage valleys. The failure of these dams resulted in multiple, catastrophic flood as the water spilled across the Columbia Basin subprovince. Maximum discharge through scabland channels has been estimated to be as much as 7.52×10^6 ft^3/s (USGS 1973). These floods eroded the basalt, Ringold and Palouse Formations, forming large coulees and thick sequences of glaciofluvial sediments (Washington 1959).

The Columbia Basin is a broad structural basin that was downwarped while lavas were periodically being extruded. The region continued to deform, forming anticlinal ridges. The Columbia Basin contains a thick sequence of Miocene basalt flows with intercalated sedimentary interbeds overlain by Pliocene-Pleistocene lacustrine and fluvial sediments, Pleistocene glaciofluvial sediments, and Holocene alluvium, colluvium, and eolian deposits.

The eastern portion of the Columbia Basin consists of rolling hills mantled by the Palouse loess derived from degradation of Quaternary sediments from the west-southwest and northwest.

The Columbia Basin subprovince is drained by three major rivers: the Yakima River and its tributaries drain the southwestern portion, the Columbia River and its tributaries drain the central and northern portion, and the Snake River and its tributaries drain the southeastern portion.

Blue Mountains Subprovince. The Blue, Ochoco, and Wallowa Mountains all occur in this subprovince and contain elevated plateau basalts similar to those of the Columbia Basin, as well as older rocks that have become exposed by erosion. Alpine glaciers were present in the Wallowa Mountains during the Pleistocene.

The structure and topography of this subprovince, which lies mostly in northeastern Oregon, have more in common with the Northern Rocky Mountains physiographic province than with the Columbia Basin subprovince. The mountains rise above the Columbia Basin subprovince to the north and the Harney-Snake River Plateau subprovince to the south. The Snake River crosses the eastern portion through deeply entrenched gorges. The eastern portion is bordered by the Idaho Batholith subprovince of the larger Northern Rocky Mountains physiographic province.

The Blue Mountains subprovince is a northeasterly trending complex of deformed Paleozoic and Mesozoic sediments and intrusive Cenozoic rocks that lie south of the Columbia Basin subprovince. The structure generally is described as an asymmetric anticline with a steep northern flank and gently dipping southern flank. Some of the region is covered with basalt that has been elevated and deformed by continued orogenic activity. Resulting erosion has stripped much of the younger basalts and exposed Paleozoic and Mesozoic rock not found in the Columbia Basin. The present topography is a result of major Pliocene deformation and Quaternary erosion.

Harney-Snake River Plateau Subprovince. The Harney region lies south of the Blue Mountains and is a high plain with little local relief, except for volcanic craters that are mostly Quaternary in age. Internal drainage is characteristic of this region.

This region extends from the Cascades to the Steens Mountains in southern Oregon. It is similar to the Columbia Basin in that it is dominated by basalt flows and sedimentary interbeds. The region lacks the fluvial and eolian overburden found in the Columbia Basin.

The Snake River Plateau region lies beyond the 200-mi radius.

3.6.1.2.2 Northern Rocky Mountains Physiographic Province. The Northern Rocky Mountains are subdivided into the Okanogan Highlands subprovince, the Idaho-Montana Rocky Mountains subprovince, and the Idaho Batholith subprovince.

Okanogan Highlands Subprovince. This subprovince lies north of the Columbia Basin subprovince of the Columbia Plateau. The southern boundary is where the Columbia River Basalt laps onto the highlands. It is made up of north-south-trending mountains between the Cascade Mountain Range

physiographic province to the west and the Idaho-Montana section of the Northern Rocky Mountains physiographic province to the east. The region slopes toward the south with stream drainage into the Columbia Basin. The Okanogan Highlands molded by Pleistocene glaciation have been highly dissected by fluvial erosion.

This subprovince can be divided into two geologic regions (USGS 1970). East of the Columbia Basin the region is composed of Precambrian Beltean rocks and lower Paleozoic rock primarily composed of quartzite, phyllites, and carbonates. This portion of the highlands has been folded and faulted during several periods of deformation and was intruded by granitic intrusions of British Columbia. The folds of this belt are cut by pre-Tertiary faults.

The area west of the Columbia River is composed of graywacke, greenstone, slate, chert, conglomerates, and limestone. The sediments have been intruded by late Mesozoic quartz monzonites and granodiorites. Tertiary volcanic rock uncharacteristically caps the older rocks. The western portion contains north-south-trending, high-angle, normal faults that have preserved the Tertiary rocks by downfaulting into older crystalline rocks.

Idaho-Montana Rocky Mountains Subprovince. The mountains of this subprovince of the Northern Rocky Mountains physiographic province have a north-northwest fabric and are drained by the Clark Fork River, Kootenai River, Pend Oreille River, and other tributaries of the Columbia River. The subprovince was glaciated by both continental and alpine glaciers. The flood waters that formed the Channeled Scablands of the Columbia Basin had their origin here when ice blockage formed the glacial Lake Missoula.

This subprovince is northeast of the Columbia Basin and primarily consists of an extensive segment of Precambrian crystalline and sedimentary rocks. The dominant rock types are quartzites, slates, and argillites of the Belt Supergroup. Major deformation and mountain building took place during the Mesozoic.

Idaho Batholith Subprovince. This subprovince of the Northern Rocky Mountains province lies east of the Blue Mountains and is drained by the Salmon and Clearwater Rivers, which flow into the Snake River.

The area lies southeast of the Columbia Basin and south of the Idaho-Montana Northern Rocky Mountains. The most prominent rock types are quartz monzonites and granodiorites with some granites. The main batholithic intrusion took place during the Cretaceous Period.

3.6.1.2.3 Cascade Mountain Range Physiographic Province. The Cascade Mountain Range is bordered by the Columbia Plateau and Northern Rocky Mountains physiographic provinces on the east and the Pacific Border physiographic province on the west. This province is divided into two subprovinces, the Northern and the Central, shown in Figure 3-30. In Washington State, the northern part of the range is referred to as the Northern Cascade Mountain Range. In Oregon, the Cascades are divided into the Western Cascade Mountain Range and the High Cascade Mountain Range, which extends into Washington State. Prominent Quaternary stratovolcanos of the High Cascades are Mt. Hood, Mt. Rainier, Mt. Adams, and Mt. St. Helens. Many glaciers are present on the high peaks of the Cascades. The Columbia River cuts across the Cascade Mountain Range at the Washington-Oregon border.

This north-south trending morphologic geotectonic unit extends from southern British Columbia to northern California along the western boundary of the Columbia Basin. The broad up-arching occurred normal to a north-south axis during late Pliocene and early Pleistocene time. The uplift increased to the north, reached a maximum in the North Cascade near the Canadian border, and decreased to the south. Quaternary volcanic activity has built large stratovolcanic cones that dominate the southern portion of the range and decrease in number to the north. The High Cascades of Oregon and Washington States are composed of coalescing Pliocene shield volcanoes capped with Quaternary stratovolcanos. The Western Cascades of Oregon extend the length of Oregon and into southern Washington State and are composed of slightly to moderately deformed rocks of Eocene through Miocene age. The Northern Cascades include the part of the range north of Snoqualamie Pass and are dominated by pre-Cenozoic igneous and metamorphic rocks.

The geology of the North Cascades is strongly influenced by large, steeply dipping faults of late Mesozoic, early Cenozoic age. The crystalline core is composed of deformed schists and gneisses and is flanked by younger sedimentary and volcanic rocks. In general, the oldest rocks are the most strongly deformed.

3.6.1.2.4 Pacific Border Physiographic Province. The Pacific Border physiographic province (USGS 1970) includes the Puget Sound-Willamette Lowlands, the Coast Range, and the Olympic Mountains subprovinces.

Puget Sound-Willamette Lowlands Subprovince. This lowlands subprovince extends from Eugene, Oregon, to Vancouver, British Columbia. The northern part, which lies in general between the Cascade Mountain Range and the Olympic Mountains, was modified during the Pleistocene by the Puget Sound ice lobe. The southern portion of the Puget Sound-Willamette Lowlands is drained by the Willamette River and contains fluvial and glaciofluvial valley fill.

The structure of this subprovince is a broad downwarp with transverse-trending faults and folds. Rock outcrops are closely related to the Tertiary rocks of the nearby Cascade and Coast Range Provinces. The lowland contains thick deposits of Quaternary fill.

Olympic Mountains Subprovince. Included in this subprovince are the Olympic Mountains of Washington State. The Olympics are higher, wider, and more rugged than the Oregon Coast Range, and many alpine glaciers are found there.

Coast Range Subprovince. The Coast Range extends about 600 mi along the Pacific Coast of Washington and Oregon. The anticlinorium in the Coast Range south of the Olympic Mountains is Miocene and Pliocene in age.

The Coast Range of Washington and Oregon extends about 600 mi from the Klamath Mountains of southwestern Oregon to the Olympic Mountains west of the Strait of Juan de Fuca in northwestern Washington. Tertiary eugeosynclinal sediments are exposed in the core of the Olympic Mountains and the Coast Range, the oldest of which are low-grade metasediments, argillites, and graywackes. The flanks of the Olympics are made up of marine basalts and marine sedimentary rocks of Eocene and Miocene age. The anticlinorium in the Coast Range south of the Olympic Mountains is Miocene and Pliocene in age.

3.6.1.3 Hanford Site Geology. The Hanford Site is located in the Pasco Basin, a structural and topographical depression within the Columbia Plateau. The terrain of the central and eastern parts of the site is relatively flat. The central part of the Hanford Site, including the 200 East and West Areas plateau, has undergone minimal erosion since deposition of the Hanford Formation sediments by glacial flood waters about 13,000 yr ago.

The Pasco Basin (Figure 3-17) is one of several structural and topographic basins within the western Columbia Plateau. The Pasco Basin is partly surrounded by large anticlinal ridges (the Yakima Folds) that developed during Miocene and Pliocene time. The Saddle Mountains form the northern boundary of the Pasco Basin; Umtanum Ridge and Yakima Ridge form the western boundary; Rattlesnake Hills and Horse Heaven Hills form the southern boundary; and a broad zone of gradually increasing westward dip forms the eastern boundary. Umtanum Ridge and Yakima Ridge plunge eastward, decrease in relief, and die out within the basin interior (Rockwell 1979a).

The Pasco Basin occupies about 2,000 mi^2 between 46°00' and 45°50' N. latitude, and 119°00' and 120°20' W. longitude. It is a semiarid steppe with a sparse covering of vegetation, as described in Section 3.1.2. Detailed descriptions of the climate, soil, terrain, and other aspects of the geography of the basin are in reports that describe the Hanford Site environment (ERDA 1975; Rockwell 1978a; DOE 1986, 1988).

The Pasco Basin is underlain by a bedrock section of the Columbia River Basalt Group at least 4,800 ft thick and in places greater than 10,000 ft. This bedrock section is overlain by 0 to approximately 700 ft of fluvial, lacustrine, and glaciofluvial sediments of Pliocene and Pleistocene age, with the greater sediment thicknesses in the synclinal positions in the basin interior. Volcaniclastic sedimentary layers are interbedded between the basalt flow in the upperpart of the bedrock section. Many of the basalt flows throughout the bedrock section are apparently blanket-like and extend laterally as single rock-stratigraphic units (and time-stratigraphic units) across the Pasco Basin and beyond; other flows are less extensive, although still blanket-like, and pinch out within the basin. A few flows in the upperpart of the section were emplaced as valley fills and are restricted in their lateral extent (Rockwell 1979a).

Yakima Folds bound the Pasco Basin on the north and south and plunge eastward into the basin from the west (Figure 3-34). Structural deformation that formed the Yakima Folds was occurring during deposition of the anticlines are generally broad, open folds. Drill holes and geophysical surveys reveal that most subsurface structures in the central Pasco Basin appear to be extensions of the Yakima Folds and their associated second-order structures, but a few subsurface structures might be related to northwest-trending structures that appear to crosscut the east-west-trending Yakima Folds (Leonhart 1979).

3.6.1.3.1 Stratigraphy and Lithology. Five major basalt units underlie the Pasco Basin: Pre-Columbia River Basalt Group, Columbia River Basalt Group, Ellensburg Formation, Ringold Formation (including the Palouse Soil), and Hanford Formation. These major rock units are locally mantled by surficial sediments. All major rock units crop out within the Pasco Basin except for Pre-Columbia River Basalt Group rocks, although they are partially penetrated in borehole RSH-1 at depths below about 4,000 ft. Formal rock

stratigraphic nomenclature used in the Pasco Basin is shown in Table 3-14 (Rockwell 1979a). The surface of the basalt is given in Figure 3-34 (Rockwell 1979b). Generalized geologic cross sections of the Pasco Basin are given in Figure 3-35.

No subbasalt rocks are exposed within the Pasco Basin so knowledge of subbasalt rocks is limited to studies along the margin of the Columbia Plateau as well as a few deep boreholes and surveys of the interior (DOE 1988). Rock types, of varying ages, surround the plateau. These subbasalt units are inferred to represent possible correlative sequences of sedimentary and volcaniclastic rock beneath the Columbia River Basalt. Recent reports (DOE 1988) estimate that Pasco Basin basalt is greater than 10,000 ft thick, subbasalt sedimentary rock is about 20,000 ft thick, and basement rock is about 6 mi deep.

1. Pre-Columbia River Basalt Group Rocks--The deep-seated, crustal rocks of the Pre-Columbia River Basalt Group are interpreted from geophysical data and from one deep borehole. The geophysical techniques included an unreversed, north-south refraction profile across eastern Washington, seismic modeling (USGS 1978), and magnetotelluric surveys (Rockwell 1979b). The borehole data are from RSH-1 drilled by Standard Oil Company of California on the south slope of Rattlesnake Mountain.

   Results from these surveys and borehole data indicate a deep-seated crystalline basement, possibly of granite origin, overlain by a 3,000- to 6,000-ft-thick section of sedimentary rocks. A volcanic rock sequence is interpreted to overlie the sedimentary rocks (Rockwell 1979a).

2. Columbia River Basalt Group Rocks--Lavas of the Columbia River Basalt Group on the Columbia Plateau (Figure 3-17) comprise a tholeitic flood-basalt province of moderate size covering an area of about 63,000 mi^2 and having an estimated volume of about 41,000 mi^3 (DOE 1988). The plateau is both a structural and topographic depression with its lowest elevation in the center of the province, the approximate location of the Pasco Basin (see Figures 3-30 and 3-35). Here, the accumulation of flows of the Columbia River Basalt Group and interbedded sediments attain their maximum known thickness (DOE 1986).

   The Columbia Plateau is the Earth's youngest recognized flood-basalt province. It was formed between 16,500,000 and 6,000,000 yr ago (American Journal of Science 1974; USGS 1977b), when large volumes of lava were erupted from north-northwest-trending linear vent systems now preserved as dikes (American Journal of Science 1961). Individual Columbia River basalt flows are voluminous, generally 2 to 6 mi^3, with a maximum known volume of 145 mi^3. Flows range in thickness from a few inches to about 300 ft, with an average thickness of 90 to 120 ft. The thickest flows are generally caused by ponding in pre-basalt valleys, in structurally controlled basins that developed during volcanism, or in narrow canyons previously eroded into older flows (Rockwell 1980).

The Columbia River Basalt Group in the Pasco Basin consists of three formations: Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt (Figure 3-17). Detailed reports of the stratigraphic and lithologic descriptions of the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt are found in (Rockwell 1979a) and (Swanson et al. 1979).

3. Ellensburg Formation--Within the upperpart of the basalt sequence, sedimentary materials are increasingly prevalent upward, beginning with Vantage sandstone (Rockwell 1979a). These volcaniclastic materials include tufts and tufaceous sediments of many kinds, now partly altered to clay. Virtually every basalt flow above the Vantage sandstone horizon is capped at one site or another by stream-deposited sediments. The extent and thickness of these interbedded sediments generally increase upward in the section and are more extensive in the western portion of the Columbia Plateau. The lower beds tend toward rock types common to the Okanogan Highlands, southern British Columbia, and the North Cascades. The upper beds show an increasing abundance of volcanic debris, referred to as the Ellensburg Formation.

   Approximately 15,000,000 yr ago, the ancestral Columbia River was crossing central Washington, laying down trains of gravel, sands, silts, and clays comparable to today's Columbia River sediments. As the basalt flows advanced upon the river, it returned by gravity to the basin center, leaving its sediment trains as a mark of earlier courses. East of the current course, river sediments are virtually nonexistent between basalt flows, attesting to the shift exclusively westward from the current basin center.

4. Ringold Formation--The Ringold Formation was deposited in response to a flattening of the gradient of the Columbia River, perhaps related to the uplift of the Horse Heaven Hills, and consequent deposition of the sediments carried. Previously, deformation of the basin was accompanied by basalt flow extrusion into the topographically low areas. Cessation of flows about 6,000,000 yr ago permitted the deposition of a continuous sequence of sediments. Initially, these were blends of upriver rock types derived from the North Cascades and the Okanogan Highlands, with volcanic debris, largely of andesitic composition, from the central and southern Cascades. These latter sediments were transported to the Pasco Basin by the ancestral Yakima and related rivers. With time, the composition of the sediments being deposited in the Pasco Basin became more and more that of the Okanogan rock type.

   The beginning of anticlinal uplift, especially to the west and slightly before the eruptions of the latest basalt flows, locked the Columbia River into the Pasco Basin and halted the east-to-west migration. Somewhat later, uplift of the Horse Heaven Hills resulted in a continuously rising base level for the river and the deposition of sediment.

   The Ringold Formation ranges in thickness from about 350 to 700 ft and is subdivided into four units, principally on the basis of

texture (DOE 1988). These units are the basal Ringold unit and the lower, middle, and upper units.

These fine-grained sediments are considered to be the equivalent of the Palouse soils (loesses) of eastern Washington and western Idaho. The climate during the period was probably comparable to that of today, with effective wind transport and deposition of sediment (General Electric 1970).

5. Plio-Pleistocene Unit--This is a locally derived unit, probably of early Pleistocene or latest Pliocene age, overlying the Ringold Formation over much of the western Pasco Basin. The Plio-Pleistocene unit appears to correlate with other widestream alluvial sequences present near the base of the basaltic ridges that bound the Pasco Basin on the north, west, and south (DOE 1988).

6. Early "Palouse" Soil--Overlying the Plio-Pleistocene unit is a fine-grained, sand-to-silt unit of mostly eolian origin, differentiated from the overlying slack water flood deposits (DOE 1988).

7. Hanford Formation--The Ringold Formation and the basalts and sedimentary interbeds were eroded and truncated by normal flow of the Columbia River and by multiple floods that occurred when ice dams breached during the Pleistocene. These ice-dammed glacial lakes released catastrophic torrents. The floods scoured the land surface of the Hanford Site, leaving a network of buried channels filled with the outwash and gravel.

   The glaciofluvial sediments were deposited in the Pasco Basin on the basalt and Ringold Formation. These sediments can be divided into the coarser sands, gravel, and boulders and are referred to as the Pasco Gravel; the fine-grained sand and silt units are called the Touchet Beds.

   The Touchet Beds represent low-energy deposits in glacial Lake Lewis, which formed when flood waters were backed up behind the Wallula Gap constriction. The Pasco Gravel represent higher energy deposition in areas of more rapid water flow. In general, the Touchet Beds are found in the margins of the basin and the Pasco Gravel in and near the center of the basin. The characteristic variability of sediment size and degree of sorting within the "gravel" unit can be attributed to changes in water velocity and water level that occurred during the flooding process. The thickness of the Hanford Formation varies significantly within the basin, with the thickest occurrence in the region of buried channels.

8. Volcanic Ash Deposits--Several volcanic ashfalls were deposited in the late Pleistocene and Holocene over the Pasco Basin sediments. The thin, widespread ash associated with the last major ashfall was identified as the Mt. St. Helens Set S (USGS 1977a) and dated by radiocarbon at 13,000 yr before present (BP). Younger ash, such as that from Mt. Mazama (6,600 yr BP) and Glacier Peak (12,000 yr BP), has been found in the basin where the environment was favorable for preservation. The latest ashfall to be deposited in the Pasco Basin

is from the May 18, 1980, eruption of Mt. St. Helens and is discussed in Section 3.6.6.

9. Eolian Deposits--Loess and sand dunes mantle the surface of the Pasco Basin. These deposits are primarily reworked sediments of the Hanford Formation. The thickness of the windblown sediments varies considerably, ranging to greater than 50 ft in some dunes.

3.6.1.3.2 Geologic Features of the Pasco Basin. The Pasco Basin is defined on the north by the Saddle Mountains, on the south by the Rattlesnake Hills and Rattlesnake-Wallula Alignment, on the east as the junction between the Yakima Fold Belt and Palouse subprovinces (which generally coincides with the Ice Harbor dike system and Jackass anticline/monocline) and on the west by the Hog Ranch-Naneum Ridge anticline. An index map to the structural features is presented in Figure 3-36.

Summaries of the geologic mapping that has been conducted in the Pasco Basin and adjacent regions can be found in reports published by the Supply System and Rockwell (Supply System 1981, Rockwell 1979a).

1. Anticlinal Features

- Saddle Mountains--The Saddle Mountains is a broad anticlinal uplift that trends generally east-west for 68 mi and forms the northern boundary of the Pasco Basin. Two dominant structural features associated with the Saddle Mountains are the Saddle Mountains anticline and the Saddle Mountains fault, although the complex geometry of the anticline has resulted in other secondary anticlines, synclines, and monoclines that parallel the main trend of the structure. The Saddle Mountains fault is either a reverse or thrust fault that has an unknown dip angle. Although the fault generally parallels the Saddle Mountains anticline, it does not appear to have the same length and may not extend east of Smyrna Bench. At least 1.9 mi of crustal shortening resulting from horizontal compression has been measured on the Saddle Mountains fault on the west side of Sentinel Gap.

- Umtanum Ridge--The Umtanum Ridge-Gable Mountain structural trend is a segmented anticlinal ridge extending for a length of 85 mi in an east-west direction. This structure consists of five segments defined on the basis of changes in style of deformation and orientation of fold segments. From the west, Umtanum Ridge can be divided into three segments, the easternmost segment of these three segments plunging eastward and joining the fourth segment, the Gable Mountain-Gable Butte structure, just east of the western boundary of the Hanford Site and south of the Vernita Bridge. The fifth segment, the Southeast Anticline segment, trends southeast off the eastern boundary of the Gable Mountain-Gable Butte segment. The Gable Mountain-Gable Butte and Southeast anticline segments have considerably less structural relief than the Umtanum Ridge structural segments.

- Umtanum Ridge Segments--The three Umtanum Ridge segments trend for about 50 mi in a northwesterly direction. In general, Umtanum Ridge is an asymmetrical, north vergent to locally overturned, anticline with a major thrust to high-angle reverse fault on the north side. West of the Priest Rapids Dam site, the Umtanum fault may include as many as three imbricate thrust slices in which the basalt is folded, overturned, and faulted over the relatively undeformed Mabton interbed. The Umtanum fault juxtaposes vertical Frenchman Springs flows over nearly horizontal Priest Rapids flows. Results from drilling suggest that this fault dips southward under the ridge at 30° to 40° although it could be as high as 60°. Continuity of the fault eastward toward Gable Mountain cannot be established by exposure; however, decreasing structural relief suggests that fault displacement also decreases. The Umtanum fault is interpreted to die out 7 mi east of Priest Rapids Dam.

- Gable Butte-Gable Mountain Segment--Gable Mountain and Gable Butte are two topographically isolated, anticlinal ridges that provide the only extensive outcrops in the central Pasco Basin. Gable Mountain and Gable Butte are composed of a series of northwest trending, doubly plunging, in echelon anticlines, synclines, and associated faults. The folds are second-order folds within the closure of the first-order Umtanum Ridge anticline. Faults have been mapped on Gable Mountain.

- Yakima Ridge--The Yakima Ridge uplift extends from west of Yakima, Washington, to the center of the Pasco Basin, where it forms the southern boundary of the Cold Creek syncline. The eastern most surface expression of the Yakima Ridge uplift is represented by an anticline that plunges eastward into the Pasco Basin. A north-dipping reverse fault occurs south of the main ridge along the southeastern end of the exposed part of Yakima Ridge. The reverse fault parallels the main trend of Yakima Ridge.

  The eastern extension of Yakima Ridge occurs beneath supra-basalt sediments with only a few exposures. There are two predominant trends in the potential-field data over the buried part of the structure: a northwest and an east-west trend. The east-west trend coincides with the subsurface extension of Yakima Ridge and is interpreted to be a westerly plunging anticline that has had little erosional modification. The northwest trend is smaller in scale and does not appear to be related to the larger features. It appears more likely to be related to cross folds or cross faults on Yakima Ridge. A fault in the Frenchman Springs Member of the Columbia River basalt was penetrated in a borehole along one of the northwest trending potential-field anomalies.

- Rattlesnake Hills--The Rattlesnake Hills uplift, in conjunction with the Rattlesnake-Wallula alignment, forms the southern boundary of the Pasco Basin. The Rattlesnake Hills extend from near Yakima, Washington, on their west end, easterly to Snively Basin, where they abruptly terminate against the Rattlesnake-

Wallula alignment. The Rattlesnake Hills uplift is an asymmetrical anticline that has been faulted. It has a steeply dipping north limb and more gently dipping south limb. At the eastern end of the Rattlesnake Hills is Snively Basin. The fold geometry of Snively Basin is more complex than any other Yakima Fold. Several thrust faults are present that may connect with faults associated with Rattlesnake Mountain.

- The Rattlesnake-Wallula Alignment--The Rattlesnake-Wallula Alignment is composed of two structural elements in the Pasco Basin: the Rattlesnake Mountain uplift and "The Rattles." The southeastern extension of this alignment is the Wallula Fault Zone. The Rattlesnake-Wallula Alignment is the southeastern part of the Cle Elum-Wallula disturbed zone.

- Rattlesnake Mountain--Rattlesnake Mountain forms the northwestern part of the Rattlesnake-Wallula Alignment in the Pasco Basin. The geometry of the structures associated with the Rattlesnake-Wallula Alignment are asymmetrical, anticlinal ridges that have high-angle reverse or thrust faults along their steep northern flanks. Several faults are associated with Rattlesnake Mountain, including the Rattlesnake Mountain Fault Zone. The Rattlesnake Mountain Fault Zone consists of at least two faults that lie along the northeast flank of Rattlesnake Mountain within and parallel to the hinge area of the Rattlesnake Mountain anticline.

- The Rattles--A series of anticlines that extend southeast of Rattlesnake Mountain along the Rattlesnake-Wallula alignment are informally referred to as "The Rattles." They include Red Mountain and Badger Mountain and merge with the eastern segment of the Horse Heaven Hills near Wallula Gap. At the gap, their trend merges with the Wallula Fault Zone. Faults subparallel to the northwest trend of these ridges are found along some of the hills.

- Wallula Fault Zone--The Wallula Fault Zone extends from the eastern limit of "The Rattles," near Wallula Gap, southeastward along the north side of the Horse Heaven Hills to the vicinity of Milton-Freewater, Oregon, where the zone intersects the Blue Mountains. The zone is up to 1,080 ft wide and contains brecciated basalt and clay gouge. The fault dips steeply to the south. The fault is a reverse or oblique-slip fault, youngest movement of which was dominantly right lateral. The age of faulting on the Wallula Fault near Warm Springs Canyon in Oregon has been postulated as Quaternary. Tectonic breccias are overlain by undisturbed late Plesitocene Touchet Beds (approximate age 13,000 yr) and loess. Data from trenching support an interpretation that faulting may be as young as Quaternary, but older than glaciofluvial Touchet Beds (Woodward-Clyde Consultants 1981). Trenches across the Wallula Fault were also studied (Gardner et al. 1981). They found that faulted basalt of the Ice Harbor Member is overlain by undisturbed glaciofluvial gravels and Touchet Beds, leading to the conclusion that the last fault movement took place between

Ice Harbor time (8.5 M yr BP) and the latest cataclysmic flooding (13,000 yr BP).

2. Synclinal Features

   - Pasco Syncline--The Pasco syncline is located in the southeastern part of the Pasco Basin. It is bounded by The Rattles of the Rattlesnake-Wallula Alignment on the south and by the Palouse Slope on the north and east. The syncline is a broad, gentle, low-amplitude, long-wavelength, northwest-trending fold. The Pasco syncline loses definition in the Wye Barricade depression, which is a relatively broad and flat structural depression.

   - Cold Creek Syncline--The Cold Creek syncline lies between the Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge uplift. The Cold Creek syncline is an asymmetric and relatively flat-bottomed structure. Its amplitude is greater and wavelength is shorter west of the Hanford Site. The Wye Barricade depression marks the southern extent of the Cold Creek syncline.

     The Yakima Barricade geophysical anomaly occurs on the west side of the Hanford Site on the south flank of the Cold Creek syncline. Two boreholes, drilled across the geophysical gradient, constrain its location and characteristics (boreholes DH-27 and DH-28) and indicate that the top of the Pomona Member (12 M yr BP) increases in elevation from about 70 ft on the east in borehole DH-28 to 234 ft on the west in borehole DH-27, suggesting 244 ft of relief over a relatively short distance of 2,600 ft.

     The overlying Elephant Mountain Member (10.5 M yr BP) apparently pinches out in an east-west direction across the feature. Relief on top of the basalt and lower Ringold unit is 145 ft and 100 ft, respectively. The top of the next younger unit, the middle Ringold, appears to be undeformed across the feature.

     The present data suggest that this feature is either a steeply dipping fold or a high-angle fault that formed during the late Miocene to early Pliocene. The top of the middle Ringold unit (age 5 M yr BP) appears undeformed, suggesting that vertical movement along this feature may have ended by late Pliocene.

3. Late Miocene to Pliocene Sedimentary Deposits--Suprabasalt sediments were deposited in most synclinal valleys of the Yakima Fold Belt and within other structural basins on the Columbia Plateau during the late Neogene (late Miocene to Pliocene time). Each synclinal basin on the Columbia Plateau is relatively unique compared to the other basins of the Plateau.

4. Quaternary Deformation--There is very little direct field evidence to indicate Quaternary deformation in the Columbia Plateau. Four areas of suspected Quaternary faulting have been documented: (1) the central Gable Mountain fault in the Pasco Basin, (2) the Toppenish Ridge fault in the Yakima Valley, (3) the Union Gap fault in Ahtanum Ridge, and (4) the Cle Elum-Wallula Alignment. The closest location to the PFP site is the central Gable Mountain. Evidence has been found that suggests Quaternary movement on the central Gable Mountain fault (see Section 3.6.2) (Puget Sound Power and Light Company 1982). This evidence includes faulting of glaciofluvial deposits, which were dated at 13,000 yr BP or older, and offsets of as much as 2.6 in.

   Fractures in these deposits are continuous with a reverse fault in the underlying Columbia River basalt along which progressively older units are increasingly offset. However, an alternative, nontectonic interpretation attributes the youngest observed offset to rapid hydrostatic loading and unloading that occurred during cataclysmic flooding (Puget Sound Power and Light Company 1982).

   A zone of nearly 100 surface ruptures on Toppenish Ridge is interpreted as representing late Quaternary tectonic deformation. These surface ruptures occur along a 20-mi portion of the ridge, between its crest and the base of its northern limb. The total width of the zone varies from 0.3 to 1.4 mi.

   Individual scarps are approximately parallel to the ridge trend, and range from 0.06 to 1.9 mi in length. Dip-slip separations on individual ruptures do not exceed 13 ft. Carbon-14 dates of organic material sampled from sag ponds associated with these fault zones are 505 ±160 yr and 620 ±135 yr.

   A third fault inferred to be of Quaternary age was exposed during highway construction near Union Gap, Washington, on Ahtanum Ridge. At this location, a high-angle reverse fault offsets Yakima River terrace gravels by at least 23 ft and results in the juxtaposition of the Ginkgo flow (Frenchman Springs Member, Wanapum Basalt) against the gravels (Supply System 1981). There is no reliable date for these terrace gravels, but it is believed that they are Pleistocene. The fault zone is capped by undeformed slack-water cataclysmic flood sediments dated elsewhere at 13,000 yr BP, indicating that the last movement of the fault occurred before that time.

   Evidence for Quaternary deformation has been reported for 14 localities either in or directly associated with the Cle Elum-Wallula disturbed zone (Supply System 1981). The areas closest to the Hanford Site include the following:

   1. Little Dry Creek fault south of Milton-Freewater, Oregon
   2. Buroker fault east of Milton-Freewater, Oregon
   3. Unnamed fault south of Umapine, Oregon
   4. Wallula Fault Zone east of Warm Springs Canyon, Oregon

5. Wallula Fault Zone near Wallula Gap, Washington
6. Wallula Fault Zone near Finley Quarry, Washington.

The last three localities lie along a 12-mi segment of the Wallula Fault Zone. No definitive evidence for Quaternary deformation has been reported northwest of the Finley Quarry location; however, the geomorphic expression and the continuity with the Wallula fault zone suggest Quaternary movement. The lack of evidence for Quaternary deformation farther northwestward along the Cle Elum-Wallula disturbed zone may result from the absence of a well-preserved stratigraphic record.

3.6.2 Vibratory Ground Motion

3.6.2.1 Geologic Conditions of the Site. The thick sequence of Columbia River Basalt masks the pre-basalt history of the Pasco Basin. The basalts are Miocene in age. An age of 6,500,000 to 16,500,000 yr has been inferred from radiogenic ages of basalts that crop out in the region (American Journal of Science 1974, USGS 1977b).

The Ringold Formation was deposited during Pliocene time. It was suggested that deposition continued into the Pleistocene, but later works (UW 1973) show evidence for termination of sedimentation in the latest Pliocene.

During the Pleistocene, glacial Lake Missoula floods scoured the area north and east of the Hanford Site, and glaciofluvial action put down thick deposits in the Pasco Basin.

3.6.2.2 Underlying Tectonic Structures. No unusual structures lie under the PFP site. The descriptions are given in Sections 3.6.1.1 and 3.6.1.2.

3.6.2.3 Behavior During Previous Earthquakes. Adverse behavior of the surficial geologic materials (i.e., soils) or the local bedrock during previous earthquakes has not been reported. A review of isoseismal maps indicates that ground motion corresponding to an earthquake of MM intensity VI is the largest projected (i.e., extrapolated) to have been felt at the Hanford Site (Supply System 1974). Such motion is perceptible but generally causes no adverse behavior of natural geologic materials.

3.6.2.4 Engineering Properties of Underlying Materials. The PFP is founded on glaciofluvial, medium-to-coarse sand and gravelly coarse sand known locally as the Hanford formation. This material is essentially dry, containing 2% moisture by weight--well above the water table--and about 120 ft thick (Tallman et al. 1979). Underlying the Hanford Formation is a sequence of sandy gravel and gravelly coarse sand that is part of the Ringold Formation. Ringold sediments overlie basalts and sedimentary interbeds of the Columbia River Basalt Group and Ellensburg Formation.

3.6.2.5 Earthquake History. The Columbia Basin, including the smaller structural unit, the Pasco Basin, is an area of low seismicity in which moderate level earthquakes (MM intensity less than or equal to VII) have occurred. While the historical record of earthquakes is relatively brief, it is sufficiently long to indicate that this area of eastern Washington

has experienced fewer earthquakes and of generally lower level than areas in the Puget Sound-Willamette Lowlands of western Washington or the Rocky Mountains. The Pasco Basin contrasts markedly with zones of higher seismicity to the west and east. A summary of eastern Washington earthquakes is presented in Tables 3-15a and 3-15b. These earthquakes attenuated rapidly eastward, so that the maximum known MM intensity in the vicinity of the Hanford Site was less than or equal to IV (Supply System 1981, DOE 1988, Weston 1977, UW 1992, UW 1993, UW 1994, UW 1995).

A network of seismographs was established in eastern Washington and has been operational since March 1969. Without this dense network of recorders, most events that have been recorded would have gone undetected. Some spatially and temporally restricted earthquake swarms have been felt, but the distribution of earthquakes generally indicates that stress is low, infrequent, and not concentrated in planar zones suggestive of discrete fault activity.

A large earthquake occurred at about 10:40 p.m. (universal time) on December 15, 1872, in a sparsely populated area of northern Washington and southern British Columbia. Because of scarce data, details of this earthquake are not well established. Research was conducted (Supply System 1977a) to determine the epicenter and epicentral intensity of this earthquake, along with any possible relationship to the geologic structure. This research was undertaken in the preparation of preliminary safety analysis reports and amendments thereto for several commercial light-water reactor units to be located on the Hanford Site. The research included detailed geologic mapping in the epicentral area, as well as in the region, analysis of imagery, compilation and review of contemporary accounts of this earthquake, geophysical investigations, development of a plate tectonic model for the Pacific Northwest, and analysis of both macroearthquakes and microearthquakes (Supply System 1977a, 1977b; Shannon and Wilson 1977b; Weston 1977).

Because the December 15, 1872, earthquake is of potential significance to the proposed Hanford Site nuclear generating stations, a number of hearings and reviews were conducted following submittal of a geologic evaluation on structures in the Columbia Plateau (Shannon and Wilson 1977a). Joint hearings involving members of the Supply System, Portland General Electric, Puget Sound Power and Light, the NRC Advisory Committee on Reactor Safeguards, and the U.S. Geological Survey (USGS) were conducted. As a result of these meetings and reviews of new information on the 1872 earthquake, the USGS and the NRC reevaluated the geology and seismology pursuant to the design of these proposed nuclear facilities. The USGS concluded that: (1) the 1872 earthquake was probably of MM intensity IX because of the numerous landslides reported; (2) an earthquake similar to the 1872 event will not occur in the Columbia Plateau but could occur along the northern margins of the plateau; and, (3) a 0.25g zero-period horizontal ground acceleration was appropriate for design of the Supply System WNP-1 and WNP-4 nuclear power plants.

The NRC concluded that: (1) the Columbia Plateau is a unique tectonic province within the context of ERDA (1975) and is distinct from the area in which the 1872 earthquake occurred; (2) an event similar to the 1872 earthquake need not be considered near Supply System WNP-1 and WNP-4; (3) a zero-period horizontal ground acceleration of 0.25g was appropriate for design of WNP-1 and WNP-4, as stated in the safety evaluation report (NRC 1975); and (4) the 1872 earthquake should be considered a "strong MM intensity VIII," based

on the absence of evidence, other than landslides (which have occurred at much lower intensities).

While many details relating to the 1872 event remain uncertain, the recent investigations indicate that this event was generated at least 140 mi northwest of the Hanford Site in a sparsely populated area that is geologically different from the Columbia Basin. The epicentral intensity was probably MM VIII, but the Hanford Site apparently experienced effects corresponding to a maximum MM VI (NRC 1975). Geologic investigations indicate that surface faulting apparently did not occur during this earthquake. Therefore, the potential for recurrence of a similar-sized event and the potential for surface faulting during an earthquake in the Columbia Basin seem low.

3.6.2.6 Correlation of Epicenters with Geologic Structures. No well-defined relationship exists between macroseismicity and geologic structure in the Columbia Basin or anywhere in the region of the Hanford site.

The July 16, 1936, MM VII Milton-Freewater earthquake occurred 30 mi east of the area where the extensions of the northwest trending Horse Heaven Hills and Rattlesnake-Wallula structures merge, along with the projected extension of the Wallula Gap fault. The northeast trending Hite fault also occurs in this area. Ground rupture was reported in the epicentral area and near Wallula Gap. Both areas are underlain by thick sequences of unconsolidated sediments. The nature of these reports suggests nontectonic deformation, especially along the edges of slopes artificially excavated for a highway and a railroad. Several aftershocks of this earthquake suggest that the plane of rupture was oriented northeast, an alignment that agrees with that of the Hite fault and the Blue Mountains anticline. The sensed area and isoseismals also display an elongation in a northeasterly direction (Supply System 1974). It is not certain whether this earthquake occurred along any of the mapped structures in the area. Since it is the only recorded MM intensity VII or greater earthquake within a 72-mi radius of the Hanford Site, it is unique.

With one exception, neither macroearthquakes nor microearthquakes appear to align along any of the northwest trending zones of steep slope on the north sides of these anticlines. The MM V-VI earthquake on November 1, 1918, near the town of Corfu, Washington, apparently occurred in a position to the north of the Saddle Mountains anticlinal axis (Supply System 1981).

Microearthquake activity that has been monitored continuously in the Columbia Basin since March 1968 (first by the USGS and later by the University of Washington with an expanded network) indicates:

- Low levels of stress release
- Shallow focal depths (less than or equal to 50 mi)
- No obvious relationship to any mapped geological structure.

Swarm activity has been recorded at Wooded Island, and events have been clustered in time within controlled zones. Unlike the situation in California, where segments of the Hayward, San Andreas, and Calaveras faults are clearly delineated by microearthquakes, there is no clustering, concentration, or alignment of microearthquake epicenters along any of the mapped northwest-trending structures in the Columbia Basin.

On the basis of probable geomorphic expression in the Touchet Beds (12,000 yr old) a fault extending 5 mi from VanSycle Canyon across the Columbia River to Yellepit Station is considered to be a capable fault (Brown 1968). The north side of this fault, known as the Wallula Gap fault, has moved down, displacing stratigraphic horizons greater than 1,000 ft (AGU 1977). There is no displacement or geomorphic expression of the fault in Holocene loess deposits. No earthquakes are known to have occurred along the fault.

3.6.2.7 Identification of Capable Faults. Four faults on Gable Mountain--the "south, central, west" faults and the "north-dipping reverse fault,"--and the Rattlesnake Mountain fault are assumed capable by the NRC using the definition in Appendix A to 10 CFR 100 (NRC 1982b).

3.6.2.8 Description of Capable Faults. The central fault is interpreted as a tear fault that developed along with the growth of Gable Mountain anticline. The fault strikes northeast-southwest and dips to the southeast with a length of about 2 mi. The central fault dies out to the northeast and southwest in the hinge zones of the east Gable Mountain anticline and west Gable Mountain anticline, respectively. Glaciofluvial deposits (13,000 to 19,000 yr BP) are displaced about 2.6 in. or less over a length of about 1,100 ft (Puget Sound Power and Light Company 1981). Long-term displacement rates are low (2.0×10^{-4} in./yr). The youngest movement is greater than 13,000 yr BP.

The south fault is an east-west trending reverse fault that dips south and has a length between 1,700 ft and 4 mi. Displacement of glaciofluvial deposits has not been observed; however, slickensides in clastic dikes derived from these deposits suggest minor dip-slip displacement since dike emplacement. Apparent accumulative dip-slip displacement has been no more than 50 ft in the last 11M yr.

The north-dipping reverse fault occurs on the south side of Gable Mountain and is probably a back-limb thrust fault. It has been traced for 2,000 ft in an east-west direction but may be as long as 4 mi in length. Apparent maximum cumulative displacement has been 380 ft in the last 11M yr. Displacement of glaciofluvial deposits has not been observed.

The west fault is a 0.5-mi-long normal fault striking northeast and dipping to the west. This fault is interpreted as a short tear fault, which formed in response to folding in the west Gable Mountain anticline hinge area. Apparent cumulative dip-slip displacement has been 15 ft over the past 11M yr; no displacement of glaciofluvial sediments has been observed.

Two faults were recognized in corehole DB-10 on the south side of Gable Mountain during drilling to delineate the extent of the echelon folds on Gable Mountain (Rockwell 1979a). Subsequent drilling by Golder Association constrained the upper fault to about 0.5 mi in length with a north-south strike and a 25 to 45° dip to the west (Puget Sound Power and Light Company 1981). Vertical stratigraphic throw has been about 165 ft over the past 11 to 13M yr. Altogether, no age determination of last movement was made. This fault was interpreted to be independent of Gable Mountain faults (Puget Sound Power and Light Company 1981).

The Rattlesnake Mountain fault, about 8 mi south of the PFP site, is also assumed to be capable (Farooqui and Thoms 1980). There is no known Quaternary

movement along this portion of the Rattlesnake-Wallula Alignment. Quaternary movement is possible southeast of Rattlesnake Mountain along a splay of the Wallula Fault at Finley Quarry (Farooqui and Thoms 1980). This exposure is a 33-ft-wide fault zone on the northern flank of one of the doubly plunging anticlines that lie along the Rattlesnake-Wallula Alignment. The fault juxtaposes colluvium of unknown age against older Miocene basalt along a high-angle reverse fault. Younger colluvium and loess overlying the fault are not displaced. These younger sediments are overlain by two caliche soil horizons, the higher of which was dated at least 70,000 yr (Woodward-Clyde Consultants 1981), indicating that the displacements occurred more than 70,000 yr ago.

3.6.2.9 Maximum Earthquake. There are four accepted sources for earthquake generation that could cause ground vibrations at the PFP site large enough for specific evaluation (NRC 1982b).

- A swarm-type of earthquake occurring in the basalt with a Richter magnitude of 4.0.
- A surface-wave magnitude 6.5 event occurring at the closest distance to the PFP from the Rattlesnake Mountain Fault, about 8 mi.
- A floating-type of earthquake, not associated with any known geologic structure. Such an event would be the largest known to have occurred in the tectonic province where the PFP is located. It would be a Richter magnitude 5.75 event assuming the 1936 Milton-Freewater earthquake is in the same tectonic province as the Pasco Basin.
- A surface-wave magnitude of 5.0 ± 0.5 earthquake on the north dipping Gable Mountain Fault. This fault is the largest and closest assumed capable structure at Gable Mountain. The distance to the PFP site is about 3 mi.

3.6.2.10 Design Basis Earthquake. The design response spectra for the DBE for Safety Class and Safety Significant nonreactor nuclear facilities is generated from the time histories of the seismology of the region (DOE-RL 1993). See Chapter 4.0, Section 4.3.5, for detailed discussions of the seismic design criteria.

3.6.2.11 Operating Basis Earthquake. See Chapter 4.0, Section 4.3.5, for discussion of the seismic design criteria for Safety Class and Safety Significant nonreactor nuclear facilities.

3.6.3 Surface Faulting

No evidence of surface faulting or potential for surface fault manifestations has been found on the PFP site.

3.6.4 Stability of Subsurface Material

3.6.4.1 Geologic Features. Geologic features at the PFP site are discussed in Section 3.6.1.2.1 and in Section 3.6.2.

3.6.4.2 Properties of Underlying Materials. The Ringold Formation at the PFP site is covered by about 100 ft of glaciofluvial gravel and associated sediments, informally called the Hanford Formation. The Hanford Formation gravel and sediments are compact, locally uncemented deposits of Pleistocene times. The Hanford Formation was laid down by glacial meltwaters and the glacial Lake Missoula floods between about 100,000 and 10,000 yr ago. The soils within the upper 100 ft at the PFP site are predominantly dense, fine-to-coarse sands with admixtures of silt and pebbles (Tallman et al. 1979).

3.6.4.3 Soil and Rock Characteristics. Seismic surveys of the PFP site were conducted to determine shear and compressional wave velocities and to develop data on the dynamic properties of the foundation soil (URS/JABE 1980). A generalized geological cross section is presented in Figure 3-37.

3.6.4.4 Excavations and Backfill. Excavations and backfill were completed for construction under the Uniform Building Code (UBC 1946), using Hanford specification HW-3259 (Giffels and Vallet 1948). The safe bearing value of the soil is 9000 lb/in^2. All excavation was done within the building lines and as required to a point 5 ft beyond the building lines to accommodate the work of all trades. Excavation for wall, column, pier, and other footings was carried to a suitable bearing area approved by the construction engineer. The depth of exterior footings was not less than 2 ft 6 in. below finish grade line. All concrete footings were carried to soil at least 1 ft below the existing ground line, or to undisturbed soil, but always to depths as shown on foundation plans (the preceding was taken from the 234-5Z Building foundation plan, H-2-16008).

All backfilling required for completion of the work included filling to a point approximately 5 ft outside the lines, of any structure. For filling and backfilling outside of building lines, suitable excavated material or material borrowed on the site was used. Backfill material inside of the PFP, against walls, over column footings, and fill under slabs was sand or uniformly graded gravel, 100% of which passed through a 1-in. mesh screen. No backfilling was performed on frozen surfaces.

Backfilling was placed in layers not over 12 in. thick by loose measurement. All backfill material was tamped using air tampers.

Excavating and backfilling are not now common practices at the PFP and, when conducted, are performed by construction personnel using approved procedures. Compaction criteria for any new engineered backfill is now specified to be in accordance with *Standard Specification for Road, Bridge and Municipal Construction* (WSDOT 1994).

3.6.4.5 Groundwater Conditions. The stability of the water table is discussed in Section 3.5.2.

3.6.4.6 Response of Soil and Rock to Dynamic Loading. Data on the dynamic properties of the PFP founding materials have been reported (URS/JABE 1980). A site-specific response spectrum was developed, based on specific density of site materials of 1.84 and a representative shear wave velocity of 1,200 ft/s. Also, the soil and rock are similar in properties to those underlying nearby sites for nuclear power plants, for which extensive analytical data are available (Supply System 1981, Puget Sound Power and Light Company 1981).

3.6.4.7 Liquefaction Potential. The water table is at a depth of about 200 ft beneath the PFP site. This fact, plus the dense, coarse nature of the underlying materials, precludes a potential for liquefaction.

3.6.4.8 Earthquake Design Basis. The major PFP buildings were designed and built over the period of 1946 through 1982. Applicable design criteria for the period were used. The specific criteria for each of the major buildings are discussed in Section 5.2 and summarized in Table 5-2.

3.6.4.9 Static Analysis. At the time of original design and construction (1947 to 1949) formal static analysis of the subsurface material, as currently required, was not performed. Evaluations consistent with UBC 1946 were performed. The subsurface conditions were found to be compliant and construction was completed. During the past 40 yr of operation there has been no indication of settlement or subsurface instabilities.

3.6.4.10 Criteria and Design Methods. For principal design criteria and design methods at the Hanford Site see Chapter 4.0, Section 4.3.5.

3.6.4.11 Techniques to Improve Subsurface Conditions. The subsurface conditions are stable. No improvements to subsurface conditions were attempted. Construction was satisfactorily completed.

3.6.5 Slope Stability

The PFP site reveals no near or adjacent slopes whose failure (instability) might constitute a hazard. Moreover, the soils at the site are typically granular and, hence, relatively resistant to failure due to sliding.

3.6.6 Volcanic Action

3.6.6.1 Volcanoes of the Cascade Mountain Range. There are several major volcanoes in the Cascade Mountain Range west of the PFP site (Figure 3-38). The closest is Mt. Adams about 100 mi distant; the most active is Mt. St. Helens about 130 mi west-southwest of the Hanford Site. Because most volcanic activity is confined to the immediate area of the volcano, mud flows, avalanches, pyroclastic rock flows, lava flows, and shock waves that may be associated with such activity do not pose a hazard to the Hanford Site. The only potential hazard to the site is ashfall resulting from a major eruption of one of these volcanoes (Supply System 1981).

3.6.6.2 Ash History for Hanford Site. The stratigraphic record of tephras in the Pasco Basin suggests that the only primary product of Cascade Mountain Range volcanism that may be expected to reach the Pasco Basin during the next 10,000 yr is air-fall tephra. The USGS made a similar assessment for the Supply System WNP-2 nuclear power plant site (Woodward-Clyde Consultants 1981).

The hazard posed by any particular Cascade volcano to the PFP site is dependent on the probability of renewed eruptive activity and amount of air-fall tephra. Sarna-Wojcichi et al. (1980) have estimated an annual probability of 10^{-4} to 10^{-5} for eruption of some Cascade Mountain Range volcanoes based on the frequency of occurrence of various ejecta during a

given interval of geologic time. Some of the volcanoes, such as Mount St. Helens, are known to erupt more frequently, and the stratigraphic record may not provide complete information on the frequency of eruptions but rather may reflect only the relatively large eruptive episodes (Sarna-Wojcichi et al. 1980).

The amount of air-fall tephra that may reach the Hanford Site depends on the volume of material erupted, the tephra characteristics, and the distance of the Hanford Site from the source. Dispersal patterns of ejecta from eruptions are determined by the wind direction and velocity and the altitude to which the ash cloud rises.

Varying amounts of ash were deposited across the Columbia Plateau during the May 18, 1980, eruption of Mt. St. Helens. About 0.3 in. of ash was deposited at the Hanford Site meteorological tower. The Hanford Site was not in the main path of the ash cloud and received only a fraction of ash compared with locations to the north that were located directly in the path of dispersing winds (Sarna-Wojcichi et al. 1980).

3.6.6.3 Ash Densities and Depth Comparisons. Studies of the impact of ashfalls associated with volcanic eruptions indicate that the density and the depth of the ash are important. Sarna-Wojcichi of the USGS indicates that there are great variations in depth just from the settling of ash from air currents and other natural means (Sarna-Wojcichi et al. 1980). For example, the depth of ash at Pullman, Washington, from the Mt. St. Helens, May 18, 1980, eruption measured 0.4 in. shortly after the event but less than 0.15 to 0.2 in. in depth after 1 d. Because of the potential effect of roof loading on structures, the density of the ash is an important parameter to consider in an ashfall event.

The actual ash densities observed from the Mt. St. Helens eruption on May 18, 1980, are shown in Figure 3-39. At a distance equal to that of the PFP from the volcano (130 mi), the apparent density would be about 31 lb/ft^3. With natural settling, this can increase to 62 lb/ft^3 with a corresponding decrease in depth. The density of the ash varies greatly with other conditions. For example, Sarna-Wojcichi indicated that the ash that fell during the later eruptions of Mt. St. Helens and was exposed to rain and subsequently dried out experienced an increase in density to 74 lb/ft^3 when compared with other densities shown in Figure 3-39 (Sarna-Wojcichi et al. 1980).

3.6.6.4 Volcanic Design Basis Ashfall. The following sections describe characteristics of the PFP design basis event.

3.6.6.4.1 Particle Size and Distribution of Ash. Particle size and distribution from a volcanic ash eruption normally vary with the distance from the volcano and the relative wind speed. The particle size generally decreases with increased distance from the volcano, reflecting settling of the coarse material near the source. Different winds at the time of the event could cause different settling rates than occurred during the May 18, 1980, eruption of Mt. St. Helens and could change the particle size distribution of the ash. For the design basis ashfall event a particle distribution was developed as listed in Table 3-16.

3.6.6.4.2 Abrasive Characteristics of Ash. The abrasive characteristics are determined by the main minerals in the ash. These main minerals, in order of decreasing abundance are: plagioclase feldspar (andesite), orthopyroxene (hypersthene), titanium-bearing magnetite, and glass. This mixture is very abrasive and may cause accelerated wear and damage to mechanical moving parts.

3.6.6.4.3 Chemical Composition of Ash. The chemical constituents in the ash may vary with each volcanic eruption, depending on whether old material or new volcanic material was being erupted and also on the distance from the volcano. Using the results obtained for the May 18, 1980, event (Long 1980), an estimated composition for the design basis ashfall event was developed and is shown in Table 3-17.

3.6.6.4.4 Composition of Water-Soluble Constituents. Reports by many observers on the ashfall from Mt. St. Helens on May 18, 1980, indicate that the dry ash was mildly corrosive. Leaching studies of the ash were conducted to determine what species would dissolve when the ash came into contact with water. These experiments showed no acidity. In fact, some of the samples increased in pH. Although this would appear to be a discrepancy, adding water to the sample may have caused any acids in the ash to react with the bulk of the ash.

The water-soluble constituents for the design basis ashfall event and a comparison with soil are given in Table 3-18 (Fruchter et al. 1980).

For the design basis ashfall event, the dry ash should be considered mildly corrosive to metals.

3.6.6.4.5 Ash Drift Characteristics. The characteristics of the ash from the standpoint of drifting will be very similar to that of snow. The density of the ash is much greater, which requires stronger winds to cause movement.

3.6.6.4.6 Ash Electrical Properties. The ash has the following properties.

- Resistivity--Dry ash resistivity equals 1 x 10^8 mohm/cm.

  NOTE: Volcanic ash is about 5 to 10 times more conductive than dirt from the Yakima Valley. However, for a material normally to be considered conductive, the range would be from 10^4 to 10^5 ohm-cm.

- Conductivity--Aqueous extract, 1:1 ash/water by volume, conductivity equals 2.99 mohm/cm. Resistivity of aqueous extract equals 334 ohm-cm.

  NOTE: In samples taken of May 18, 1980, Mt. St. Helens eruptions, a considerable variation in conductivities within any one sample was observed because of the inherent heterogeneity of each ash sample.

- Equivalent Salt Deposit Densities--The severity of contamination is generally quantified in terms of Equivalent Salt Deposit Densities (ESDD). Since volcanic ash dissolves slowly, it will retain its

conductive nature over a longer period of time. In Table 3-19, volcanic ash is compared to the equivalent salt found in soil (Nellis and Hendrix 1980).

In making a comparison of severities of contamination on insulators, the Institute of Electrical and Electronic Engineers has established ESDD ranges to categorize the severity of contamination (see Table 3-20).

The volcanic ash would be in the heavy severity range for electrical insulators.

3.6.6.5 Design Basis Ashfall. A volcanic ashfall is considered to be a potentially occurring natural phenomenon in the category of tornado and earthquake. Early design criteria did not account for ashfall specifically from volcanic activity but did consider roof loading. The design basis ashfall was added to the Hanford Site design criteria following the May 18, 1980, eruption of Mt. St. Helens (Table 3-21).

The basis for evaluation is an assumed eruption of Mt. Adams (100 mi from the Hanford Site) in a similar manner to that which occurred at Mt. St. Helens.

The probability of a volcanic eruption of Mt. Adams is indeterminable, but it was chosen because it is closest of the volcano peaks to the Hanford Site. Southwesterly winds, could easily make the Hanford Site a target for ashfall with wind conditions similar to the St. Helens eruption, and its physical construction is very similar to Mt. St. Helens. Mt. St. Helens or Mt. Rainier, based on past history, have a higher probability of eruption; however, Mt. Adams, because of location, is the worst case.

While the Hanford Site is distant enough to avoid danger from the immediate eruption (i.e., the stone wind or avalanche), ashfall does present a problem as it did on May 18, 1980, during the eruption of Mt. St. Helens.

With winds to the northeast, the ash flow would be directly toward the PFP, as shown in Figure 3-40. For a total ashfall duration of 20 h, with a decreasing rate after the first 6 h, the ash accumulation would be as follows:

Average ashfall: 3 in./20 h = 0.15 in./h.

For the purpose of this scenario, the ash will be dry in form with the only compaction caused by its own weight, which is dependent on the depth of accumulation.

Ash causes three immediate concerns to the PFP management. The ash is extremely abrasive to any exposed mechanical equipment, ash may cause pluggage problems with the ventilation system, and heavy accumulations on top of the facility may exceed roof loading limits.

In the event of ashfall at the PFP, most exterior equipment that would be exposed to the abrasiveness of the ash would be shut down, including the vehicles such as the process and sample trucks. Ashfall accumulations of 1 to 2 in. can be washed at the ventilation intakes by turning the wet cell washers on full and maintaining clean water in the spray pans. However, for

heavier ashfalls it would be advisable to shut down the normal ventilation, leaving the wet cell washers on, and rely on natural circulation for ventilation through the facility exhaust stack until the ashfall is over. It may become necessary for the PFP personnel to clear the roof of ash before excessive buildup occurs. This effort requires special safety precautions and includes protective clothing and respiratory protection and is included in the plant emergency planning for response to volcanic eruption.

3.6.6.5.1 Design Criteria. Facility design criteria for ashfall loading at the Hanford Site is discussed in Chapter 4.0, Section 4.3.6 and 4.3.9.

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Table 3-1. Active Nuclear Areas on the Hanford Site.

Area	Facilities/Activities	Distance from PFP (mi)
100	100 Area decommissioned reactors, 100 K irradiated fuel storage	9
200 East	PUREX (deactivated), B Plant (deactivated), Waste retention and treatment, waste storage	5
200 West	PFP, waste storage and disposal, laboratories, WSCF	0.0 to 1.5
300	Fabrication development, radiochemistry, radiometallurgy, waste vitrification	22
400	FFTF, MASF, FSF, FMEF	16
Other	U.S. Ecology WNP-2 Reactor Siemens Power Corporation, Nuclear Division (fuels plant)	4 16 22

Table 3-2. Miscellaneous Snowfall Statistics, 1946 through 1994.

Average number of days of given depth at 0400 PST	OCT	NOV	DEC	JAN	FEB	MAR	Season
≥1 in.	(a)	1	7	9	4	(a)	21
≥3 in.	0	1	3	6	2	(a)	12
≥6 in.	0	(a)	1	3	1	(a)	5
≥12 in.	0	0	(a)	(a)	0	0	(a)
Record greatest number of days of given depth at 0400 PST	OCT	NOV	DEC	JAN	FEB	MAR	Season
≥1 in.	0	(1978)[b] 12	(1985) 31	(1969) 31	(1989) 20	(1989) 7	(1992-93) 72
≥3 in.	0	(1978) 12	(1978) 31	(1993) 27	(1950) 16	(1993) 6	(1985-86) 58
≥6 in.	0	(1978) 6	(1978) 23	(1993) 25	(1993) 9	(1993) 5	(1992-93) 43
≥12 in.	0	0	(1964) 4	(1993) 10	0	0	(1992-93) 10
Record greatest depth	(1973) 1.5	(1985) 10.0	(1985) 15.6	(1993) 15.0	(1969) 10.0	(1993) 9.1	(Dec. 1985) 15.6
Greatest in 24 h	(1973) 1.5	(1985) 8.8	(1985) 6.6	(1954) 7.1	(1993) 10.2	(1989) 2.7	(Feb. 1993) 10.2

Record consecutive number of days of given depth at 0400 PST	Number of days	From	To
≥1 in.	60	November 20, 1985	January 18, 1986
≥3 in.	57	November 22, 1985	January 17, 1986
≥6 in.	32	December 20, 1964	January 20, 1965
≥12 in.	6	January 15, 1993	January 20, 1993

a - Denotes less than ½ day.
b - Year of occurrence in parentheses.
PST - Pacific Standard Time.

Table 3-3. Percent Frequency Distribution and Wind Speed at 50-ft, 1955 through 1994. (2 sheets)

Percent frequency distribution													
Direction	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
N	4.5	5.0	4.9	4.3	3.9	3.7	4.8	4.8	5.8	5.2	4.5	4.5	4.7
NNE	3.5	4.6	4.4	3.5	3.4	3.2	4.3	4.0	5.5	4.2	3.5	3.2	3.9
NE	3.0	3.6	3.4	3.4	3.4	3.1	3.7	3.5	4.3	3.6	2.9	2.7	3.4
ENE	2.3	2.1	2.1	2.2	2.4	2.1	2.5	2.4	2.3	2.6	2.5	2.4	2.3
E	2.6	2.1	2.2	2.4	2.4	2.4	2.8	3.0	3.0	2.9	2.7	2.6	2.6
ESE	2.8	2.6	2.7	2.4	2.6	2.6	2.8	3.3	3.1	3.8	3.3	3.2	2.9
SE	4.3	3.8	3.9	3.1	3.3	3.1	3.1	3.7	3.9	5.2	4.6	4.6	3.9
SSE	3.3	3.2	3.2	2.8	2.8	2.5	2.2	2.7	3.0	3.8	3.7	3.6	3.1
S	3.3	3.3	3.6	3.1	2.7	2.6	2.4	2.6	2.6	3.5	4.0	3.5	3.1
SSW	4.7	4.4	5.1	4.4	3.5	3.4	2.6	3.0	3.3	4.1	5.1	4.6	4.0
SW	6.6	7.7	9.2	8.9	6.7	6.7	5.6	6.0	5.7	6.8	7.5	6.7	7.0
WSW	6.7	7.3	10.3	11.8	10.3	9.7	8.4	8.8	9.1	8.5	7.9	7.0	8.8
W	6.7	8.3	9.7	11.8	11.7	11.1	9.8	10.8	11.4	10.4	8.4	7.1	9.7
WNW	14.7	14.6	14.6	16.6	18.8	19.3	19.4	18.0	15.2	13.1	12.6	13.7	15.9
NW	19.2	18.0	14.2	14.3	17.5	19.5	20.0	17.6	14.8	13.4	15.6	18.2	16.9
NNW	7.2	6.8	5.7	4.5	4.2	4.6	5.2	5.3	5.8	6.5	7.0	7.1	5.8
CALM	4.6	2.7	0.9	0.5	0.5	0.4	0.3	0.5	1.1	2.4	4.2	5.3	2.0
Wind speed at 50 ft													
Speed (mi/h)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
CALM	4.6	2.7	0.9	0.5	0.5	0.4	0.3	0.5	1.1	2.4	4.2	5.3	2.0
1-3	32.0	26.0	17.9	13.8	12.5	10.4	11.6	14.6	19.1	27.6	30.4	33.9	20.8
4-7	33.4	34.5	35.6	33.7	34.4	35.2	38.3	41.3	40.2	38.3	34.4	32.5	36.0
8-12	19.2	23.3	27.1	28.6	30.0	29.7	28.9	27.3	25.7	20.9	20.0	18.3	24.9
13-18	6.8	8.6	12.1	15.7	15.9	16.7	14.6	11.7	10.1	7.6	7.1	6.3	11.1
19-24	2.6	3.1	4.6	6.0	5.6	6.3	5.4	4.0	3.3	2.5	2.7	2.5	4.1
25-31	1.0	1.3	1.5	1.6	1.0	1.2	0.9	0.6	0.6	0.6	1.0	1.0	1.0
Wind speed at 50 ft													
Speed (mi/h)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
32-38	0.3	0.3	0.2	0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.2	0.2	0.1

Table 3-3. Percent Frequency Distribution and Wind Speed at 50-ft, 1955 through 1994. (2 sheets)

39-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3-4. Tower Observation Levels.

Tower levels (ft)					
	3	30	50	200	400
Temperature	X	X	-	X	X
Wind	-	-	X	X	X

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Table 3-5. Normal and Extreme Values of Meteorological Parameters. (2 sheets)

NUMBER OF DAYS (1945-1975)**

	CLEAR					PARTLY CLOUDY					CLOUDY					THUNDERSTORMS					HEAVY FOG (VISIBILITY 1/4 mi OR LESS)					PRECIPITATION 0.10 in. OR MORE					SNOW 1.0 in. or MORE				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
JAN	3	7	1963	0	1955 +	6	22	27	1969	17	1963	0	0	--	0	---	5	14	1965	0	1949	3	8	1970	0	1972 +	2	10	1960	0	1967 -
FEB	6	9	1966 +	1	1972 +	5	18	26	1958	12	1964	#	1	1972 +	0	1975 +	3	11	1963	0	1971 +	2	5	1961 -	0	1972 +	2	4	1975 +	0	1974 -
MAR	8	12	1965 +	2	1961	8	17	22	1968	9	1965	#	1	1969 +	0	1975 +	1	5	1951	0	1975 +	2	6	1957	0	1973 +	#	2	1957 +	0	1975 +
APR	6	12	1962	1	1963	10	14	21	1963	6	1958	1	3	1948	0	1975 +	#	1	1975 +	0	1974 +	1	5	1948	0	1973 +	0	0	---	0	---
MAY	9	14	1973	2	1960	10	12	19	1960	8	1958	2	7	1956	0	1974 +	#	1	1958	0	1975 +	2	4	1967 +	0	1968 +	0	0	---	0	---
JUNE	16	21	1961	5	1972 +	10	10	15	1973 +	5	1960 +	3	8	1972 +	0	1963 +	#	1	1971	0	1975 +	2	6	1950	0	1973 +	0	0	---	0	---
JUL	29	26	1960	13	1974	7	4	9	1974	1	1961	2	7	1975	0	1973 +	0	0	---	0	---	1	3	1974 +	0	1973 -	0	0	---	0	---
AUG	19	30	1965	11	1968	7	6	13	1968	0	1960 +	2	8	1953	0	1974 +	#	1	1959	0	1975 +	1	4	1975	0	1974	0	0	---	0	---
SEPT	15	27	1975	8	1969	7	8	13	1969	1	1975	1	4	1959	0	1975 +	#	1	1957	0	1975 +	1	5	1959	0	1975 -	0	0	---	0	---
OCT	9	14	1970	1	1976	7	15	22	1973	9	1970	#	1	1975	0	1974 +	1	6	1962	0	1974 +	2	8	1950	0	1972 +	#	1	1973	0	1975 -
NOV	4	10	1957	1	1973 +	5	21	25	1973 +	15	1961	0	0	---	0	---	6	13	1965	0	1960	3	10	1973	0	1967	#	6	1966	0	1974 -
DEC	3	7	1972 +	1	1962 +	5	23	28	1962	18	1967 +	#	1	1971	0	1975 -	8	17	1960	2	1968 +	3	10	1964	0	1949 +	2	6	1964	0	1974 -
			AUG		JAN				DEC		AUG			JUNE					DEC					NOV		SEPT			JAN		
YEAR	109	30	1965	0	1955 -	87	169	28	1962	0	1969 -	11	8	1972 -	0	---	24	17	1960	0	---	23	10	1973	0	1975 +	5	10	1950	0	---

REFERENCE NOTES

* CALORIES/cm^2

** SKY COVER AND PRECIPITATION OBSERVATIONS NOT BEGUN UNTIL 1946

LESS THAN 1/2

\+ ALSO ON EARLIER YEARS

	NUMBER OF DAYS (1945-1975)										NUMBER OF DAYS (1912-1975)																					
	3 in. OR MORE SNOW ON GROUND					PEAK GUST 40 mi/hr OR GREATER					MAXIMUM TEMPERATURE 90°F OR ABOVE					MAXIMUM TEMPERATURE 100°F OR ABOVE					MAXIMUM TEMPERATURE 32°F OR BELOW					MINIMUM TEMPERATURE 32°F OR BELOW					MINIMUM TEMPERATURE 0°F OR BELOW				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
JAN	5	23	1968	0	1975 +	3	11	1972	0	1973 +	0	0	---	---	0	---	0	0	---	0	---	11	29	1937	0	1967 +	28	31	1960 +	9	1953	2	14	1950	0	1975 +
FEB	3	16	1950	0	1974 +	3	6	1961 -	0	1973 +	0	0	---	---	0	---	0	0	---	0	---	3	15	1956	0	1974 +	22	28	1944 +	5	1958	1	9	1929	0	1976 +
MAR	0	0	---	0	---	3	9	1956	1	1973 +	0	0	---	---	0	---	0	0	---	0	---	#	2	1960	0	1975 +	16	25	1944 +	6	1968 +	0	0	---	0	---
APR	0	0	---	0	---	3	7	1972	0	1967	#	4	1928	0	1975 +	0	0	---	0	---	0	0	---	0	---	5	15	1935	0	1974 +	0	0	---	0	---
MAY	0	0	---	0	---	2	6	1971 +	0	1963 +	3	11	1924	0	1974 +	#	1	1965 +	0	1975 +	0	0	---	0	---	#	3	1938	0	1975 +	0	0	---	0	---
JUNE	0	0	---	0	---	2	6	1973	0	1971 +	9	20	1940 +	0	1953	1	9	1970	0	1975 +	0	0	---	0	---	0	0	---	0	---	0	0	---	0	---
JULY	0	0	---	0	---	1	4	1962 +	0	1976 +	21	29	1941	8	1963	7	16	1971 -	0	1963 +	0	0	---	0	---	0	0	---	0	---	0	0	---	0	---
AUG	0	0	---	0	---	1	5	1951	0	1974 +	18	29	1916	7	1948	4	16	1942	0	1975 +	0	0	---	0	---	0	0	---	0	---	0	0	---	0	---
SEPT	0	0	---	0	---	2	4	1946	0	1975 -	5	16	1938	0	1970 +	#	2	1958 +	0	1975 +	0	0	---	0	---	#	4	1933 +	0	1976 +	0	0	---	0	---
OCT	0	0	---	0	---	2	8	1967	0	1974 -	#	1	1933	0	1975 +	0	0	---	0	---	#	2	1935	0	1975 -	5	12	1916	0	1962 +	0	0	---	0	---
NOV	#	10	1955	0	1976 +	2	6	1973 -	0	1974 -	0	0	---	0	---	0	0	---	0	---	2	15	1955	0	1974 -	17	30	1936	4	1948	#	1	1955 -	0	1976 +
DEC	2	14	1955	0	1975 +	3	8	1957 +	0	1969 +	0	0	---	0	---	0	0	---	0	---	2	15	1955	0	1974 -	26	31	1963 +	14	1933	1	14	1919	0	1975 +
			JAN					JAN					JULY					JULY					JAN					DEC					JAN			
YEAR	10	23	1969	0	---	27	11	1972	0	---	68	29	1941 +	0	---	12	16	1971 +	0	---	24	29	1937	0	---	119	31	1963 +	0	---	4	14	1950 +	0	---

NUMBER OF DAYS

CLEAR (0-3 TENTHS SKY COVER, SR TO SS)		
GREATEST ANNUAL (1946-75)	141	1961
LEAST ANNUAL (1946-75)	85	1966
CLOUDY (8-10 TENTHS SKY COVER, SR TO SS)		
GREATEST ANNUAL (1946-75)	181	1969 +
LEAST ANNUAL (1946-75)	84	1949
THUNDERSTORMS		
GREATEST ANNUAL (1974-75)	23	1948
LEAST ANNUAL (1974-75)	3	1949
HEAVY FOG VISABILITY 1/4 mi OR LESS		
GREATEST SEASONAL (1945-1975)	42	1950-51
LEAST SEASONAL (1945-75)	9	1948-49
PRECIPITATION 0.10 in. OR MORE		
GREATEST ANNUAL (1946-75)	39	1950
LEAST ANNUAL (1946-75)	10	1965
SNOW 1.0 in. OR MORE		
GREATEST SEASONAL (1946-75)	15	1955-56
LEAST SEASONAL (1946-75)	0	1957-58
3 in. OR MORE SNOW ON GROUND		
GREATEST SEASONAL (1946-75)	40	1964-65
LEAST SEASONAL (1946-75)	0	1966-67 -
PEAK GUST 40 mi/hr OR GREATER		
GREATEST ANNUAL (1946-75)	41	1961
LEAST ANNUAL (1946-75)	13	1956
MAXIMUM TEMPERATURE 90°F OR ABOVE		
GREATEST ANNUAL (1912-75)	85	1940 -
LEAST ANNUAL (1912-75)	21	1964
MAXIMUM TEMPERATURE 100°F OR ABOVE		
GREATEST ANNUAL (1912-75)	39	1942
LEAST ANNUAL (1912-75)	1	1964
MAXIMUM TEMPERATURE 32°F OR BELOW		
GREATEST SEASONAL (1912-75)	63	1966-66
LEAST SEASONAL (1912-75)	1	1937-38
MINIMUM TEMPERATURE 32°F OR BELOW		
GREATEST SEASONAL (1912-75)	141	1916-17
LEAST SEASONAL (1912-75)	75	1957-58
MINIMUM TEMPERATURE 0°F OR BELOW		
GREATEST SEASONAL (1912-75)	18	1949-50
LEAST SEASONAL (1912-75)	0	1974-75 -

LOCATION AND HISTORY

PRESENT LOCATION 25 mi NW OF RICHLAND, WASHINGTON
LATITUDE 46°34'N; LONGITUDE 119°36'W. ELEVATION 733 ft
OBSERVATIONS FROM 1913 TO 1944 WERE BY UNITED STATES WEATHER BUREAU COOPERATIVE OBSERVERS AT A SITE ABOUT 10 mi ENE OF PRESENT LOCATION. BETWEEN 1944 AND 1975, OBSERVATIONS HAVE BEEN MAINTAINED ON A 24 hr-A-DAY BASIS BY THREE DIFFERENT GOVERNMENT CONTRACTORS

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Table 3-5. Normal and Extreme Values of Meteorological Parameters. (2 sheets)

	TEMPERATURE (°F)																DEGREE DAYS (BASE 65°F)								PRECIPITATION (INCHES)											
	1912-1975 AVERAGES							1912-1975 EXTREMES									HEATING 1974-1975 TOTALS				COOLING 1990 1976 TOTALS				1912-1975 TOTALS						SNOW, ICE PELLETS (SLEET)					
								DAILY MAXIMUM				DAILY MINIMUM																							
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MAXIMUM IN 24 hr	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MAXIMUM IN 24 hr	YEAR	MAXIMUM DEPTH	YEAR
JAN	37.0	22.2	29.6	42.5	1963	12.1	1960	72	1971	-2	1950	53	1971	-23	1934	1086	1440	1950	664	1963	0	0	...	0	...	0.82	2.47	1970	0.13	1982+	1.08	1948	5.1	23.4	1950	7.1	1964	12.0	1969
FEB	40.4	27.6	38.4	44.5	1958	21.4	1929	71	1924	-3	1960	55	1932	-23	1960	778	1147	1956	576	1956	6	0	...	0	...	0.50	3.08	1940	T	1987+	1.24	1916	2.4	26.0	1916	6.5	1975	10.0	1969
MAR	50.9	33.7	45.1	49.9	1926	39.4	1955	83	1968	24	1960	54	1942	8	1966	641	794	1966	476	1947	0	0	...	0	...	0.37	1.86	1967	0	1942+	0.59	1948	0.3	4.2	1951	2.2	1957+	2.3	1957
APR	66.1	39.8	53.1	58.6	1934	47.5	1966	95	1934	41	1945	60	1966	12	1935	396	522	1966	266	1947	1	5	1968+	0	1976+	0.38	1.22	1969	0	1933+	0.53	1951	T	T	1975+	T	1975+	0	—
MAY	75.6	48.0	61.9	68.8	1947	56.6	1933	103	1936+	49	1918	70	1966	28	1964	164	255	1962	36	1947	49	99	1971	3	1962	0.47	2.03	1972	0	1931	1.39	1972	T	T	1960	T	1960	0	—
JUNE	83.2	55.4	69.4	75.4	1922	63.0	1963	110	1912	56	1966	81	1924	33	1933	34	90	1963	3	1958	192	310	1969	59	1971	0.56	2.92	1950	0	1919	1.50	1934	0	0	...	0	...	0	
JULY	91.9	61.1	76.8	81.8	1960	72.4	1963	115	1939	59	1966	82	1926	41	1935	3	22	1955	0	1976+	404	518	1960	232	1963	1.15	6.31	1966	0	1939+	0.73	1914	0	0	...	0	...	0	...
AUG	90.4	59.5	74.3	81.8	1967	69.8	1964	113	1961	53	1920	81	1961	40	1918	5	32	1960	0	1974+	335	508	1967	171	1964	0.20	1.18	1920	0	1956+	0.89	1976	0	0	...	0	...	0	...
SEPT	79.6	50.7	65.2	71.7	1967	58.8	1926	102	1950	52	1934+	72	1955	25	1926	71	176	1972	13	1967	107	216	1967	27	1970	0.30	1.34	1947	T	1961+	0.32	1947	0	0	...	0	...	0	...
OCT	66.3	40.7	53.0	59.0	1952	48.8	1930	90	1933	31	1935	60	1946+	6	1935	377	479	1946	200	1952	2	10	1971	0	1975+	0.58	2.72	1957	0	1917+	1.91	1957	7	7.5	1973	1.5	1973	1.5	1973
NOV	48.9	31.6	40.0	46.0	1954+	31.2	1955	75	1976	14	1966	52	1969+	1	1966	747	1008	1956	567	1954	0	0	...	0	...	0.86	3.05	1926	T	1939—	0.78	1966	1.3	12.7	1955	4.8	1965	5.1	1946
DEC	39.3	26.0	32.7	42.0	1933	18.5	1919	68	1933	-3	1919	56	1975	-27	1919	990	1224	1964	622	1957	0	0	...	0	...	0.89	2.53	1931	0.11	1946	1.00	1958	3.9	18.1	1964	5.4	1945	12.1	1964
					JULY		JAN		JULY		FEB		JULY		DEC			JAN		JULY			JULY		OCT			FEB		AUG		OCT			FEB		JAN		DEC
YEAR	64.8	41.3	53.1	81.8	1960	12.1	1950	115	1939	-3	1960+	82	1925	-27	1919	5271	6640	1950	0	1975+	1083	618	1999	0	1975+	6.28	3.08	1940	0	1955—	1.91	1967	13.0	26.0	1916	7.1	1964	12.1	1964

	WIND (mi/hr)							PEAK GUSTS			RELATIVE HUMIDITY (%)									SKY COVER SCALE (0-10)				SOLAR RADIATION (LANGLEYS)*							
	1945-1975 AVERAGES										1948-1975 AVERAGES					1948-1975 EXTREMES				1946-1975 AVERAGES (SUNRISE TO SUNSET)				1953-1975 AVERAGE DAILY TOTALS				1953-1975 EXTREME DAILY TOTALS			
	PREVAILING DIRECTION	MEAN MONTHLY SPEED	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	SPEED	DIRECTION	YEAR	MEAN	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST	YEAR	LOWEST	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR
JAN	NW	6.6	10.3	1972	3.1	1955	80	SW	1972	75.2	86.9	1966	60.9	1963	100	1975+	13	1963	7.8	9.0	1966	4.3	1949	120	136	1973	86	1966	277	1969	16	1971+
FEB	NW	7.1	9.4	1961	4.8	1983	66	SW	1971	78.0	86.9	1963	64.0	1967	100	1975—	14	1962	7.4	8.5	1961	5.9	1964	202	238	1960	164	1954	422	1958	37	1970—
MAR	WNW	8.4	10.7	1964	5.9	1958	70	SW	1966	65.8	85.9	1960	44.8	1965	100	1974—	12	1965+	6.8	7.9	1950	4.9	1965	340	388	1965	305	1961	542	1968	47	1972
APR	WNW	9.1	11.1	1972+	7.4	1958	73	SSW	1972	48.5	64.5	1963	36.9	1966	100	1973—	8	1954	6.4	8.1	1953	3.7	1951	475	535	1973	374	1953	704	1972	75	1974
MAY	WNW	8.9	10.5	1965+	5.8	1957	71	SSW	1948	42.3	61.9	1948	31.2	1966	100	1975—	7	1953	5.8	7.7	1960	4.6	1948	575	634	1970	511	1962	782	1969	67	1962
JUNE	WNW	9.2	10.7	1949	7.7	1950+	72	SW	1967	39.5	53.6	1950	30.0	1949	100	1972+	10	1964+	5.3	7.0	1950	2.8	1961	628	698	1960	563	1953	821	1971	112	1965
JULY	WNW	8.8	9.8	1963	6.8	1966	66	WSW	1968	31.8	40.5	1955	21.9	1950	99	1972	6	1951	2.8	4.5	1974+	0.9	1953	659	714	1973	588	1955	809	1974	198	1972
AUG	WNW	8.0	8.1	1946	6.8	1964	66	SW	1961	34.8	43.8	1968	24.5	1967	100	1972+	7	1961	3.2	5.9	1968	0.6	1956	558	613	1955	475	1968	721	1967	107	1959
SEPT	WNW	7.6	9.2	1961	5.4	1957	65	SSW	1953	40.6	55.1	1958	33.2	1974	100	1963+	10	1962+	4.6	6.1	1958	1.4	1976	423	483	1975	364	1958	581	1970	61	1957
OCT	WNW	6.7	8.1	1946	4.4	1952	63	SSW	1950	57.0	74.2	1962	42.5	1952	100	1975+	10	1962+	6.9	8.0	1975	3.9	1952	262	299	1968	216	1975	434	1973	33	1974
NOV	NW	6.1	7.9	1945	3.9	1958	64	SSW	1949	73.5	88.1	1972	64.2	1963—	100	1975+	16	1958	7.6	9.1	1972	6.2	1957	132	180	1957	97	1964	295	1971	14	1963
DEC	NW	6.1	8.3	1969	3.9	1963—	71	SW	1966	80.1	90.5	1964	69.0	1948	100	1976+	25	1972	8.1	9.2	1962	6.8	1954	92	116	1970	57	1969	196	1972	9	1973
			APR		NOV			JAN			DEC		JULY			DEC		JULY		DEC		AUG			JULY		DEC		JUNE		DEC	
YEAR	WNW	7.7	11.1	1972+	2.9	1966	80	SW	1972	53.9	90.5	1950	21.9	1950	100	1975+	8	1961	5.9	9.2	1962	0.6	1965	372	714	1973	57	1969	821	1971	9	1973

EXTREME AVERAGES OR TOTALS AND YEAR OR SEASON OF OCCURRENCE

1912-1975 TEMPERATURE AVERAGES (°F)		
HIGHEST ANNUAL	56.2	1958
LOWEST ANNUAL	39.2	1929
HIGHEST WINTER (D-J-F)	41.1	1933-34
LOWEST WINTER	24.7	1948-49
HIGHEST SPRING (M-A-M)	58.2	1947
LOWEST SPRING	48.0	1956
HIGHEST SUMMER (J-J-A)	78.2	1958
LOWEST SUMMER	70.3	1954
HIGHEST FALL (S-O-N)	59.9	1963
LOWEST FALL	49.6	1946
1912-1975 PRECIPITATION TOTALS (IN.)		
GREATEST ANNUAL	11.45	1950
LEAST ANNUAL	3.26	1967
SNOW, ICE PELLETS (SLEET)		
GREATEST SEASONAL	43.6	1915-16
LEAST SEASONAL	0.3	1957-58
1946-1975 WIND SPEED AVERAGE (mi/hr)		
HIGHEST ANNUAL	8.3	1968
LOWEST ANNUAL	6.3	1957
1946-1975 RELATIVE HUMIDITY AVERAGE (%)		
HIGHEST ANNUAL	57.9	1950
LOWEST ANNUAL	46.4	1963
1946-1975 SKY COVER AVERAGES (SUNRISE TO SUNSET, SCALE 0 - 10)		
HIGHEST ANNUAL	6.4	1966
LOWEST ANNUAL	5.1	1949
1953-1975 SOLAR RADIATION AVERAGE DAILY TOTAL (LANGLEYS)		
HIGHEST ANNUAL	390	1973
LOWEST ANNUAL	357	1967

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Table 3-6. Joint Frequency Distributions for the 200 West Area at Ground Level (1983 - 1991). (2 sheets)

Wind speed[a] (m/s)	Stability type[b]	Wind direction																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.36	0.20	0.23	0.26	0.40	0.24	0.17	0.10	0.10	0.06	0.06	0.06	0.10	0.10	0.14	0.22
	B	0.15	0.13	0.10	0.11	0.16	0.09	0.07	0.03	0.05	0.02	0.01	0.03	0.04	0.05	0.07	0.10
	C	0.14	0.10	0.09	0.12	0.14	0.10	0.06	0.04	0.04	0.02	0.02	0.02	0.04	0.04	0.10	0.10
	D	0.87	0.58	0.59	0.59	0.77	0.50	0.43	0.32	0.27	0.19	0.21	0.17	0.40	0.44	0.54	0.55
	E	0.39	0.26	0.28	0.25	0.46	0.34	0.31	0.30	0.34	0.21	0.25	0.29	0.49	0.44	0.45	0.39
	F	0.23	0.13	0.12	0.14	0.31	0.23	0.28	0.26	0.35	0.23	0.22	0.27	0.48	0.36	0.32	0.23
	G	0.10	0.04	0.08	0.08	0.13	0.13	0.13	0.14	0.17	0.09	0.10	0.09	0.22	0.14	0.14	0.09
2.7	A	0.69	0.44	0.29	0.32	0.60	0.51	0.45	0.29	0.24	0.12	0.17	0.19	0.25	0.30	0.42	0.48
	B	0.21	0.15	0.06	0.08	0.16	0.13	0.13	0.09	0.08	0.04	0.03	0.05	0.07	0.09	0.16	0.16
	C	0.19	0.12	0.06	0.09	0.13	0.13	0.19	0.10	0.06	0.02	0.03	0.05	0.08	0.10	0.19	0.15
	D	0.84	0.48	0.40	0.33	0.66	0.57	0.75	0.53	0.35	0.18	0.24	0.28	0.69	1.09	1.05	0.77
	E	0.32	0.17	0.11	0.13	0.31	0.34	0.47	0.52	0.46	0.21	0.29	0.48	1.58	1.68	1.11	0.39
	F	0.13	0.05	0.05	0.05	0.16	0.21	0.39	0.44	0.45	0.21	0.27	0.46	1.60	1.69	0.82	0.25
	G	0.04	0.02	0.02	0.03	0.09	0.10	0.20	0.23	0.20	0.08	0.10	0.20	0.82	0.69	0.30	0.08
4.7	A	0.26	0.24	0.10	0.03	0.08	0.10	0.10	0.13	0.12	0.07	0.14	0.34	0.35	0.35	0.40	0.17
	B	0.09	0.06	0.03	0.01	0.03	0.03	0.04	0.05	0.03	0.02	0.05	0.07	0.10	0.14	0.12	0.06
	C	0.08	0.05	0.03	0.01	0.02	0.02	0.04	0.04	0.05	0.02	0.03	0.06	0.09	0.13	0.12	0.03
	D	0.32	0.20	0.09	0.04	0.12	0.11	0.25	0.27	0.24	0.13	0.23	0.39	0.83	1.46	0.84	0.21
	E	0.19	0.09	0.04	0.01	0.06	0.06	0.15	0.25	0.22	0.12	0.18	0.39	1.98	2.50	0.75	0.13
	F	0.04	0.03	0.01	0.01	0.01	0.02	0.05	0.17	0.14	0.03	0.07	0.20	1.19	1.60	0.32	0.06
	G	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.07	0.01	0.02	0.09	0.56	0.84	0.13	0.01
7.2	A	0.07	0.07	0.05	0.01	0.00	0.00	0.01	0.03	0.04	0.04	0.11	0.25	0.25	0.25	0.33	0.05
	B	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.01	0.04	0.08	0.06	0.07	0.09	0.01
	C	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.07	0.06	0.07	0.06	0.01
	D	0.10	0.10	0.03	0.01	0.00	0.01	0.03	0.07	0.10	0.11	0.25	0.38	0.58	1.14	0.50	0.05
	E	0.07	0.12	0.01	0.00	0.00	0.00	0.01	0.05	0.07	0.08	0.17	0.30	0.65	1.75	0.41	0.02
	F	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.02	0.07	0.08	0.03	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
9.8	A	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.16	0.10	0.11	0.24	0.00
	B	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.02	0.03	0.06	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.05	0.02	0.03	0.05	0.00
	D	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.16	0.24	0.13	0.50	0.29	0.01
	E	0.01	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.11	0.15	0.06	0.38	0.11	0.00
	F	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.02	0.02	0.03	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.01	0.00

Table 3-6. Joint Frequency Distributions for the 200 West Area at Ground Level (1983 - 1991). (2 sheets)

Wind speed[a] (m/s)	Stability type[b]	Wind direction																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.00
	D	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.09	0.03	0.07	0.08	0.00
	E	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.02	0.01	0.05	0.03	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	A	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	D	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.00	0.00	0.00
	E	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	F	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	A	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.07	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] Wind speed (m/s) classification as follows:

< 1.8	=	0.89
1.8 - 3.6	=	2.7
3.6 - 5.8	=	4.7
5.8 - 8.5	=	7.2
8.5 - 11	=	9.8
11 - 14	=	13
14 - 17	=	16
> 17	=	19

[b] Atmospheric stability classification (from NRC 1974) (Pasquill Category)

extremely unstable	=	A
moderately unstable	=	B
slightly unstable	=	C
neutral	=	D
slightly stable	=	E
moderately stable	=	F
extremely stable	=	G

Table 3-7. Joint Frequency Distributions for the 200 West Area at Stack Level (1983 - 1991). (2 sheets)

Wind speed[a] (m/s)	Stability type[b]	Wind direction																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.35	0.18	0.20	0.24	0.38	0.23	0.17	0.09	0.10	0.06	0.05	0.06	0.10	0.10	0.12	0.18
	B	0.12	0.10	0.09	0.10	0.13	0.08	0.06	0.03	0.05	0.02	0.01	0.02	0.04	0.05	0.06	0.08
	C	0.11	0.08	0.07	0.10	0.13	0.09	0.07	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.08	0.08
	D	0.62	0.42	0.39	0.45	0.60	0.41	0.36	0.27	0.21	0.16	0.17	0.12	0.26	0.32	0.42	0.39
	E	0.23	0.16	0.17	0.15	0.31	0.26	0.23	0.27	0.27	0.16	0.16	0.19	0.31	0.28	0.24	0.22
	F	0.13	0.08	0.08	0.09	0.19	0.20	0.28	0.31	0.33	0.16	0.16	0.21	0.40	0.29	0.23	0.15
	G	0.07	0.03	0.05	0.05	0.12	0.11	0.16	0.21	0.20	0.09	0.09	0.10	0.25	0.14	0.12	0.07
2.7	A	0.60	0.40	0.29	0.33	0.59	0.52	0.42	0.24	0.20	0.11	0.14	0.14	0.20	0.24	0.35	0.43
	B	0.18	0.13	0.06	0.09	0.16	0.12	0.11	0.07	0.07	0.03	0.02	0.04	0.06	0.07	0.14	0.13
	C	0.18	0.11	0.06	0.10	0.13	0.13	0.15	0.07	0.05	0.02	0.02	0.04	0.05	0.08	0.16	0.15
	D	0.81	0.42	0.39	0.32	0.63	0.50	0.62	0.37	0.29	0.13	0.16	0.22	0.42	0.59	0.71	0.68
	E	0.26	0.13	0.14	0.13	0.27	0.26	0.25	0.30	0.32	0.14	0.21	0.29	0.58	0.60	0.57	0.28
	F	0.15	0.06	0.05	0.04	0.16	0.12	0.20	0.20	0.28	0.16	0.19	0.26	0.64	0.55	0.37	0.17
	G	0.04	0.02	0.03	0.03	0.07	0.07	0.10	0.11	0.11	0.06	0.07	0.12	0.46	0.27	0.14	0.06
4.7	A	0.35	0.27	0.11	0.05	0.12	0.10	0.14	0.15	0.14	0.07	0.15	0.29	0.30	0.31	0.34	0.22
	B	0.11	0.08	0.03	0.01	0.04	0.05	0.06	0.06	0.03	0.02	0.05	0.06	0.08	0.10	0.11	0.09
	C	0.09	0.06	0.04	0.02	0.03	0.02	0.06	0.05	0.05	0.02	0.02	0.03	0.07	0.08	0.12	0.05
	D	0.38	0.26	0.14	0.07	0.17	0.16	0.27	0.24	0.20	0.11	0.19	0.25	0.61	0.90	0.79	0.34
	E	0.20	0.11	0.05	0.04	0.12	0.13	0.23	0.23	0.23	0.11	0.15	0.31	1.05	0.95	0.65	0.25
	F	0.08	0.03	0.02	0.03	0.05	0.09	0.11	0.17	0.19	0.10	0.13	0.27	0.89	0.92	0.44	0.13
	G	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.10	0.06	0.02	0.05	0.10	0.49	0.38	0.15	0.04
7.2	A	0.11	0.11	0.05	0.02	0.01	0.02	0.02	0.04	0.06	0.05	0.10	0.25	0.25	0.26	0.32	0.07
	B	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.05	0.07	0.10	0.08	0.03
	C	0.03	0.03	0.02	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.02	0.07	0.08	0.11	0.06	0.01
	D	0.19	0.13	0.06	0.01	0.03	0.02	0.10	0.01	0.15	0.09	0.20	0.32	0.59	1.11	0.54	0.11
	E	0.13	0.08	0.03	0.02	0.04	0.04	0.11	0.06	0.13	0.09	0.15	0.31	1.52	1.67	0.62	0.12
	F	0.04	0.03	0.01	0.01	0.03	0.02	0.07	0.08	0.09	0.03	0.06	0.15	0.92	1.03	0.32	0.07
	G	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.04	0.01	0.01	0.05	0.28	0.51	0.13	0.01
9.8	A	0.03	0.05	0.04	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.07	0.14	0.15	0.15	0.23	0.02
	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.05	0.04	0.06	0.00
	C	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.04	0.04	0.04	0.05	0.00
	D	0.06	0.06	0.01	0.01	0.00	0.01	0.03	0.00	0.07	0.08	0.16	0.29	0.47	0.81	0.35	0.04
	E	0.09	0.09	0.01	0.00	0.01	0.00	0.06	0.02	0.08	0.07	0.13	0.24	0.99	1.92	0.41	0.03
	F	0.03	0.03	0.00	0.00	0.01	0.00	0.02	0.03	0.04	0.01	0.02	0.06	0.45	0.72	0.13	0.01
	G	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.02	0.13	0.29	0.04	0.00
13	A	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.14	0.08	0.09	0.19	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.04	0.02	0.03	0.05	0.00

Table 3-7. Joint Frequency Distributions for the 200 West Area at Stack Level (1983 - 1991). (2 sheets)

Wind speed[a] (m/s)	Stability type[b]	Wind direction																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.04	0.01	0.02	0.04	0.00
	D	0.02	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.04	0.07	0.15	0.23	0.25	0.77	0.37	0.02
	E	0.05	0.08	0.02	0.00	0.00	0.00	0.02	0.00	0.03	0.04	0.11	0.19	0.36	1.26	0.30	0.01
	F	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.02	0.12	0.29	0.03	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.13	0.01	0.00
16	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.02	0.02	0.05	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.02	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01	0.02	0.00
	D	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.13	0.13	0.04	0.29	0.14	0.00
	E	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.07	0.10	0.06	0.30	0.10	0.00
	F	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00
19	A	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.01	0.00
	B	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
	C	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
	D	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.07	0.04	0.03	0.02	0.00
	E	0.02	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.02	0.01	0.03	0.01	0.00
	F	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	G	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] Wind speed (m/s) classification as follows:

< 1.8	=	0.89
1.8 - 3.6	=	2.7
3.6 - 5.8	=	4.7
5.8 - 8.5	=	7.2
8.5 - 11	=	9.8
11 - 14	=	13
14 - 17	=	16
> 17	=	19

[b] Atmospheric stability classification (from NRC 1974) (Pasquill Category)

extremely unstable	=	A
moderately unstable	=	B
slightly unstable	=	C
neutral	=	D
slightly stable	=	E
moderately stable	=	F
extremely stable	=	G

Table 3-8. Ring Correspondence to Transportation Distances.

Ring number	Location (mi)	Ring midpoint (mi)
1	00 - 01	0.5
2	01 - 02	1.5
3	02 - 03	2.5
4	03 - 04	3.5
5	04 - 05	4.5
6	05 - 10	7.5
7	10 - 20	15.0
8	20 - 30	25.0
9	30 - 40	35.0
10	40 - 50	45.0

Table 3-9. Definition of Directional Sectors.

Degrees	Sector
180.0	S
202.5	SSW
225.0	SW
247.5	WSW
270.0	W
292.5	WNW
315.0	NW
337.5	NNW
0	N
22.5	NNE
45.0	NE
67.5	ENE
90.0	E
112.5	ESE
135.0	SE
157.5	SSE

Table 3-10. 99.5 Percentile $\bar{\chi}/Q'$ Values and 95 Percentile $\bar{\chi}/Q'$s at Site Boundary Locations for a Maximum Individual for Ground and Stack Level Acute and Chronic Releases.

Sector	Distance (km)	Ground level release	Stack level release
		$\bar{\chi}/Q'$ (s/m^3) Chronic	$\bar{\chi}/Q'$ (s/m^3) Chronic
S	15.0	3.62 E-08	9.69 E-09
SSW	15.4	2.09 E-08	6.05 E-09
SW	16.1	1.94 E-08	4.99 E-09
WSW	13.2	2.57 E-08	5.86 E-09
W	12.5	5.02 E-08	1.03 E-08
WNW	13.2	3.85 E-08	7.83 E-09
NW	16.5	3.29 E-08	7.04 3-09
NNW	17.4	3.12 E-08	6.23 E-09
N	19.2	2.91 E-08	5.47 E-09
NNE	26.0	1.07 E-08	2.37 E-09
NE	28.9	1.09 E-08	2.65 E-09
ENE	25.6	1.72 E-08	3.92 E-09
E	25.2	4.82 E-08	9.21 E-09
ESE	30.0	3.95 E-08	9.47 E-09
SE	25.2	2.95 E-08	7.86 E-09
SSE	22.9	1.85 E-08	5.29 E-09

Note: This table needs validating in the next annual FSAR update.

Table 3-11. Geologic and Hydrogeologic Characteristics of the Pasco Basin.

Geologic Time Scale			Geologic Characteristics				Hydrogeology	
Era	Period	Epoch	Radiogenic Date, Years Before Present	Stratigraphic Unit	Bed or Flow Unit	General Lithologic Character	Average Thickness (ft)	Hydrologic Character	Aquifer
Cenozoic	Quaternary	Holocene	6,600 — 10,000	Alluvium Colluvium and Eolian Sediments		Sands, silts, gravels, and clays modified by wind erosion	Dunes to 50	Occur everywhere above the water table	Dry
		Pleistocene	12,500	Glaciofluvial Sands and Gravels (Hanford Formation)	Touchet Silts	Fine-grained facies of the glacio-fluvial deposits. Bedded in quiet water	0 - 400	Occur above the water table, except between the high terrace plateaus and the Columbia River. Has very high transmissivity and storage	Occasionally an unconfined aquifer or dry
			>12,000		Pasco Gravels	Predominantly coarse-grained gravels. Cobbles and sands with cut-and-fill structure			
			<18,000		Palouse Soil	Calcareous sand and silt Eolian deposit mainly derived from Ringold Formation	0 - 80	Above water table when present	Dry
			40,000 — 1,000,000	Ringold Formation	Upper Ringold	Locally capped by Caliche. Mostly well-bedded fluvial silts and sands with some gravels	0 - 400	Sands and gravel beds have very high hydraulic conductivity and storage. Some beds of silty clay or clay are essentially impermeable	Local confined and unconfined aquifer
					Middle Ringold	Sands and gravels, well sorted, compact, but variably cemented	0 - 400		
					Lower Ringold	Silts and clays with interbedded gravels and sands. Clay is characteristically blue, but may be green, brown, or tan	0 - 400		Aquitard
	Tertiary	Pliocene	4,000,000 — 5,500,000		Saddle Mountains	Basalt flows with interflow zones. Several sedimentary interbeds or Ellensburg Formation are present	900	Flows are dense with low-hydraulic conductivity. Interflows and interbeds have higher hydraulic conductivity and transmissivity	Confined aquifers
		Miocene	11,000,000 — 15,000,000	Columbia River Basalt Group	Wanapum	Basalt flows with interflow zones. Few interbeds of Ellensburg Formation are present	1,000		
					Grande Ronde	Basalt flows with interflow zones. Interbeds of Ellensburg Formation are infrequent and very thin when present	3,000		

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Table 3-12. Hydraulic Conductivity of Unconfined Aquifer.

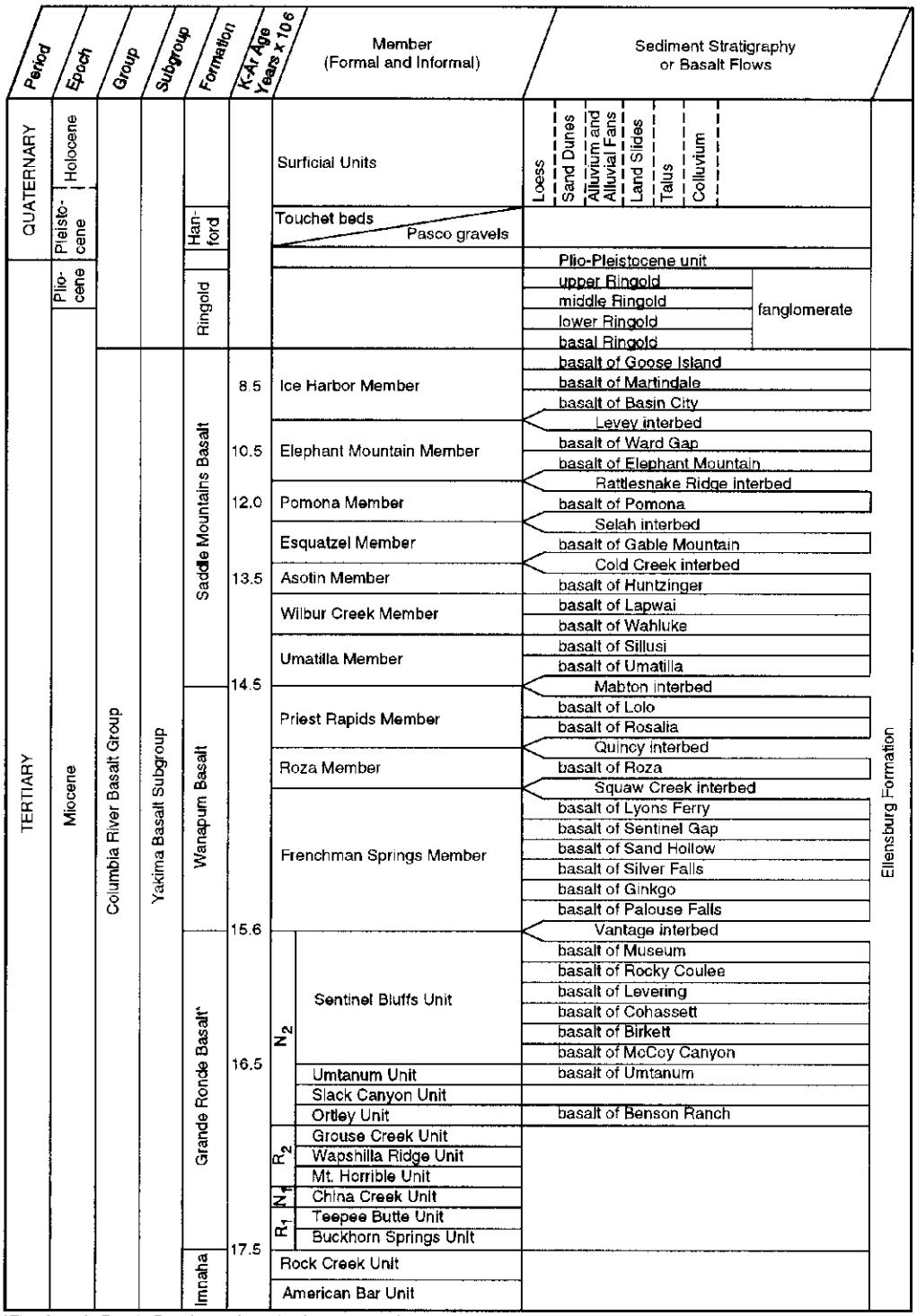
Interval tested (formation)	Hydraulic conductivity (ft/d)
Hanford	500 to 20,000
Hanford and Ringold	100 to 1,000
Ringold (including clay)	1 to 200

Table 3-13. Transmissivity of Unconfined Aquifer.

Region	Transmissivity (ft^2/d)
North of Gable Butte and Gable Mountain	4,000 to 25,000
On the flank of Gable Butte and Gable Mountain and along Paleochannels	40,000 to 600,000
Other areas of the Hanford Site	2,000 to 40,000

NOTE: Storage coefficient ranges from 0.05 to 0.15 throughout the Hanford Site.

Table 3-14. Pasco Basin Stratigraphic Nomenclature.



*The Grande Ronde Basalt consists of at least 120 major basalt flows. Only a few flows have been named.
N_2, R_2, N_1 and R_1 are magnetostratigraphic units.

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Table 3-15a. Eastern Washington Earthquake Summary. (3 sheets)

Date	Universal time	Intensity[a]/ magnitude	Coordinates	Remarks
Earthquakes with magnitude ≥3 or intensity ≥IV, 1866 to 1969 (source: WPPSS, 1981, pp. 2.5-299 to 385).				
November 24, 1866	18:10:00.0	IV	45.595° N, 121.173° W	The Dalles, Oregon
December 15, 1872	05:40:00.0	IX	49.000° N, 121.000° W	Lake Chelan, Washington
September 2, 1891	10:30:LT	IV	47.100° N, 118.400° W	Ritzville, Washington
September 17, 1891	04:30:00.0	IV	44.940° N, 121.033° W	Salem, Oregon
February 29, 1892	10:45:00.0	IV	45.595° N, 121.173° W	The Dalles, Oregon
March 5, 1892	LT	VI	46.600° N, 120.500° W	North Yakima, Washington
March 5, 1893	LT	VI	45.900° N, 119.333° W	Umatilla, Oregon
December 15, 1897	LT	V	47.800° N, 120.000° W	Lakeside, Washington
October 18, 1905	23:LT	V	47.800° N, 120.000° W	Chelan, Washington
January 2, 1906	LT	VI	48.700° N, 117.800° W	Stevens County, Washington
November 2, 1906	01:49:00.0	V	48.500° N, 117.900° W	Reported felt information
February 18, 1907	12:20 LT	V	47.842° N, 120.023° W	Chelan, Washington
January 21, 1909	05:LT	IV	47.800° N, 120.000° W	Chelan, Washington
May 24, 1909	22:LT	V	47.730° N, 120.360° W	Chelan-Leavenworth, Washington
July 5, 1911	08:00:00.0	V	46.998° N, 120.540° W	Ellensburg, Washington
October 14, 1913	23:00:00.0	V	45.700° N, 117.100° W	Reported felt information
March 5, 1915	05:10:00.0	IV	47.830° N, 120.020° W	Lakeside, Washington
March 5, 1915	05:30:00.0	IV	47.830° N, 120.020° W	Lakeside, Washington
July 18, 1915	20:54:00.0	IV	47.830° N, 120.020° W	Lakeside, Washington
August 18, 1915	14:05:00.0	V	48.500° N, 121.400° W	Felt over 78,000 km^2 (30,000 mi^2)
December 10, 1915	20:45:00.0	IV	47.672° N, 117.405° W	Spokane, Washington
February 21, 1918	LT	IV	46.867° N, 121.333° W	Bumping Lake, Washington
February 28, 1918	23:15:00.0	V	46.500° N, 120.500° W	Near Yakima, Washington
March 12, 1918	03:26:00.0	V	47.600° N, 117.000° W	Reported felt information
April 18, 1918	21:13:00.0	IV	47.600° N, 117.400° W	White Bluffs Prairie, Washington
November 1, 1918	17:20:00.0	VI	46.858° N, 119.375° W	Corfu, Washington
October 7, 1920	02:LT	V	47.633° N, 120.067° W	Waterville, Washington
November 28, 1920	11:30:00.0	IV	45.700° N, 121.500° W	Hood River, Oregon
September 14, 1921	11:00:00.0	VI	46.100° N, 118.250° W	Dixie-Walla Walla, Washington
June 1, 1922	23:30:00.0	IV	47.672° N, 117.405° W	Spokane, Washington
January 6, 1924	13:09:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
January 6, 1924	23:10:00.0	V	45.800° N, 118.300° W	Milton and Weston, Oregon
May 27, 1924	00:19:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
November 28, 1925	01:25:00.0	4.30 ML	47.500° N, 116.000° W	-
April 23, 1926	13:56:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
October 17, 1926	02:45:00.0	V	45.730° N, 121.483° W	White Salmon, Washington
November 27, 1926	18:25:LT	V	47.500° N, 116.000° W	Near Rathdrum, Idaho
December 30, 1926	17:57:00.0	VI	47.700° N, 120.200° W	Chelan-East Central Washington
January 3, 1927	04:58:00.0	VI	47.593° N, 120.658° W	Leavenworth, Washington
September 3, 1930	13:00:00.0	V	47.300° N, 117.804° W	Near Lamont, Washington
December 8, 1931	14:25:00.0	IV	47.830° N, 120.020° W	Lakeside-Chelan Falls, Washington
May 31, 1933	20:20:00.0	IV	47.842° N, 120.013° W	Chelan, Washington
May 31, 1933	20:30:00.0	IV	47.842° N, 120.013° W	Chelan, Washington
March 9, 1934	16:00:00.0	IV	47.830° N, 120.020° W	Lakeside, Washington
September 18, 1934	24:00:LT	V	46.998° N, 120.540° W	Ellensburg, Washington
September 22, 1934	11:30:LT	IV	46.998° N, 120.540° W	Ellensburg, Washington
September 22, 1934	17:37:LT	IV	46.998° N, 120.540° W	Ellensburg, Washington
September 26, 1934	16:15:LT	V	46.998° N, 120.540° W	Ellensburg, Washington

Table 3-15a. Eastern Washington Earthquake Summary. (3 sheets)

Date	Universal time	Intensity[a]/ magnitude	Coordinates	Remarks
Earthquakes with magnitude ≥3 or intensity ≥IV, 1866 to 1969 (source: WPPSS, 1981, pp. 2.5-299 to 385).				
September 26, 1934	16:45:LT	V	46.998° N, 120.540° W	Ellensburg, Washington
September 26, 1934	21:15:LT	V	46.998° N, 120.540° W	Ellensburg, Washington
October 4, 1934	02:26:LT	IV	46.998° N, 120.540° W	Ellensburg, Washington
October 11, 1934	21:19:LT	IV	46.998° N, 120.540° W	Ellensburg, Washington
October 19, 1934	23:31:LT	V	46.998° N, 120.540° W	Ellensburg, Washington
November 1, 1934	07:28:LT	V	46.998° N, 120.540° W	Ellensburg, Washington
November 2, 1934	15:17:LT	V	46.998° N, 120.540° W	Ellensburg, Washington
July 9, 1935	22:45:00.0	V	47.700° N, 120.000° W	Near Chelan Falls, Washington
October 12, 1935	01:03:00.0	V	47.662° N, 120.223° W	Entiat, Washington
November 1, 1935	03:35:00.0	IV	47.472° N, 115.925° W	Wallace, Idaho
July 16, 1936	07:07:49.0	VII 6.10 ML	46.208° N, 118.233° W	Milton-Freewater, Oregon
July 18, 1936	16:30:00.0	V	45.933° N, 118.383° W	Milton-Freewater, Oregon
July 30, 1936	11:20:00.0	IV	45.935° N, 118.388° W	Freewater, Oregon
July 30, 1936	12:00:00.0	IV	45.935° N, 118.388° W	Freewater, Oregon
July 30, 1936	12:20:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
August 4, 1936	09:19:00.0	V	45.800° N, 118.600° W	Helix, Oregon
August 28, 1936	04:39:00.0	V	45.933° N, 118.383° W	Milton-Freewater, Oregon
February 9, 1937	22:20:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
June 4, 1937	14:43:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
August 11, 1938	18:52:00.0	IV	45.935° N, 118.388° W	Milton, Oregon
October 27, 1938	23:10:00.0	IV	45.935° N, 118.388° W	Milton, Oregon
January 26, 1939	07:59:00.0	IV	45.700° N, 118.700° W	Mission, Oregon
March 24, 1940	03:04:00.0	IV	46.000° N, 121.200° W	Mt. Rainier, Washington
April 7, 1941	09:25:00.0	VI 4.50	48.300° N, 119.600° W	Felt over 14,000 km^2 (5,500 mi^2)
April 12, 1941	17:40:00.0	IV	47.648° N, 120.069° W	Waterville, Washington
February 23, 1942	14:03:00.0	V	47.600° N, 120.200° W	Wenatchee-Chelan, Washington
June 12, 1942	09:30:00.0	V	44.900° N, 117.100° W	Halfway and Pine, Oregon
October 14, 1942	11:30:00.0	V	48.310° N, 120.652° W	Stehekin, Washington
November 1, 1942	18:50:06.0	VI 5.50 ML	48.000° N, 116.700° W	Sandpoint, Idaho
April 24, 1943	00:10:46.0	VI	47.300° N, 120.600° W	Felt over 24,000 km^2 (10,000 mi^2)
September 22, 1943	21:50:LT	IV	47.967° N, 119.000° W	Grande Coulee, Washington
September 2, 1944	01:25:14.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
September 20, 1944	03:00:00.0	IV	44.900° N, 116.900° W	Rockville, Oregon
October 31, 1944	11:34:28.7	V	47.800° N, 120.600° W	-
December 25, 1944	13:12:08.8	IV	47.662° N, 120.223° W	Entiat, Washington
January 4, 1945	02:34:48.7	V	47.662° N, 120.223° W	Entiat, Washington
February 27, 1945	11:00:00.0	IV	48.480° N, 121.190° W	Winthrop, Washington
March 2, 1945	07:54:59.3	IV	47.662° N, 120.223° W	Entiat, Washington
September 23, 1945	02:40:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
February 5, 1946	16:12:42.0	IV	47.800° N, 120.200° W	Chelan-Ardenvoir, Washington
February 6, 1946	03:20:00.0	IV	48.527° N, 121.430° W	Marblemount, Washington
December 22, 1947	10:30:00.0	IV	47.662° N, 120.223° W	Entiat, Washington
January 13, 1948	06:55:00.0	V	47.900° N, 120.300° W	Lucerne-Waterville, Washington
August 28, 1948	22:25:00.0	IV	47.957° N, 117.475° W	Deer Park, Washington
October 25, 1948	19:50:00.0	IV	47.842° N, 120.013° W	Chelan, Washington
December 20, 1948	16:18:00.0	IV	44.996° N, 120.215° W	Fossil, Oregon
March 15, 1949	20:53:11.0	4.80 ML	45.500° N, 117.000° W	-
October 20, 1949	16:00:00.0	IV	48.500° N, 120.500° W	Lost River, Washington

Table 3-15a. Eastern Washington Earthquake Summary. (3 sheets)

Date	Universal time	Intensity[a]/ magnitude	Coordinates	Remarks
Earthquakes with magnitude ≥3 or intensity ≥IV, 1866 to 1969 (source: WPPSS, 1981, pp. 2.5-299 to 385).				
March 8, 1950	06:25:00.0	IV	47.662° N, 120.223° W	Entiat, Washington
June 25, 1950	23:45:00.0	IV	47.491° N, 117.575° W	Cheney, Washington
January 4, 1951	13:45:00.0	V	47.700° N, 120.000° W	Chelan-Waterville, Washington
January 7, 1951	22:45:00.0	V	45.900° N, 119.200° W	McNary, Oregon
March 4, 1952	19:42:00.0	V	47.672° N, 117.405° W	Spokane, Washington
September 9, 1952	09:30:00.0	IV	48.698° N, 116.315° W	Felt Bonners Ferry, Idaho
September 9, 1952	09:45:00.0	IV	48.698° N, 116.315° W	Felt Bonners Ferry, Idaho
May 23, 1954	13:41:42.0	V	48.342° N, 120.137° W	Twisp, Washignton
June 8, 1954	00:16:13.0	V	47.500° N, 116.000° W	Mortaern-Coeur D'Alene, Idaho
February 6, 1955	LT	IV	47.967° N, 119.000° W	Grand Coulee, Washington
May 31, 1955	23:35:00.0	IV	47.680° N, 116.773° W	Felt Coeur D'Alene, Idaho
February 24, 1956	22:00:00.0	V	47.900° N, 119.100° W	Electric City, Washington
November 1, 1957	10:12:02.0	4.20 ML	46.700° N, 121.500° W	-
December 18, 1957	25:25:00.0	5.00 ML	47.500° N, 116.000° W	-
April 12, 1958	00:00:00.0	V	47.900° N, 119.100° W	Electric City, Washington
April 12, 1958	22:37:11.0	4.10 ML	48.000° N, 120.000° W	-
January 21, 1959	07:41:00.0	IV	46.070° N, 118.328° W	Walla Walla, Washington
July 11, 1959	15:LT	IV	47.600° N, 119.300° W	Deep Lake, Washington
August 6, 1959	03:44:32.0	4.40 ML	47.800° N, 119.900° W	-
November 9, 1959	21:10:00.0	IV	45.353° N, 119.550° W	Heppner, Oregon
May 22, 1961	01:57:51.4	IV	47.600° N, 120.200° W	-
June 28, 1961	10:22:52.9	IV	47.537° N, 120.293° W	Rocky Reach Dam, Washington
October 31, 1961	02:35:00.0	4.30 ML	48.400° N, 120.000° W	-
October 31, 1961	03:34:29.8	V	48.400° N, 120.000° W	Felt Over 3,000 km^2 (1,200 mi^2)
January 15, 1962	05:29:00.0	4.30 ML	47.800° N, 120.200° W	-
December 22, 1963	02:54:04.9	V 4.40 MB	48.590° N, 119.760° W	Reported felt information
April 28, 1965	19:00:00.0	4.30 ML	48.600° N, 116.900° W	-
November 7, 1965	16:41:47.4	4.30 MB	44.900° N, 117.000° W	-
July 23, 1966	01:57:08.8	4.30 MB	47.200° N, 119.500° W	-
December 30, 1966	03:51:40.3	4.20 MB	44.900° N, 117.000° W	-

[a]All intensities are modified Mercalli.
LT = Local time.
MB = Body-wave magnitude.
ML = Local (Richter) magnitude.

Table 3-15b. Eastern Washington Earthquake Summary. (4 sheets)

Date	Universal time	Magnitude[a]	Coordinates	Depth (km)	Remarks
Earthquakes with magnitude ≥3 within the Columbia Plateau, 1969 to 1986 and 1991 to 1995. (source: University of Washington On-line Earthquake Catalog).					
April 19, 1969	05:46:03:20	3.1	45.889° N, 119.742° W	3.00	-
April 20, 1969	02:19:16:04	3.2	48.250° N, 119.272° W	5.72	-
May 11, 1969	05:50:11:92	3.1	48.194° N, 119.228° W	3.00	-
August 2, 1969	03:04:16:35	3.4	47.198° N, 117.375° W	15.22	-
August 31, 1969	16:27:35:05	3.1	46.286° N, 120.776° W	1.50	-
January 1, 1970	06:44:28:24	3.0	46.324° N, 118.396° W	0.68	-
July 11, 1970	10:24:31:17	3.0	48.180° N, 121.311° W	34.20	-
July 29, 1970	20:42:31:56	3.0	48.175° N, 119.313° W	3.00	-
August 23, 1970	11:11:40:67	3.3	46.745° N, 119.345° W	2.08	-
September 11, 1970	02:20:54:11	3.5	46.642° N, 120.386° W	9.57	-
October 2, 1970	15:56:24:73	3.3	46.760° N, 119.371° W	3.78	-
October 19, 1970	07:15:08:09	3.2	46.904° N, 117.684° W	3.00	-
November 6, 1970	18:15:16:77	3.1	46.691° N, 118.884° W	3.00	-
January 26, 1971	10:17:05:02	3.2	46.921° N, 119.554° W	1.36	-
May 22, 1971	15:57:10:83	3.3	47.788° N, 118.964° W	14.54	-
July 13, 1971	23:29:24:49	3.5	44.922° N, 117.946° W	3.00	-
August 18, 1971	23:44:25:96	3.2	47.610° N, 120.083° W	1.86	-
October 25, 1971	18:52:49:98	3.8	46.709° N, 119.548° W	0.07	-
November 23, 1971	02:12:15:42	4.1	48.233° N, 121.248° W	18.20	-
June 19, 1972	23:57:57:57	3.2	48.131° N, 121.186° W	9.00	-
February 6, 1973	07:17:06:89	3.0	46.936° N, 120.896° W	8.00	-
September 4, 1973	17:56:49:92	3.7	48.239° N, 121.165° W	6.10	-
December 20, 1973	01:08:28:24	4.4	46.869° N, 119.354° W	2.35	-
June 15, 1975	17:51:31:49	3.1	46.237° N, 119.104° W	0.07	-
June 28, 1975	16:33:43:66	3.3	46.129° N, 119.702° W	10.67	-
July 1, 1975	05:28:02:24	3.6	45.628° N, 120.002° W	1.50	-
July 7, 1975	20:41:17:79	3.2	46.074° N, 118.449° W	2.50	-
September 18, 1975	12:19:28:51	3.5	47.796° N, 118.231° W	0.50	-
April 13, 1976	00:47:17.1	4.8 ML, 4.5 MB	45.22° N, 120.77° W	15	Depth constrained (NOAA)
April 17, 1976	02:11:44.1	4.2 ML	45.08° N, 120.79° W	15	Depth constrained (NOAA)
May 15, 1976	13:04:53:56	3.0	47.707° N, 120.033° W	4.58	-
June 15, 1976	01:01:45:68	3.0	46.488° N, 117.683° W	0.90	-
June 15, 1976	09:08:04:90	3.0	47.627° N, 120.296° W	0.55	-
July 23, 1976	17:59:36:78	3.0	46.080° N, 118.745° W	2.70	-
August 30, 1976	16:34:01:55	3.0	47.649° N, 120.177° W	3.00	-
December 13, 1976	08:47:29:41	3.1	47.643° N, 120.120° W	5.60	-
January 27, 1977	07:47:29:20	3.2	46.939° N, 119.593° W	1.40	-
March 11, 1977	22:50:11:41	3.1	45.895° N, 119.675° W	0.08	-
July 13, 1977	07:15:05:68	3.8	47.058° N, 121.046° W	0.10	-
January 25, 1978	01:09:20:80	3.3	47.892° N, 120.108° W	1.03	-
March 22, 1978	03:08:59:57	3.3	48.090° N, 119.492° W	11.96	-
April 16, 1978	19:45:16:90	3.3	47.752° N, 120.234° W	0.71	-
June 11, 1978	02:43:55:05	3.1	46.841° N, 120.955° W	0.10	-
June 27, 1978	02:19:00:26	3.4	46.938° N, 121.137° W	3.10	-
October 10, 1978	12:04:27:93	3.1	47.901° N, 119.682° W	2.43	-
January 19, 1979	14:55:16:97	3.9	47.896° N, 119.686° W	6.69	-

Table 3-15b. Eastern Washington Earthquake Summary. (4 sheets)

Date	Universal time	Magnitude[a]	Coordinates	Depth (km)	Remarks
Earthquakes with magnitude ≥3 within the Columbia Plateau, 1969 to 1986 and 1991 to 1995. (source: University of Washington On-line Earthquake Catalog).					
January 21, 1979	20:40:06:14	3.0	47.895° N, 119.682° W	3.19	-
January 30, 1979	16:06:45:71	3.0	47.662° N, 120.120° W	5.06	-
February 17, 1979	08:36:21:41	3.6	46.169° N, 119.935° W	9.10	-
April 7, 1979	03:47:23:62	3.0	46.956° N, 120.412° W	9.83	-
April 8, 1979	07:29:37:81	4.2	45.995° N, 118.447° W	4.70	-
July 28, 1979	02:19:06:94	3.7	46.670° N, 120.591° W	0.10	-
November 10, 1979	04:53:29:82	3.2	47.720° N, 120.057° W	0.09	-
November 18, 1979	02:08:45:53	3.1	46.887° N, 119.567° W	1.10	-
November 24, 1979	11:51:14:98	3.4	46.931° N, 119.566° W	0.45	-
December 10, 1979	05:40:07:46	3.4	46.657° N, 120.575° W	5.10	-
November 19, 1980	21:35:24:07	3.3	46.950° N, 119.469° W	0.86	-
February 2, 1981	01:23:18:30	4.0	46.263° N, 120.989° W	1.98	Depth fixed
February 18, 1981	06:09:38:71	4.2	47.197° N, 120.892° W	3.37	-
March 15, 1981	07:23:66:85	3.6	47.987° N, 121.493° W	5.35	-
May 28, 1981	08:55:62:54	4.6	46.530° N, 121.398° W	2.98	-
May 28, 1981	09:01:45:90	5.0	46.525° N, 121.394° W	3.22	-
June 14, 1981	13:12:56:81	3.2	45.962° N, 120.507° W	13.58	-
July 22, 1981	06:05:50:38	3.0	47.777° N, 120.288° W	9.53	-
October 25, 1981	03:20:63:67	3.2	47.758° N, 120.196° W	7.58	-
January 23, 1982	15:31:37:16	3.2	46.546° N, 121.378° W	3.33	-
September 26, 1982	10:09:23:58	3.4	46.867° N, 121.048° W	3.25	-
March 22, 1983	12:47:02:37	3.8	45.992° N, 118.403° W	7.53	-
April 25, 1983	15:48:20:43	3.0	48.630° N, 119.567° W	8.03	Depth fixed
October 20, 1983	09:44:58:46	3.4	46.717° N, 119.584° W	1.86	-
November 14, 1983	11:18:60:40	3.8	46.655° N, 120.600° W	7.87	-
December 5, 1983	07:24:18:61	3.8	46.915° N, 120.713° W	7.76	Depth and location fixed
January 31, 1984	05:29:17:96	4.0	45.496° N, 116.673° W	5.65	Depth and location fixed
April 11, 1984	06:07:42:05	4.3	47.535° N, 120.185° W	8.02	-
June 18, 1984	19:34:08:93	3.1	45.486° N, 118.840° W	5.96	-
August 24, 1984	04:42:67:21	3.0	47.649° N, 120.955° W	0.75	Depth and location fixed
October 10, 1984	03:24:18:24	3.0	47.904° N, 119.079° W	15.39	-
January 9, 1985	05:46:13:26	3.3	47.064° N, 120.094° W	0.34	-
January 25, 1985	07:28:54:49	3.1	46.500° N, 120.632° W	16.63	-
January 31, 1985	03:02:35:09	3.3	47.059° N, 120.084° W	0.29	-
February 10, 1985	20:29:31:72	3.9	45.704° N, 119.634° W	18.41	-
March 9, 1985	01:31:24:44	3.3	46.984° N, 118.590° W	3.41	-
April 19, 1985	10:52:44:29	3.2	46.897° N, 120.284° W	5.35	-
June 9, 1985	01:24:51:45	3.2	46.675° N, 118.977° W	3.21	-
June 17, 1985	07:00:17:26	3.0	47.058° N, 120.077° W	0.28	-
July 16,1985	21:13:16:33	3.2	49.189° N, 121.009° W	0.02	Depth fixed
October 1, 1985	05:21:60:00	3.0	46.796° N, 120.048° W	1.09	-
October 1, 1985	06:53:11:58	3.0	46.789° N, 120.047° W	1.71	-
October 10, 1985	10:06:40:72	3.2	47.749° N, 120.265° W	7.04	-
November 22, 1985	18:09:56:76	3.2	47.263° N, 119.351° W	20.82	-
February 4, 1986	01:58:67:17	3.2	46.044° N, 118.810° W	7.80	-
April 8, 1986	10:57:37:58	3.3	47.770° N, 120.230° W	13.76	-
September 1, 1986	21:32:44:96	3.4	46.718° N, 119.285° W	14.09	-

Table 3-15b. Eastern Washington Earthquake Summary. (4 sheets)

Date	Universal time	Magnitude[a]	Coordinates	Depth (km)	Remarks
Earthquakes with magnitude ≥3 within the Columbia Plateau, 1969 to 1986 and 1991 to 1995. (source: University of Washington On-line Earthquake Catalog).					
July 6, 1991	13:49:59.46	3.4	46.937° N. 120.339° W	4.08	-
July 7, 1991	02:58:38.70	3.3	46.930° N. 120.338° W	3.84	-
November 24, 1991	21:11:22.49	3.2	47.604° N. 120.241° W	7.18	-
November 28, 1991	01:08:58.95	4.3	45.990° N. 118.317° W	9.47	-
December 15, 1991	22:14:53.12	3.3	45.995° N. 118.329° W	7.98	-
January 24, 1992	09:09:54.34	3.4	47.659° N. 120.132° W	7.36	-
February 18, 1992	16:04:42.79	3.2	46.951° N. 119.550° W	2.22	-
April 27, 1992	00:48:58.12	3.0	46.624° N. 118.906° W	1.04	Depth fixed
July 14, 1992	20:01:51.50	4.1	45.993° N. 118.309° W	11.62	Depth and location fixed
August 7, 1992	17:23:17.83	3.9	45.860° N. 119.590° W	0.57	-
October 26, 1992	07:56:35.25	3.5	46.857° N. 120.721° W	0.04	Depth fixed
October 17, 1993	01:51:02.97	3.1	44.217° N. 118.478° W	14.56	-
December 16, 1993	12:21:34.50	3.0	45.196° N. 120.090° W	6.69	-
January 5, 1994	03:37:25.61	3.0	48.515° N. 119.917° W	0.05	Depth fixed
January 13, 1994	08:02:38.90	3.4	46.887° N. 118.699° W	0.02	Depth fixed
June 18, 1994	07:01:07.28	4.3	47.621° N. 121.270° W	0.04	Depth fixed
November 13, 1994	16:50:47.20	3.3	46.592° N. 119.584° W	28.22	-
January 13, 1995	19:38:23.02	3.2	46.579° N. 120.711° W	13.17	-
March 9, 1995	07:22:36.62	3.0	47.191° N. 120.955° W	1.61	Depth and location fixed
June 12, 1995	01:48:24.40	3.3	46.405° N. 119.263° W	0.95	-
June 30, 1995	22:17:05.06	3.0	47.107° N. 120.528° W	11.23	-
July 13, 1995	10:28:50.27	3.7	46.819° N. 121.878° W	8.29	-
July 15, 1995	14:36:18.64	3.0	47.624° N. 122.202° W	24.98	Depth fixed
July 25, 1995	21:47:37.62	3.1	46.727° N. 122.789° W	1.48	-
July 28, 1995	21:47:56.94	3.2	46.767° N. 122.833° W	0.56	-
July 31, 1995	21:51:39.79	3.0	46.769° N. 122.835° W	1.74	-
August 3, 1995	21:42:41.15	3.1	46.769° N. 122.842° W	0.04	Depth fixed
August 4, 1995	21:58:51.62	3.0	46.734° N. 122.801° W	0.89	-
August 22, 1995	21:56:49.17	3.0	46.820° N. 122.813° W	0.05	Depth fixed
August 23, 1995	21:23:45.61	3.2	46.732° N. 122.796° W	0.04	Depth fixed
August 24, 1995	21:49:55.94	3.2	46.729° N. 122.799° W	0.47	-
August 26, 1995	21:36:26.51	3.0	46.777° N. 122.818° W	1.36	-
August 29, 1995	13:02:48.76	3.1	46.208° N. 119.906° W	15.34	-
August 29, 1995	21:43:03.67	3.1	46.730° N. 122.804° W	0.71	-
September 6, 1995	19:08:08.12	3.3	46.734° N. 122.805° W	9.30	-
September 6, 1995	22:05:38.27	3.0	46.754° N. 122.817° W	0.04	Fixed depth
September 7, 1995	21:43:49.65	3.3	46.775° N. 122.841° W	0.03	Fixed depth
September 8, 1995	22:13:27.23	3.1	46.768° N. 122.825° W	2.12	Fixed depth
September 11, 1995	21:27:38.36	3.0	46.774° N. 122.824° W	5.95	-
September 12, 1995	21:20:19.09	3.4	46.767° N. 122.839° W	0.84	-
September 14, 1995	21:45:04.74	3.3	46.773° N. 122.836° W	1.63	-
September 15, 1995	17:27:03.36	3.0	46.735° N. 122.798° W	0.86	-

Table 3-15b. Eastern Washington Earthquake Summary. (4 sheets)

Date	Universal time	Magnitude[a]	Coordinates	Depth (km)	Remarks
Earthquakes with magnitude ≥3 within the Columbia Plateau, 1969 to 1986 and 1991 to 1995. (source: University of Washington On-line Earthquake Catalog).					
September 16, 1995	21:32:38.35	3.1	46.768° N. 122.833° W	2.37	-
September 17, 1995	20:27:21.87	3.4	46.771° N. 122.832° W	4.43	Depth fixed
September 18, 1995	19:01:43.48	3.1	46.768° N. 122.823° W	2.70	-
September 19, 1995	21:28:00.92	3.1	46.775° N. 122.815° W	1.87	-
September 20, 1995	21:04:56.64	3.2	46.778° N. 122.822° W	1.08	-
September 21, 1995	21:23:16.97	3.2	46.733° N. 122.809° W	1.12	-
September 24, 1995	21:23:05.49	3.0	46.761° N. 122.813° W	2.67	-
September 25, 1995	22:42:52.59	3.0	46.777° N. 122.826° W	2.01	-
September 28, 1995	17:39:49.28	3.1	46.736° N. 122.792° W	1.20	-
September 29, 1995	21:03:42.57	3.4	46.772° N. 122.824° W	2.24	-
October 1, 1995	20:49:38.35	3.0	46.776° N. 122.821° W	2.38	-
October 2, 1995	20:06:41.85	3.4	46.748° N. 122.807° W	7.57	-
October 3, 1995	21:13:01.58	3.2	46.768° N. 122.840° W	2.03	-
October 4, 1995	20:04:03.93	3.4	46.775° N. 122.826° W	1.51	-
October 5, 1995	21:49:17.37	3.2	46.772° N. 122.820° W	1.39	-
October 6, 1995	18:57:56.93	3.2	46.768° N. 122.837° W	1.35	-
October 31, 1995	19:59:34.58	3.1	46.734° N. 122.809° W	0.04	Depth fixed
November 1, 1995	22:19:09.04	3.4	46.762° N. 122.836° W	2.50	-
November 2, 1995	14:30:14.29	3.1	46.150° N. 119.564° W	21.30	-
November 3, 1995	21:29:54.23	3.0	46.765° N. 122.825° W	2.28	-
November 3, 1995	23:12:16.55	3.0	46.766° N. 122.836° W	1.55	-
December 17, 1995	15:01:47.90	3.1	47.595° N. 120.219° W	12.42	-
December 27, 1995	22:52:54.84	3.1	46.778° N. 122.829° W	0.15	-

[a]Unless otherwise noted, all magnitudes are coda-length magnitudes.
MB = Body-wave magnitude.
ML = Local (Richter) magnitude.
NOAA = National Oceanic and Atmospheric Administration.

Table 3-16. Hanford Site Ashfall Particle Size Distribution.

Fraction (wt%)	Particle size (μm)
5	>150
64	75 - 150
5	45 - 75
24	20 - 45
1	3.5 - 20
1	<3.5

Table 3-17. Chemical Composition of Ash.

Major compound	Composition (%)
SiO_2(not free silica)	60.3
Al_2O_3	16.4
Fe_2O_3	5.61
CaO	5.55
Na_2O	4.83
MgO	2.77
K_2O	1.56
TiO_2	0.85
P_2O_5	0.46
MnO	0.087
Trace element	**Composition (ppm)**
Boron	34
Sulfur	1,100
Chlorine	500
Vanadium	127
Chromium	31
Cobalt	19
Nickel	27
Copper	41
Zinc	56
Gallium	8
Arsenic	2.6
Selenium	1
Bromine	1
Rubidium	27
Strontium	510
Yttium	12
Zirconium	160
Niobium	5.7
Molybdenum	4.4
Cadmium	4
Barium	--
Mercury	0.0070
Lead	6

NOTE: These were used as input data for the ashfall design basis for the Hanford Site.

Table 3-18. Water-Soluble Ions in Volcanic Ash.

Ion	Concentration (ppm)	Soil (ppm)
Cl^-	400.0	1.9
No_3^-	20.0	2.5
SO_2^-	750.0	2.2
Aluminum	0.25	1.8
Barium	0.18	0.03
Calcium	290.0	6.2
Iron	0.09	2.4
Potassium	40.0	1.4
Magnesium	38.0	2.0
Manganese	5.8	0.05
Sodium	210.0	4.6
Silicon	11.0	20.0
Strontium	1.6	0.02
Titanium	0.01	0.01
Zinc	0.3	0.4

Table 3-19. Equivalent Salt Deposit Densities.

Sample matrix	Equivalent salt for 100-m^2 sample (mg)	ESDD* (mg/cm^3)
Volcanic ash	132	0.40
Soil	20	0.06

*Calculated for a 3-mm ash layer uniformly deposited on an insulator surface. The ESDD is defined as the equivalent amount of salt (NaCl) that would yield the same conductivity as the contaminant (volcanic ash) in the same volume of water.

Table 3-20. Equivalent Salt Deposit Densities Severity Range.

ESDD (mg/cm^3)	Severity
0.0 to 0.03	Very Light
0.03 to 0.06	Light
0.06 to 0.10	Moderate
0.10 and up	Heavy

Table 3-21. Ashfall Loading Variables.

Ash depth		Ash density		Ash loading
in.	Condition	lb/ft^3	Condition	lb/ft^2
4.5	Uncompacted	72	Dry, loose	27
3	Compacted	96 101	Dry, compacted Wet, compacted	24* 25.5

*SDC 4.1, Rev 12 (DOE-RL 1993), specifies 24 lb/ft^2 as the design basis ashfall loading.

Figure 3-1. Location of the Hanford Site in the State of Washington.

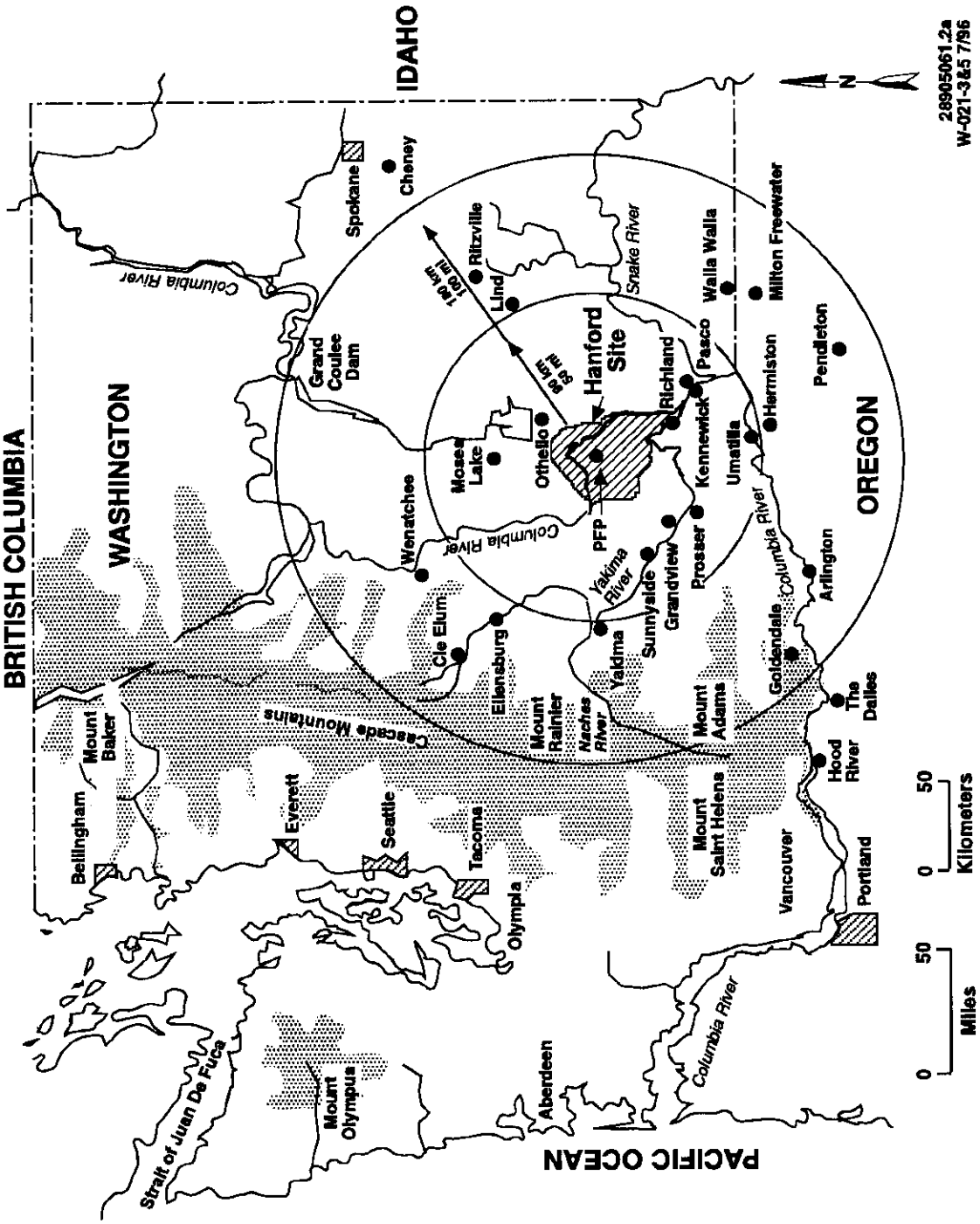
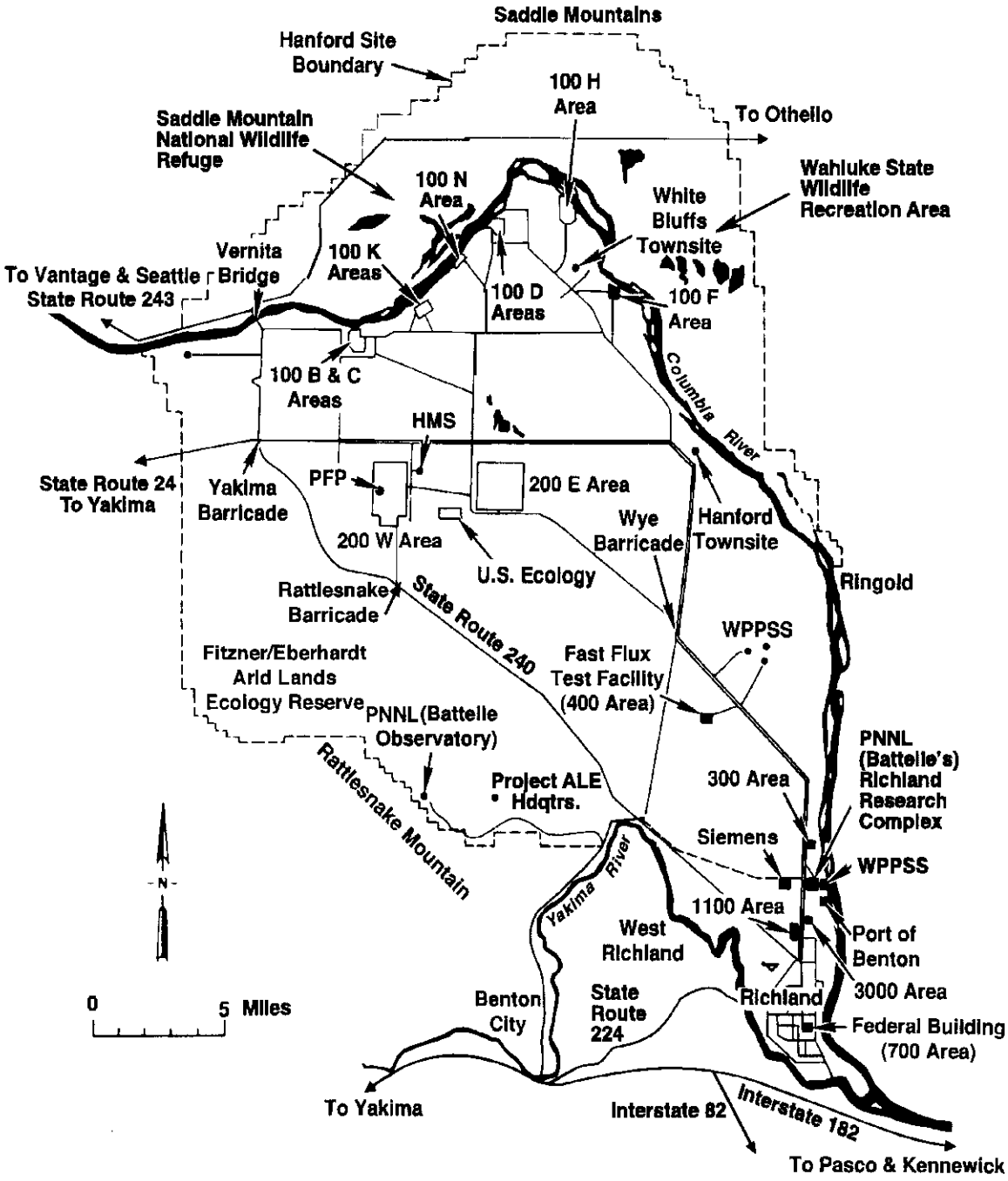
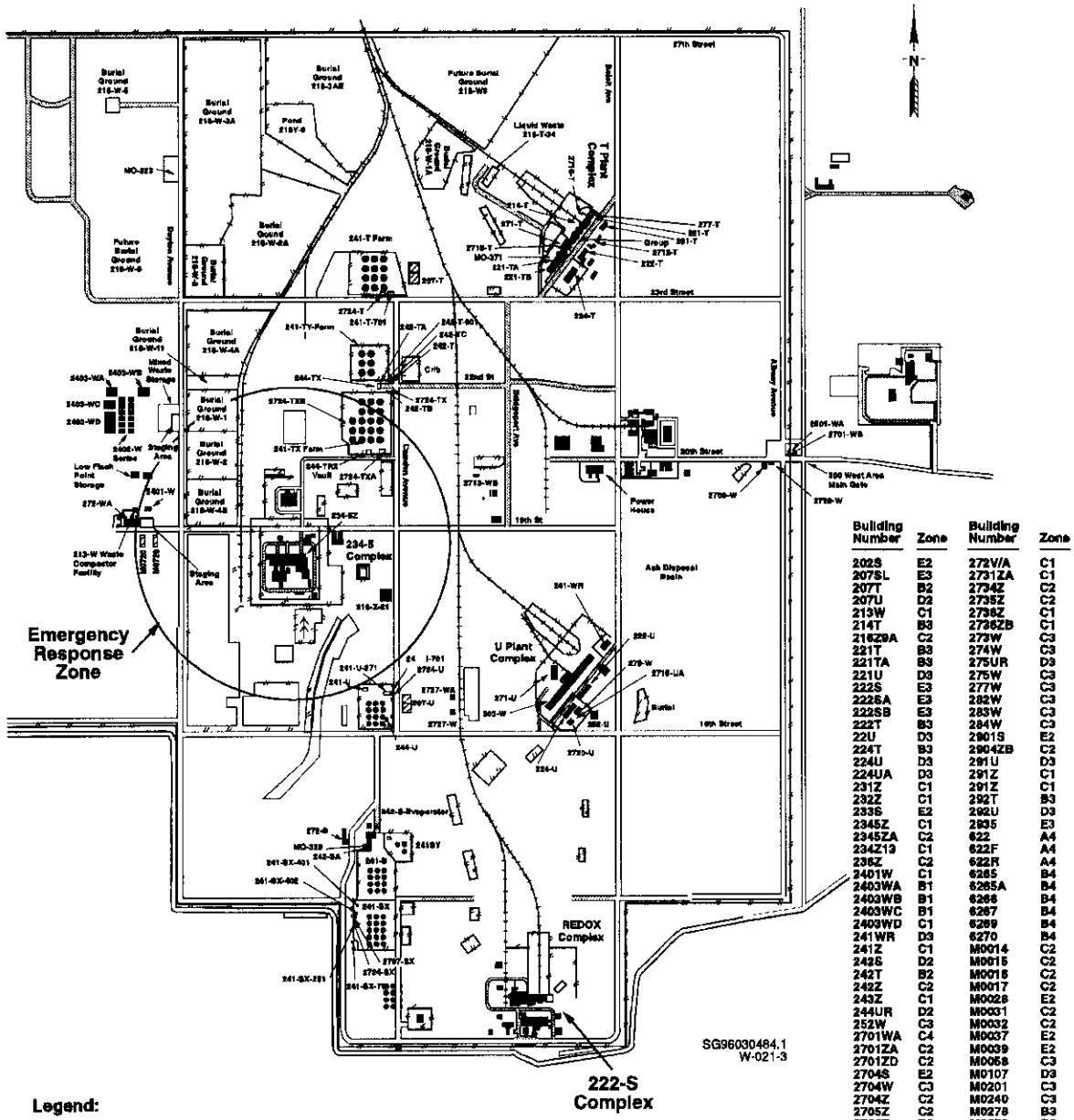


Figure 3-2. Hanford Site.



HMS - Hanford Meteorological Station
PNNL - Pacific Northwest National Laboratory
PFP - Plutonium Finishing Plant
WPPSS - Washington Public Power Supply System

Figure 3-3. 200 West Area.



Building Number	Zone	Building Number	Zone
202S	E2	272V/A	C1
207SL	E3	2731ZA	C1
207T	B2	2734Z	C2
207U	D2	2735Z	C2
213W	C1	2736Z	C1
214T	B3	2736ZB	C1
216Z9A	C2	273W	C3
221T	B3	274W	C3
221TA	B3	275UR	D3
221U	D3	275W	C3
222S	E3	277W	C3
222SA	E3	282W	C3
222SB	E3	283W	C3
222T	B3	284W	C3
22U	D3	2901S	E2
224T	B3	2904ZB	C2
224U	D3	291U	D3
224UA	D3	291Z	C1
231Z	C1	291Z	C1
232Z	C1	292T	B3
2336	E2	292U	D3
2345Z	C1	2935	E3
2345ZA	C2	622	A4
234Z13	C1	622F	A4
236Z	C2	622R	A4
2401W	C1	6285	B4
2403WA	B1	6285A	B4
2403WB	B1	6286	B4
2403WC	B1	6287	B4
2403WD	C1	6289	B4
241WR	D3	6270	B4
241Z	C1	M0014	C2
242S	D2	M0015	C2
242T	B2	M0016	C2
242Z	C2	M0017	C2
243Z	C1	M0026	E2
244UR	D2	M0031	C2
252W	C3	M0032	C2
2701WA	C4	M0037	E2
2701ZA	C2	M0039	E2
2701ZD	C2	M0058	C3
2704S	E2	M0107	D3
2704W	C3	M0201	C3
2704Z	C2	M0240	C3
2705Z	C2	M0278	B3
2706T	B3	M0279	B3
2707SX	E2	M0280	B4
2707W	C3	M0281	C1
2709W	C4	M02W215	C3
270Z	C1	M02W221	C3
2713W	B3	M0321	D3
2713WB	C2	M0328	D2
2714U	D3	M0346	E2
2715T	B3	M0371	B3
2715UA	D3	M0377	C3
2716S	E3	M0406	C3
2719WA	C3	M0412	C3
271T	B3	M0419	D3
271U	D3	M0658	C2
2720W	C4	M0667	B4
2721Z	C1	M0716	C2
2722W	B3	M0720	C1
2723W	C3	M0721	C1
2724WA	C3	M0837	C2
2724WB	C3	M0841	C2
2727W	D2	M0847	C2
2727WA	D2	M0892	B3
2728W	C3	M0924	E2
2729Z	C2	M0936	E2
272S	D2	M0939	C2
272U	D3	M0947	E2
272W	C3		

Figure 3-4. Plutonium Finishing Plant Site.

(Ref. Dwg. H-2-80249, Sheet 1)

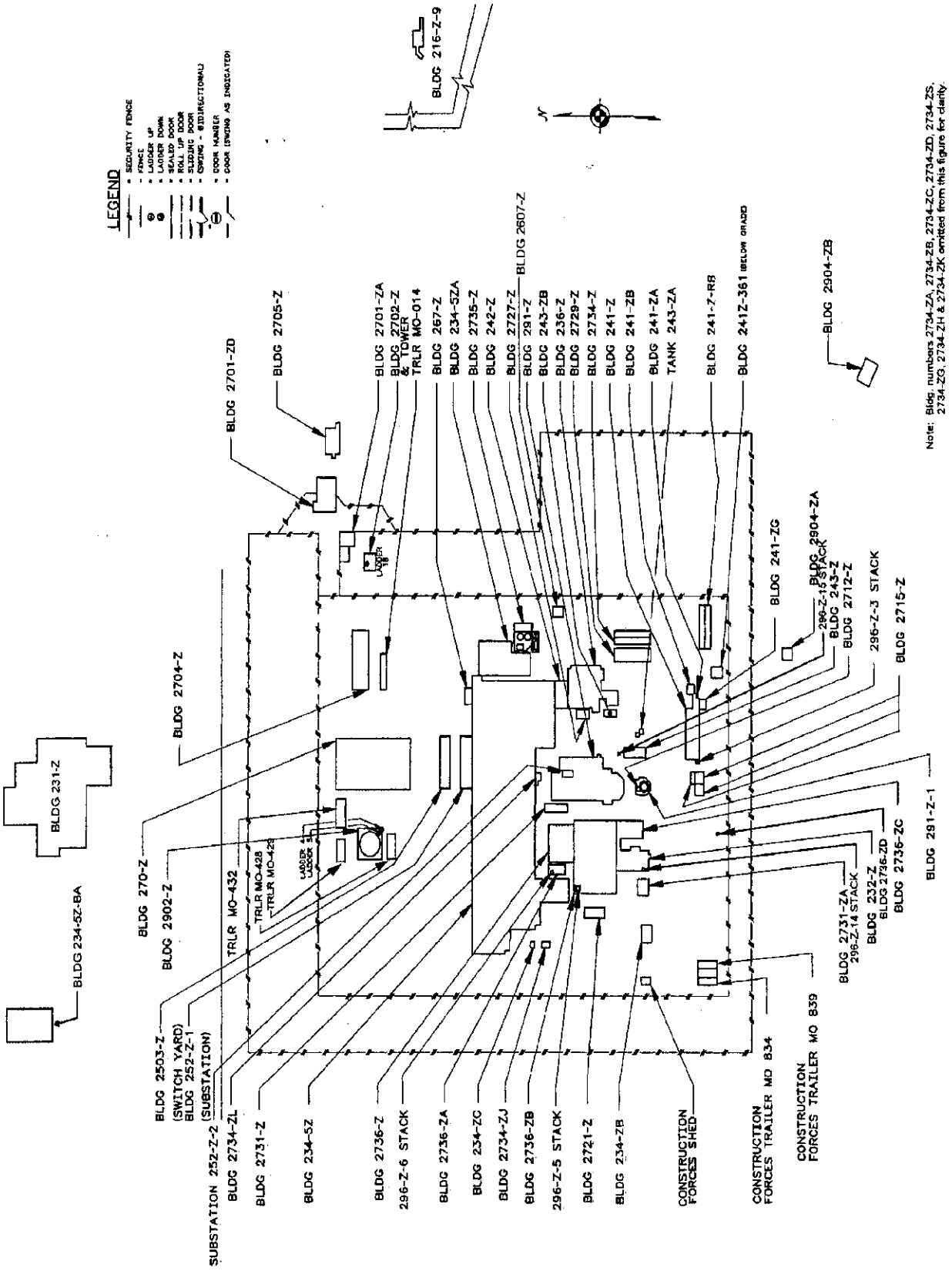


Figure 3-5. 1990 Population Centers within a 50-mi Radius from Hanford Meteorological Station.

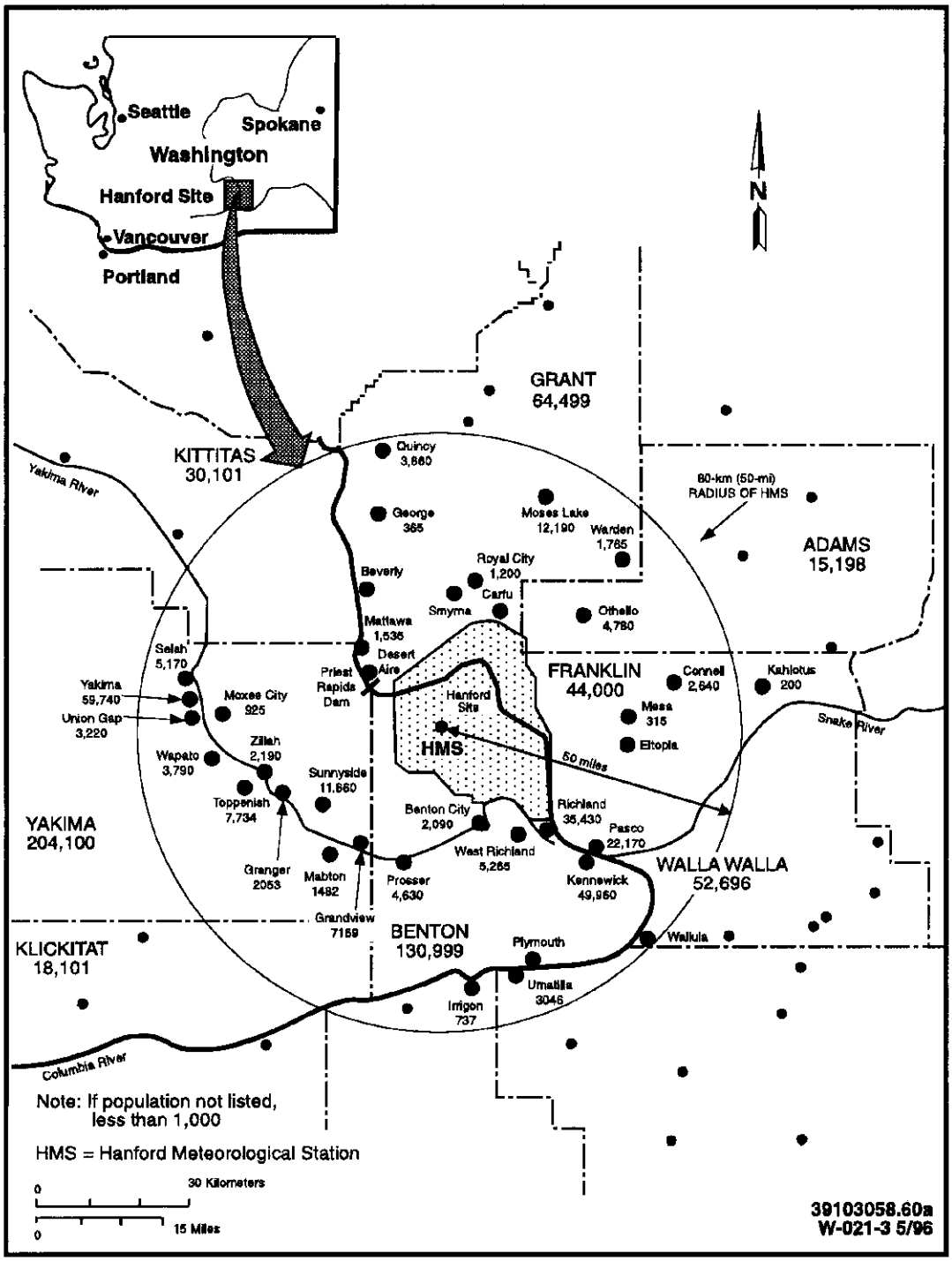


Figure 3-6. Residential Population within a 50-mi Radius of the Hanford Meteorological Station - 1990. (Sheet 1 of 6)

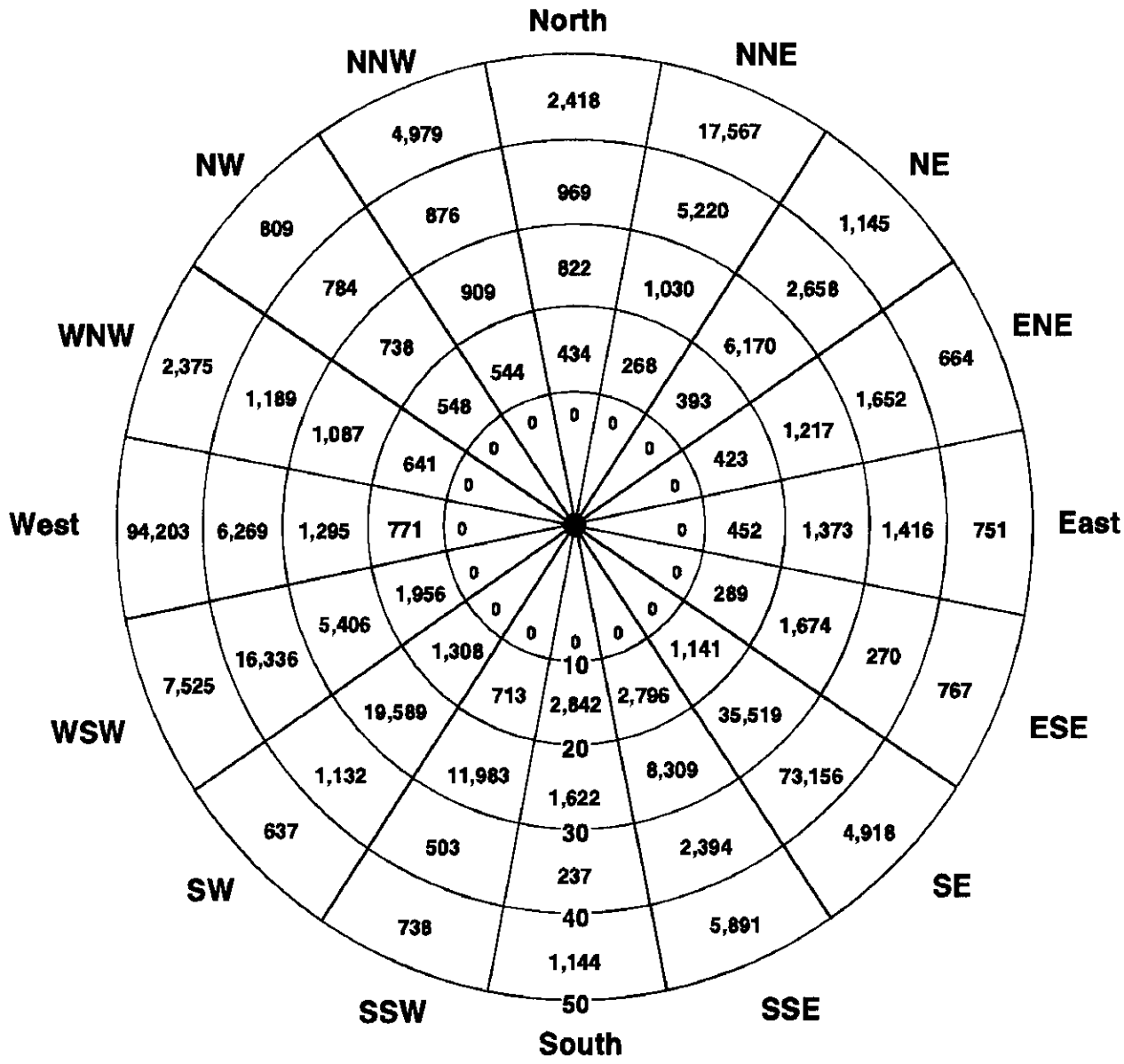

North
NNE
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South
SSW
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WSW
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WNW
NW
NNW
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17,567
969
5,220
822
1,030
434
268
0
0
0
0
4,979
876
1,145
2,658
664
1,652
1,217
423
809
784
738
544
548
393
6,170
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771
452
1,373
1,416
751
94,203
6,269
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0

Figure 3-6. Residential Population within a 50-mi Radius of the Hanford Meteorological Station - 2000. (Sheet 2 of 6)

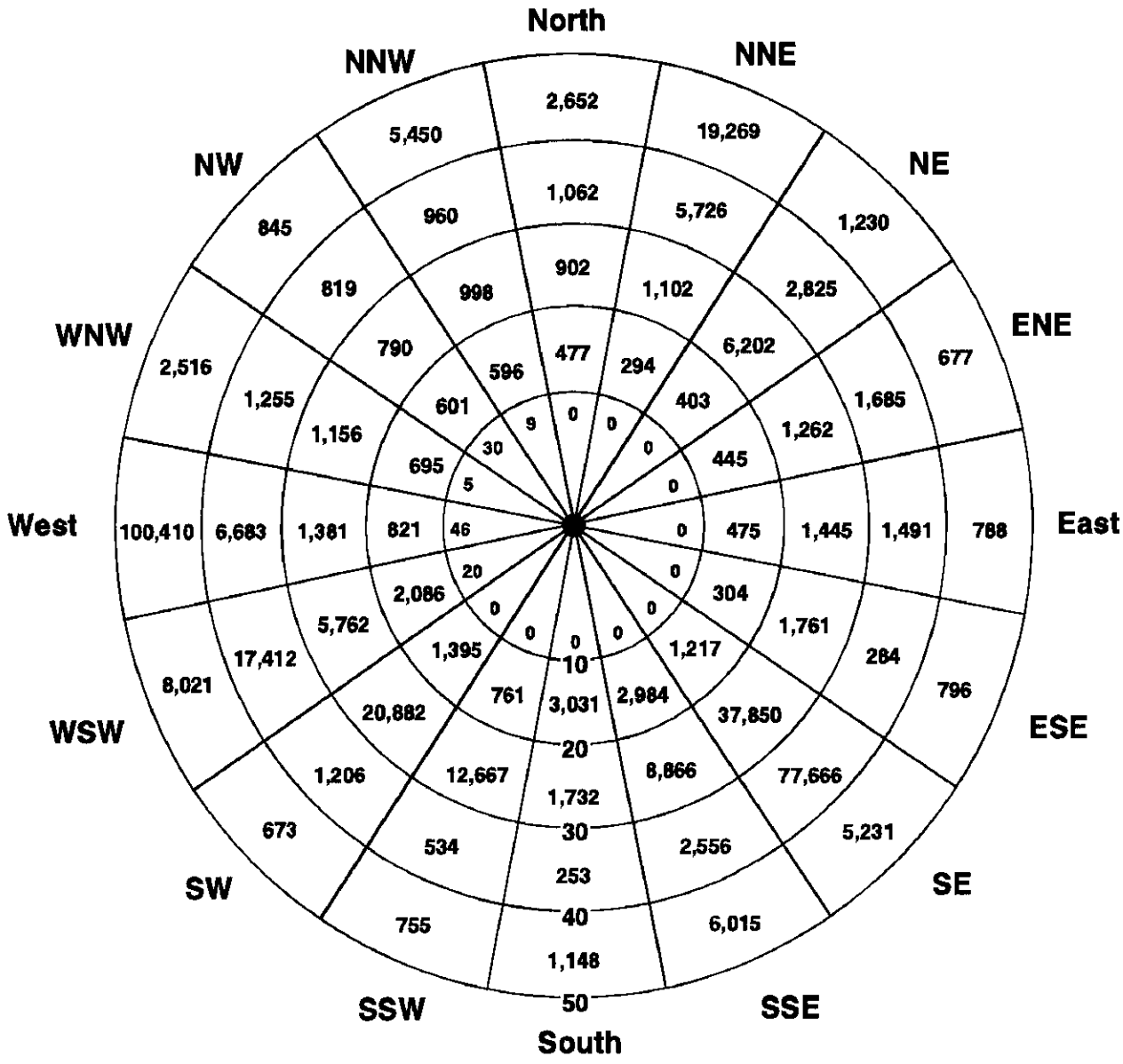
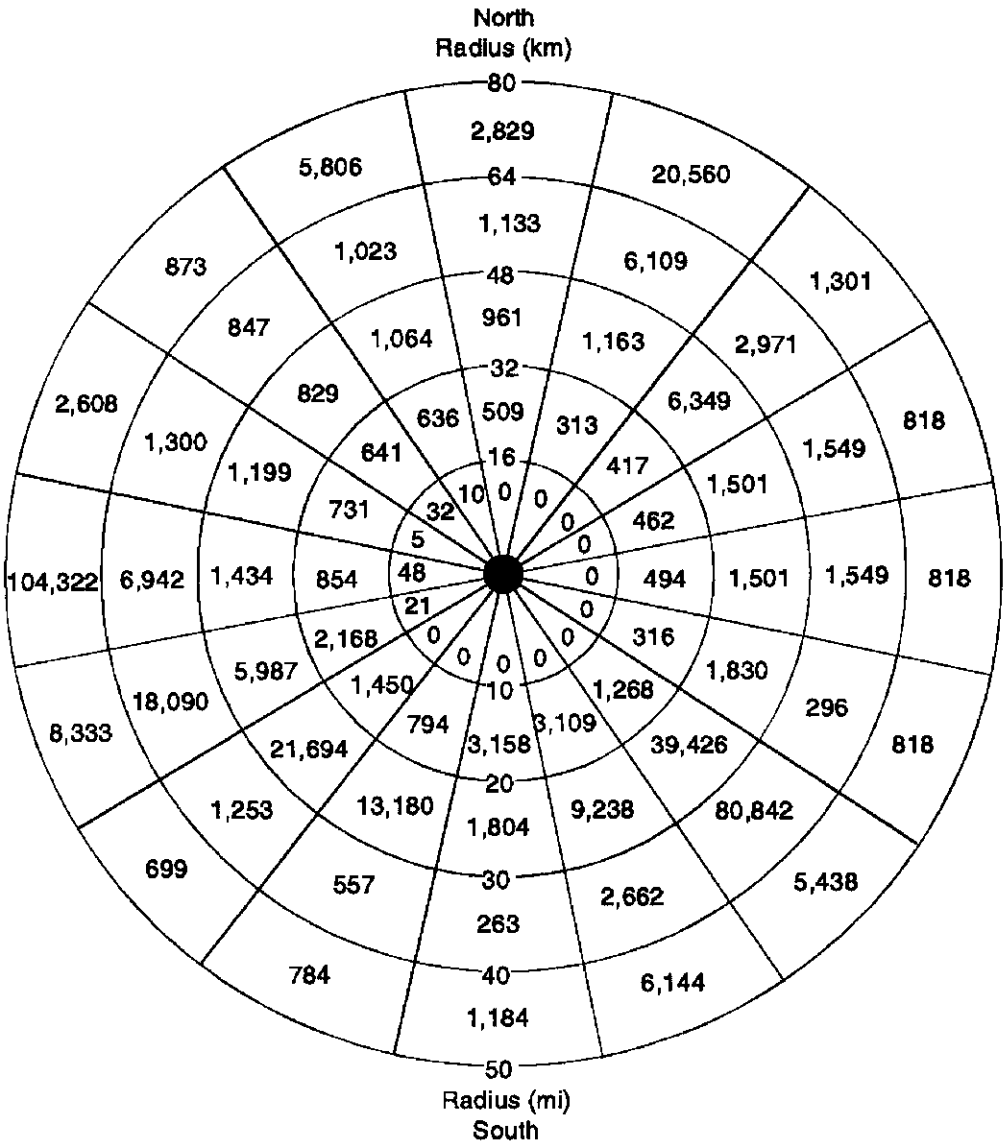

North
NNE
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South
SSW
SW
WSW
West
WNW
NW
NNW
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19,269
1,230
677
788
796
284
1,761
304
1,217
2,984
37,850
77,666
5,231
6,015
2,556
8,866
1,732
3,031
761
1,395
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601
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960
5,450
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902
477
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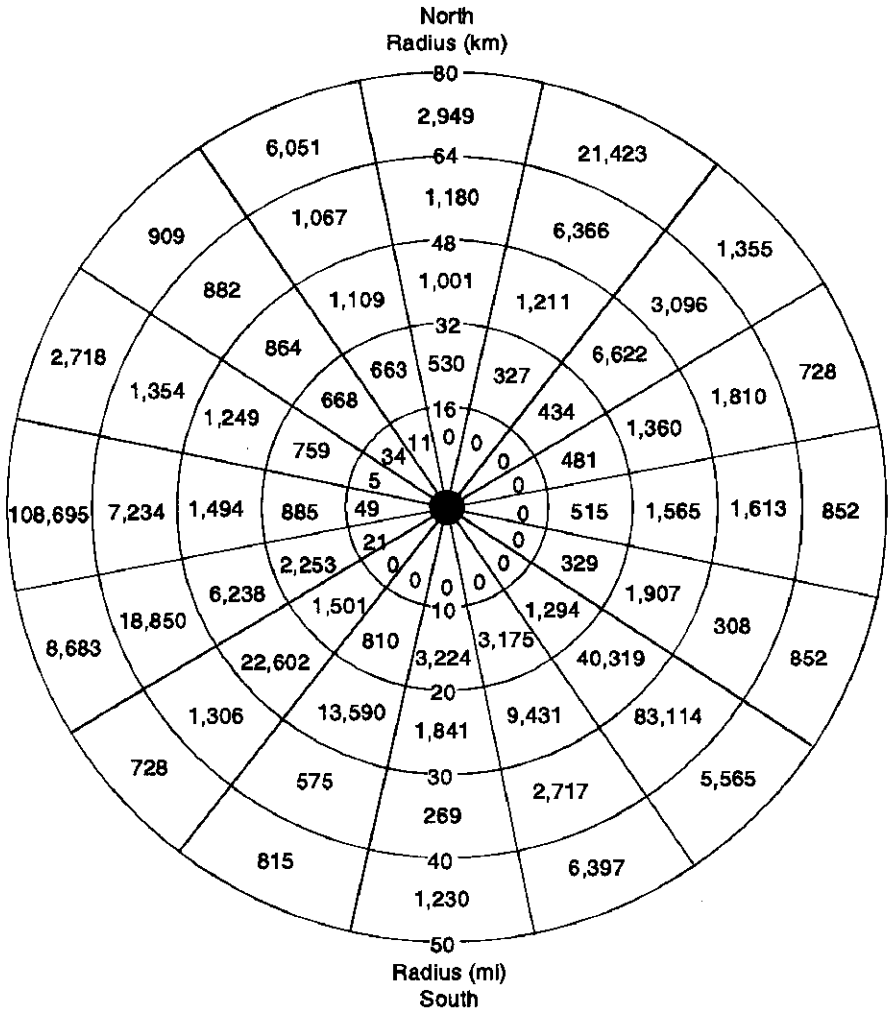
Figure 3-6. Residential Population within a 50-mi Radius of the Hanford Meteorological Station - 2010. (Sheet 3 of 6)



Ring km (mi)	0 - 16 (0 - 10)	16 - 32 (10 - 20)	32 - 48 (20 - 30)	48 - 64 (30 - 40)	64 - 80 (40 - 50)	Total 0 - 80 (0 - 50)
Population	116	17,320	109,160	127,386	163,335	417,317

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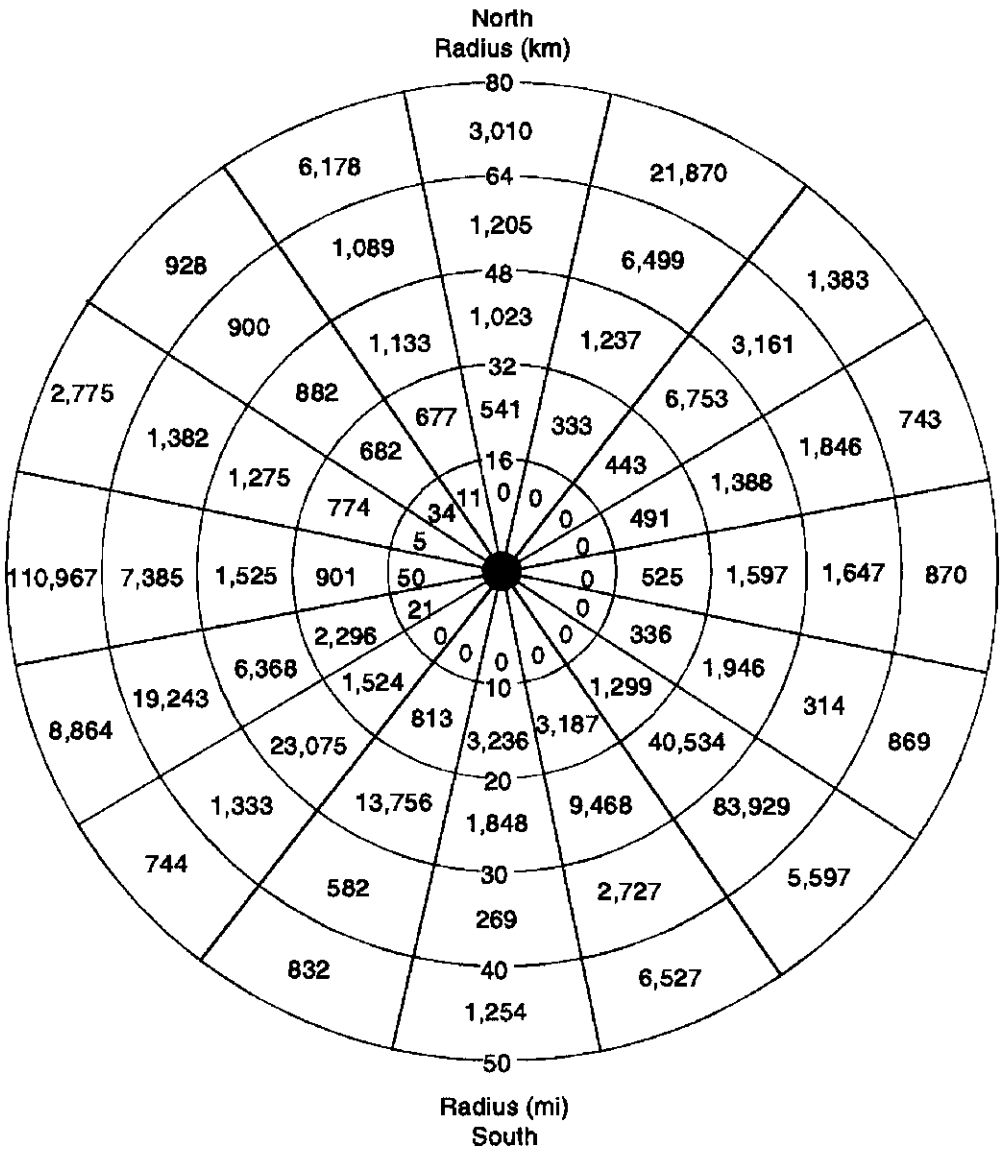
Figure 3-6. Residential Population within a 50-mi Radius of the Hanford Meteorological Station - 2020. (Sheet 4 of 6)



Ring km (mi)	0 - 16 (0 - 10)	16 - 32 (10 - 20)	32 - 48 (20 - 30)	48 - 64 (30 - 40)	64 - 80 (40 - 50)	Total 0 - 80 (0 - 50)
Population	120	17,848	112,403	131,741	169,950	432,062

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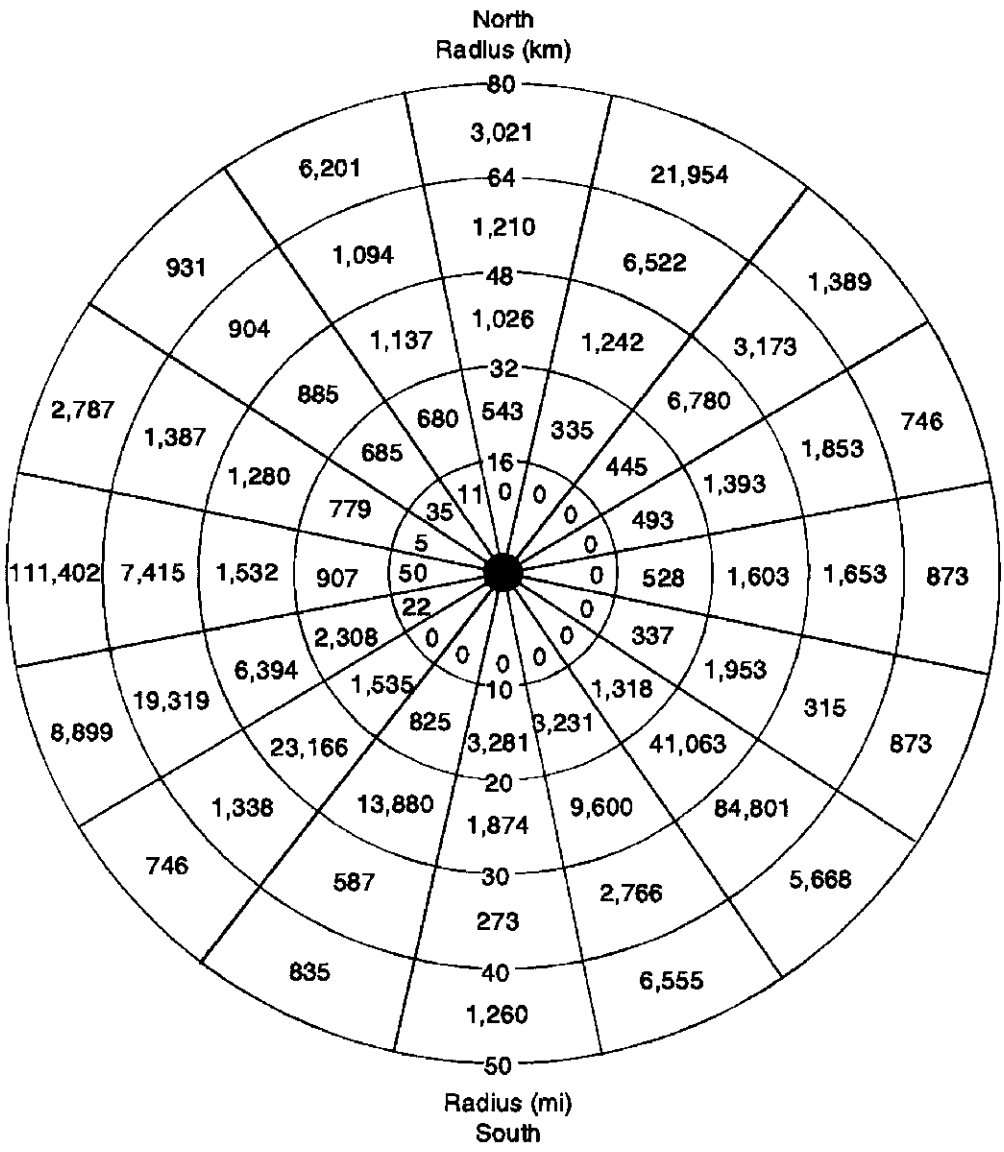
Figure 3-6. Residential Population within a 50-mi Radius of the Hanford Meteorological Station - 2030. (Sheet 5 of 6)



Ring km (mi)	0 - 16 (0 - 10)	16 - 32 (10 - 20)	32 - 48 (20 - 30)	48 - 64 (30 - 40)	64 - 80 (40 - 50)	Total 0 - 80 (0 - 50)
Population	121	18,058	113,808	133,511	173,411	438,909

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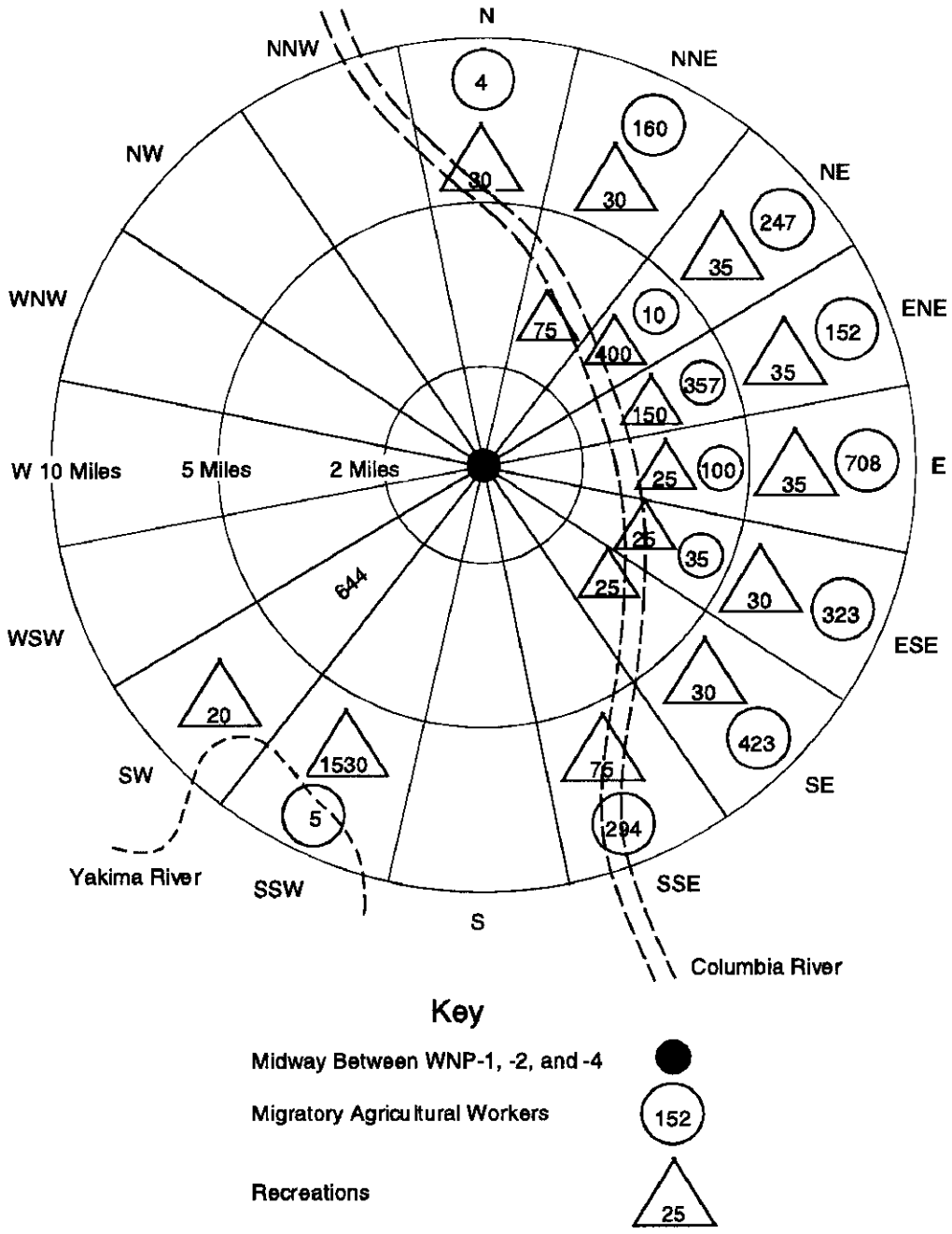
Figure 3-6. Residential Population within a 50-mi Radius of the Hanford Meteorological Station - 2040. (Sheet 6 of 6)



Ring km (mi)	0 - 16 (0 - 10)	16 - 32 (10 - 20)	32 - 48 (20 - 30)	48 - 64 (30 - 40)	64 - 80 (40 - 50)	Total 0 - 80 (0 - 50)
Population	123	18,230	114,808	134,610	174,140	441,911

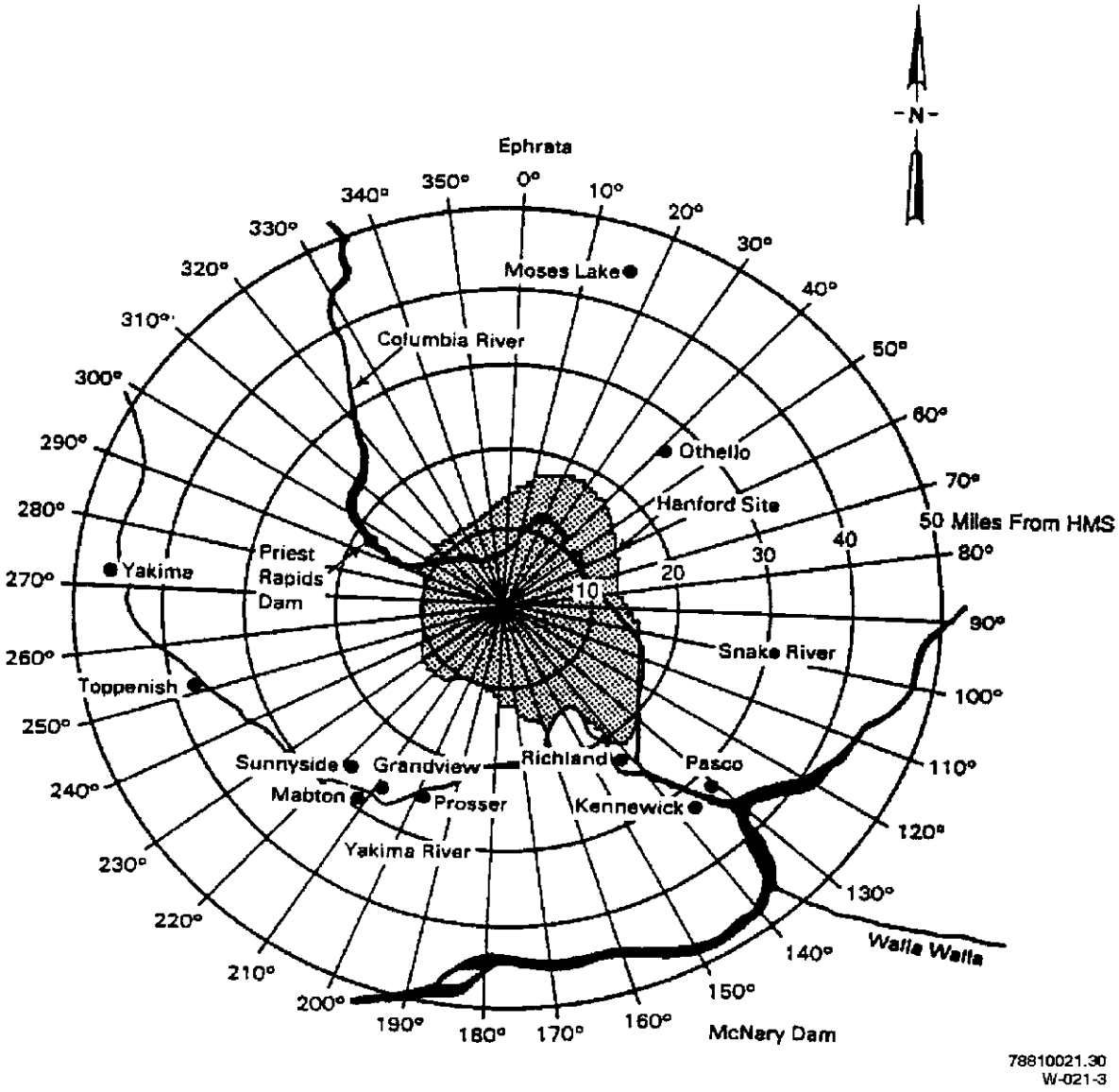
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Figure 3-7. Distribution of Transient Population.



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Figure 3-8. Hanford Site Vicinity Map/Overlay.



HMS - Hanford Meteorological Station.

Figure 3-9. Recreation/Refuge/Reserve Areas of the Hanford Site.

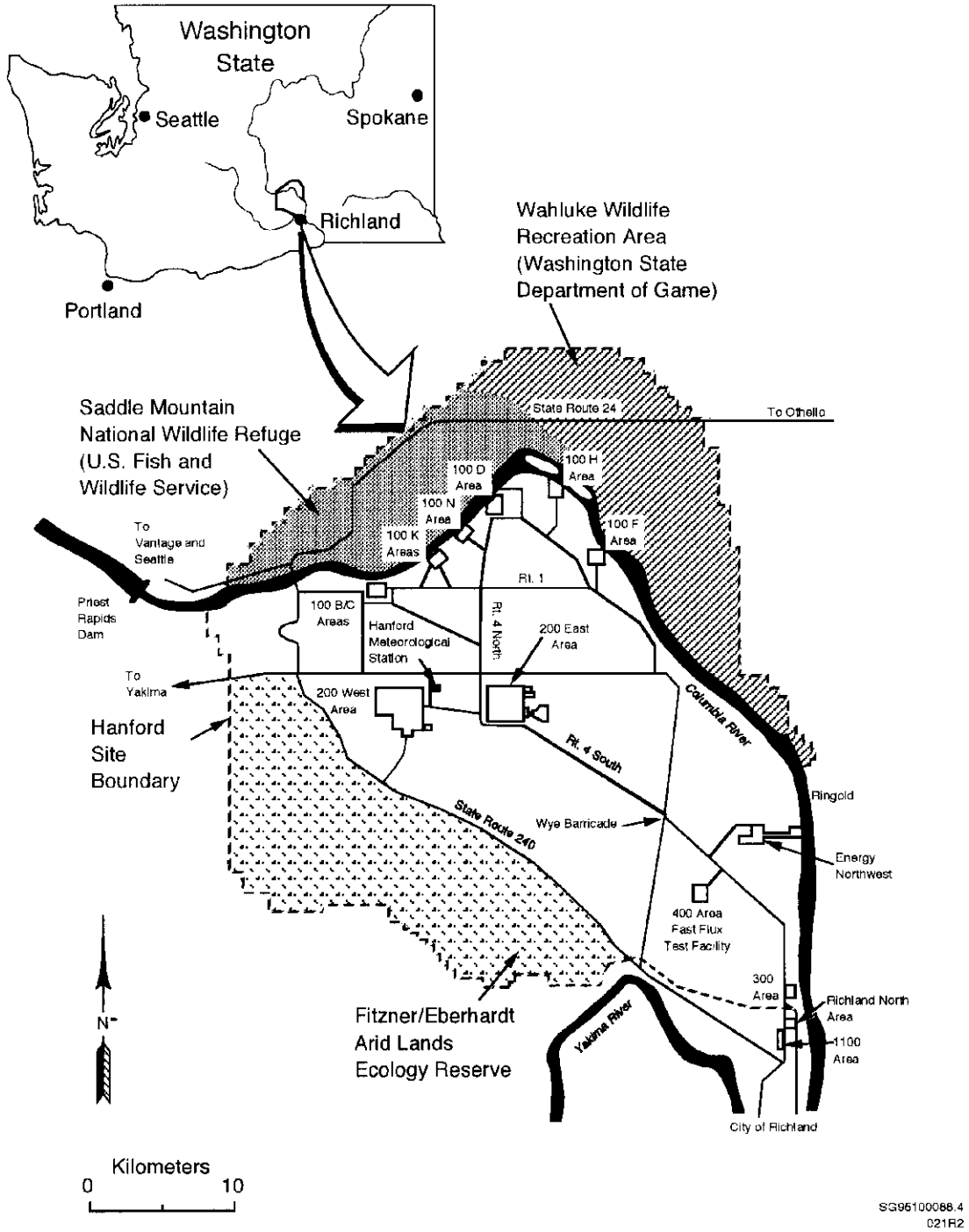
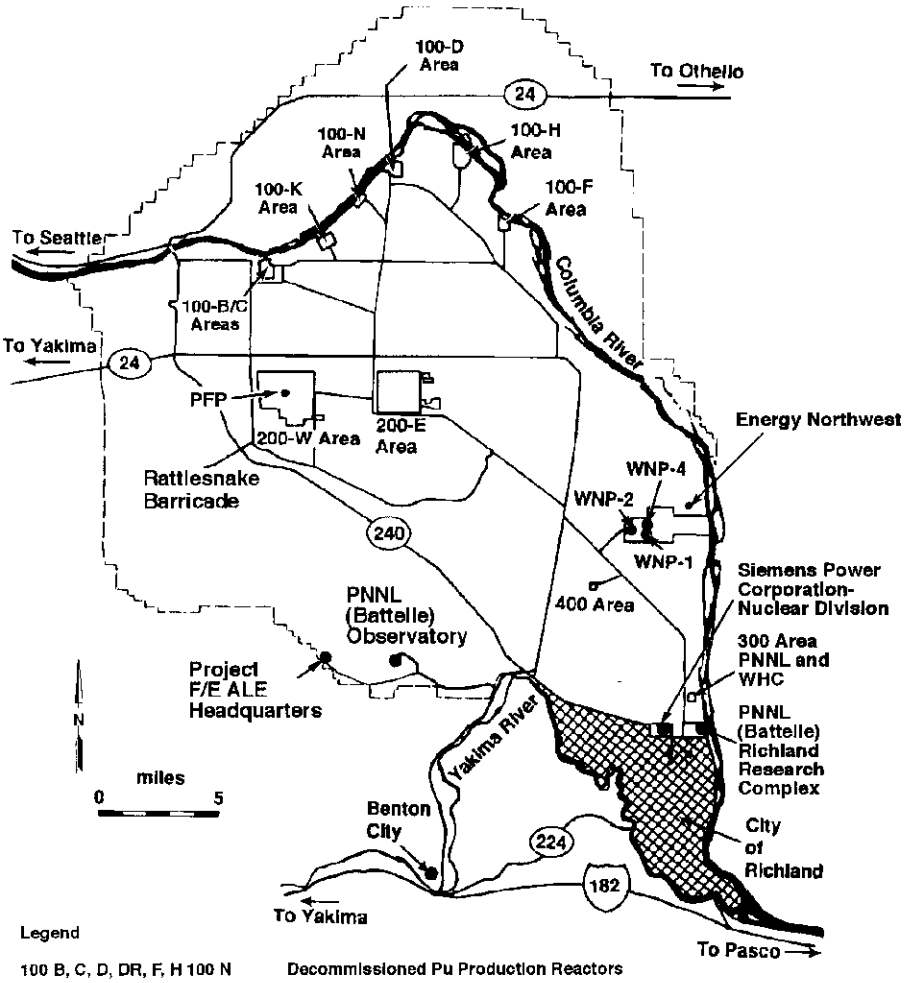


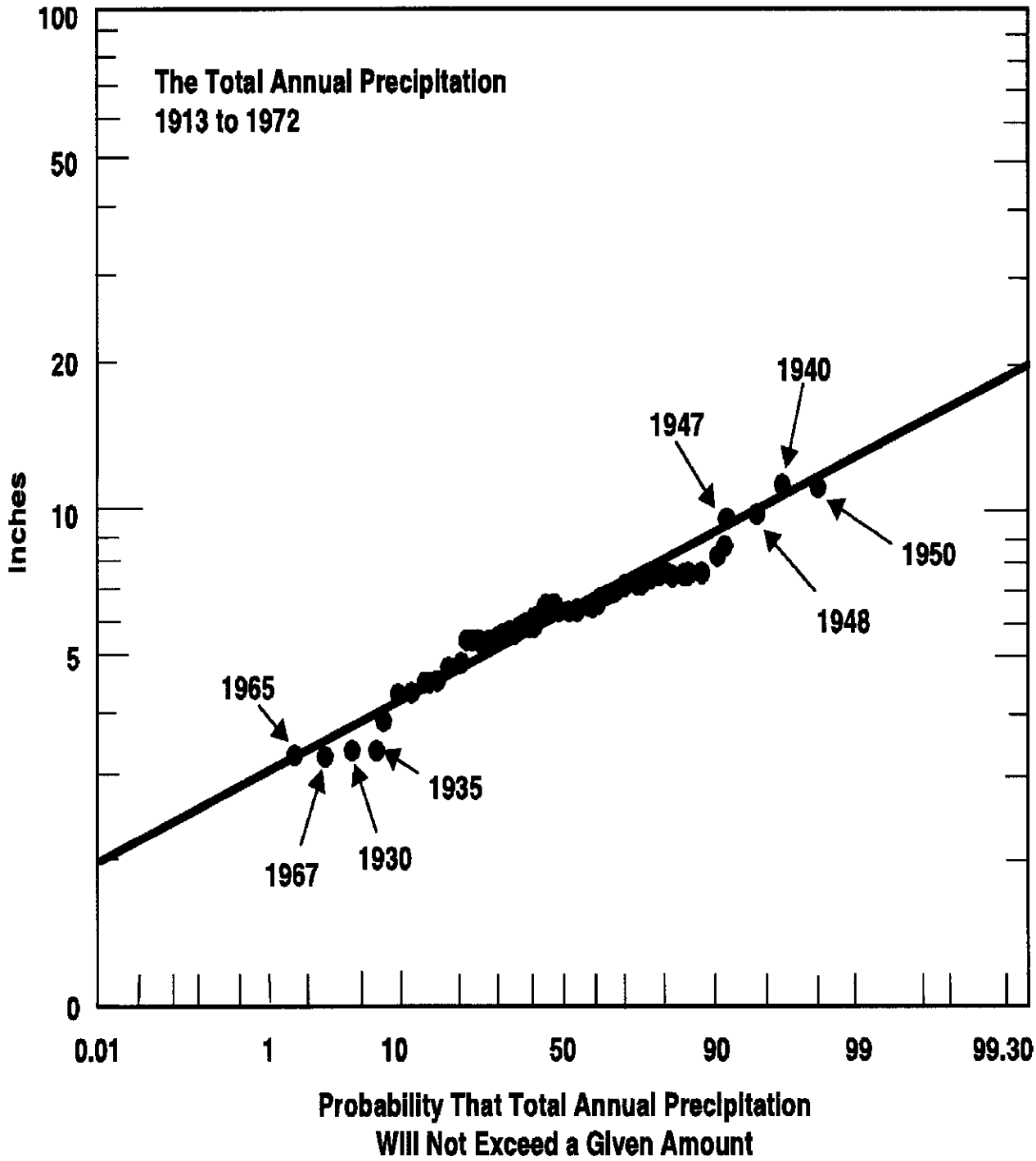
Figure 3-10. Hanford Site Facilities.



Legend	
100 B, C, D, DR, F, H 100 N	Decommissioned Pu Production Reactors
100 KE, KW	Active Irradiated Fuel Storage Basins
200E	Liquid Waste Tankage and Evaporator Operations Solid Waste Burial Grounds Liquid Waste Treatment Plant (B Plant) – Inactive Spent Fuel Reprocessing Plant (PUREX) – Inactive Liquid Effluent Treatment Facility Waste Encapsulation Facility Burial Grounds
200W	Liquid Waste Tankage Decommissioned Spent Fuel Reprocessing Plant (REDOX) – Inactive Chemistry Laboratory (222-S) Plutonium Finishing Plant (PFP) UO_3 Plant – Inactive Decontamination and Repair Facility (T Plant) Central Waste Complex Burial Grounds
300	Plutonium Fuels Laboratory (308) Spent Fuel Examination Laboratory (327) Materials Test Examination Laboratory (324) Analytical Chemistry Laboratory (325) Radiobiology Laboratory (326)
400	Fast Flux Test Facility (FFTF) – Inactive Maintenance and Storage Facility (MASF) – Inactive Fuel Cycle Plant (FCP) Irradiated Fuel Storage Facility (FSF)
Siemens Power Corporation – Nuclear Division	Uranium Fuel Fabrication Plant
Energy Northwest	Nuclear Power Plant, WNP-1 and WNP-4 partly constructed, but terminated; WNP-2 operating
PNNL	Pacific Northwest National Laboratory
PFP	Plutonium Finishing Plant

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Figure 3-11. Total Annual Precipitation at the Hanford Site from 1913 to 1980 and the Probability (%) that the Total Annual Precipitation Will Not Exceed a Given Amount.



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Figure 3-12. Greatest Depth of Snow on the Ground During the Winters of 1946-1947 to 1980-1981 and the Probability (%) that the Greatest Depth of Snow Will and Will Not Exceed a Given Amount.

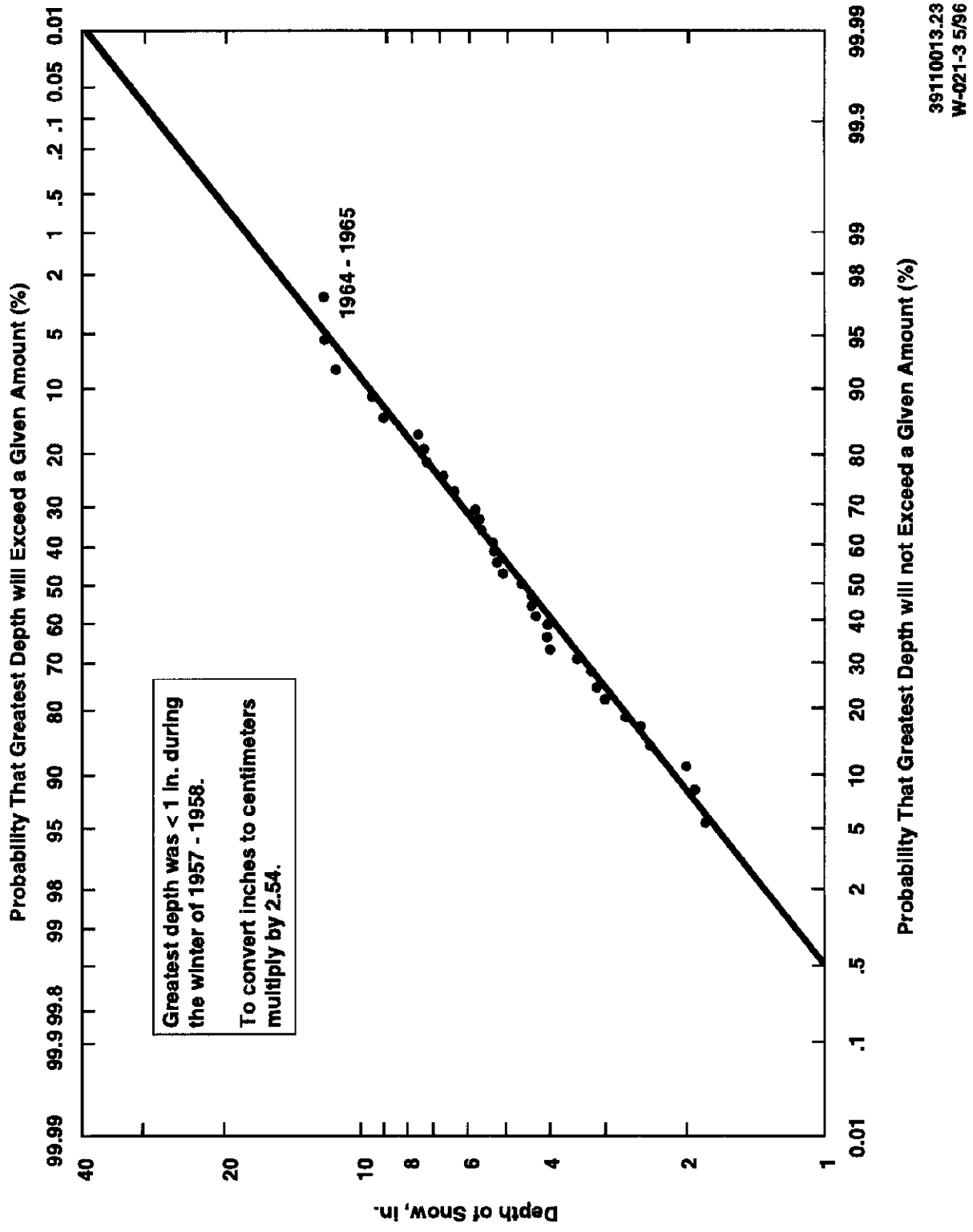


Figure 3-13. Peak Wind Gust Return Period Diagram.

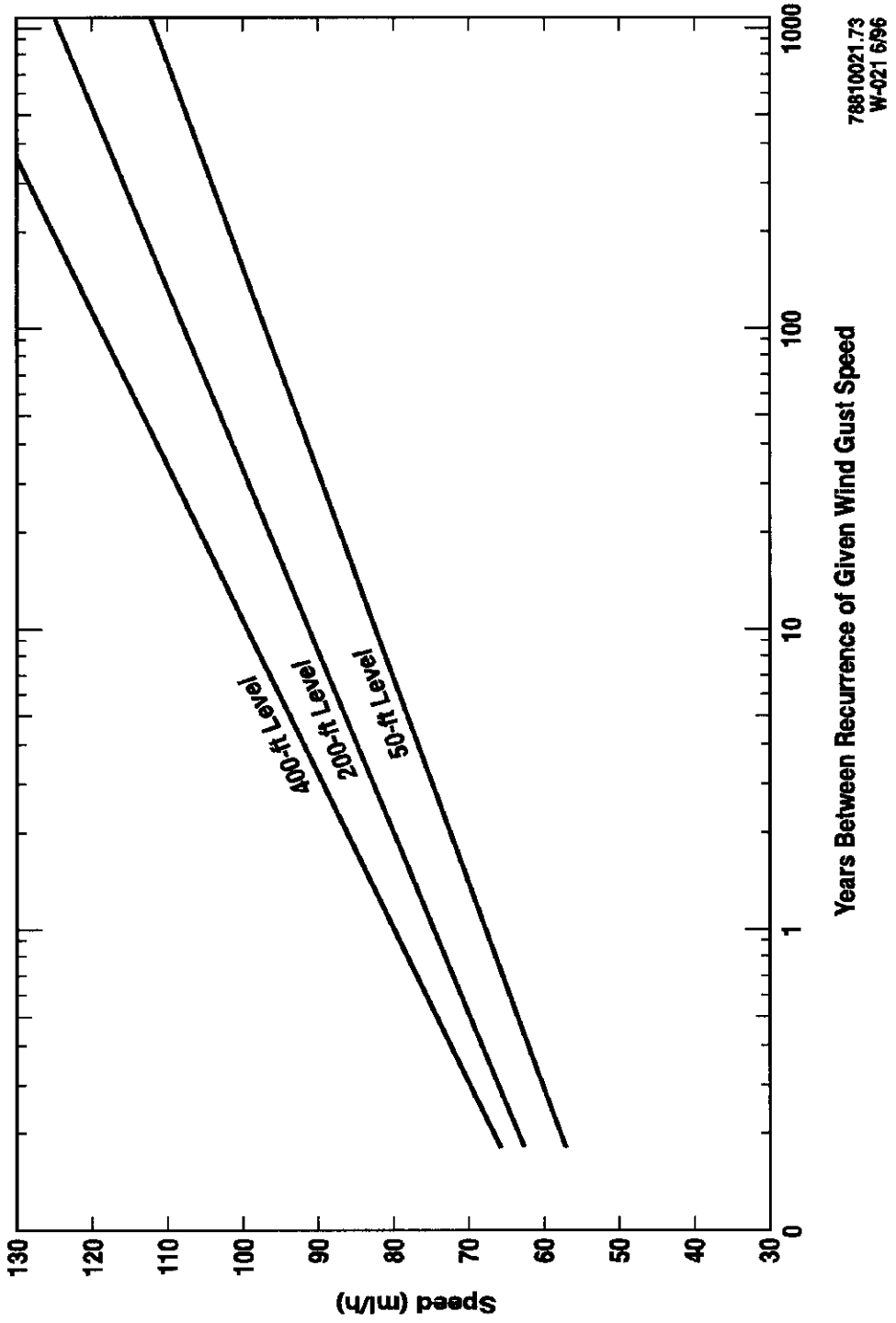
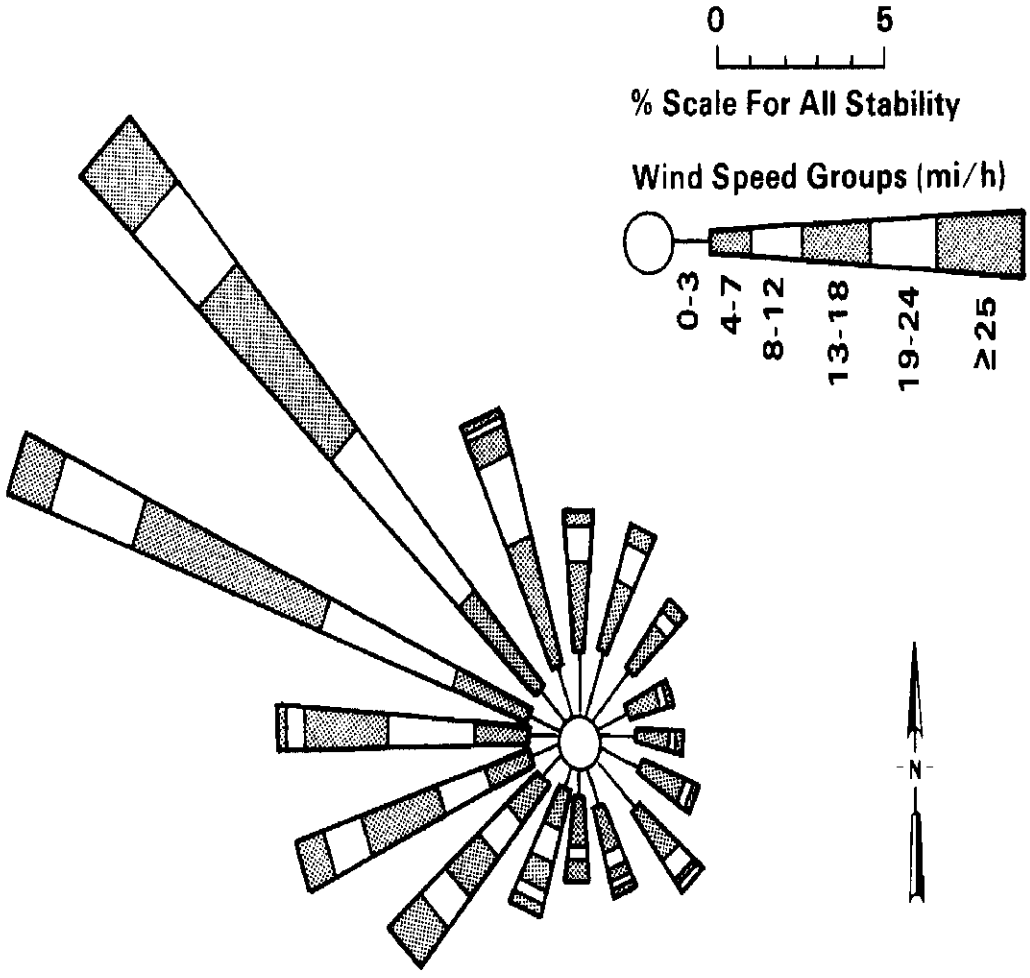
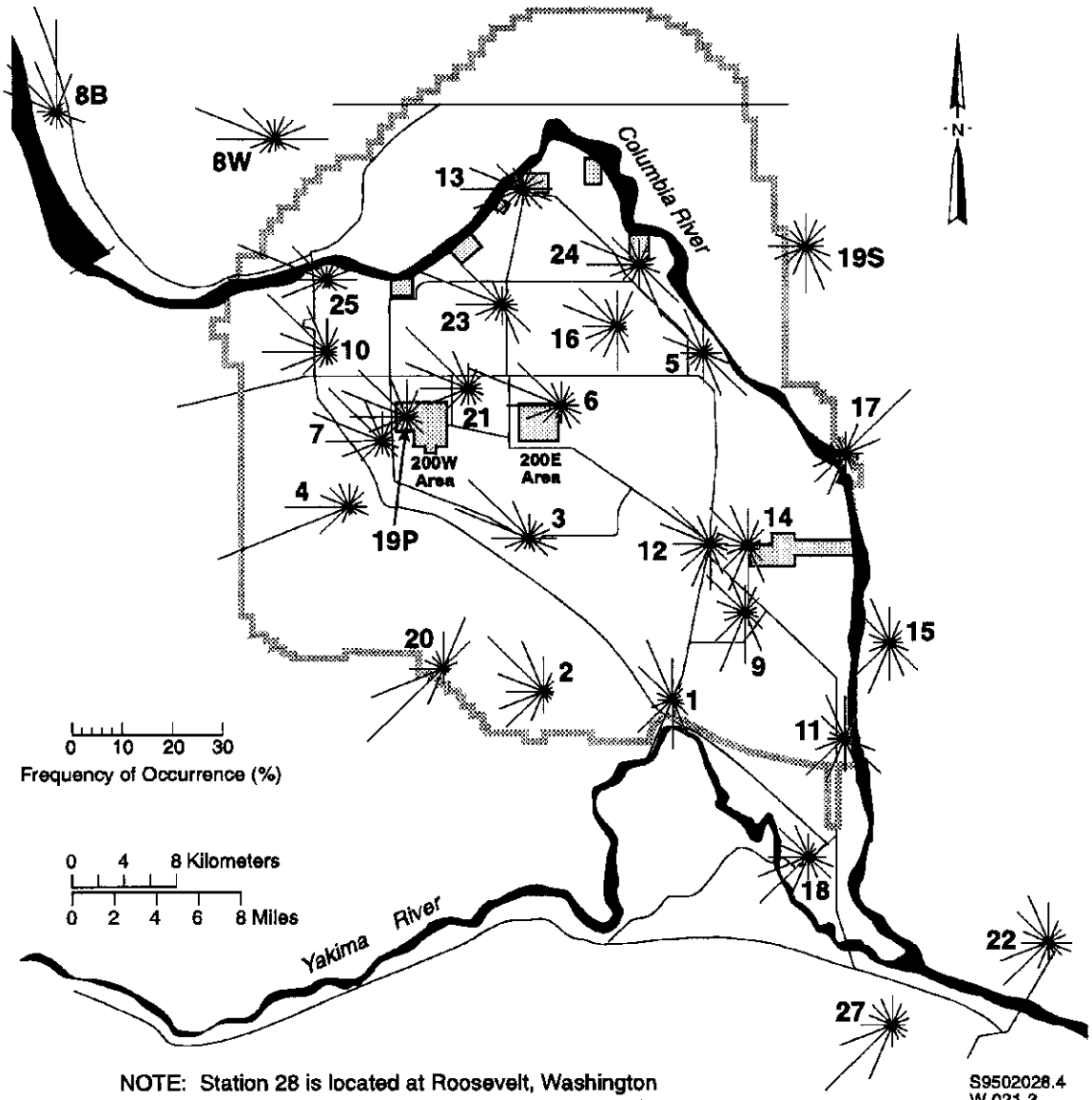


Figure 3-14. Joint Frequency Distribution of Wind Speed Direction. (Sheet 1 of 2)



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Figure 3-14. Joint Frequency Distribution of Wind Speed Direction 1982 through 1994. (Sheet 2 of 2)



NOTE: Station 28 is located at Roosevelt, Washington
Station 21 is the Hanford Meteorological Station
Station 19P is situated in the 200 West Area (where the PFP is located)

Lines indicate direction from which wind blows; line length is proportional to frequency of occurrence.

PFP – Plutonium Finishing Plant

Figure 3-15. Surface Water within the Hanford Site Boundary.
(Extracted from the Quarterly Report of RCRA Groundwater Monitoring Data for Period January 1 through March 31, 1995)
(Sheet 1 of 2)

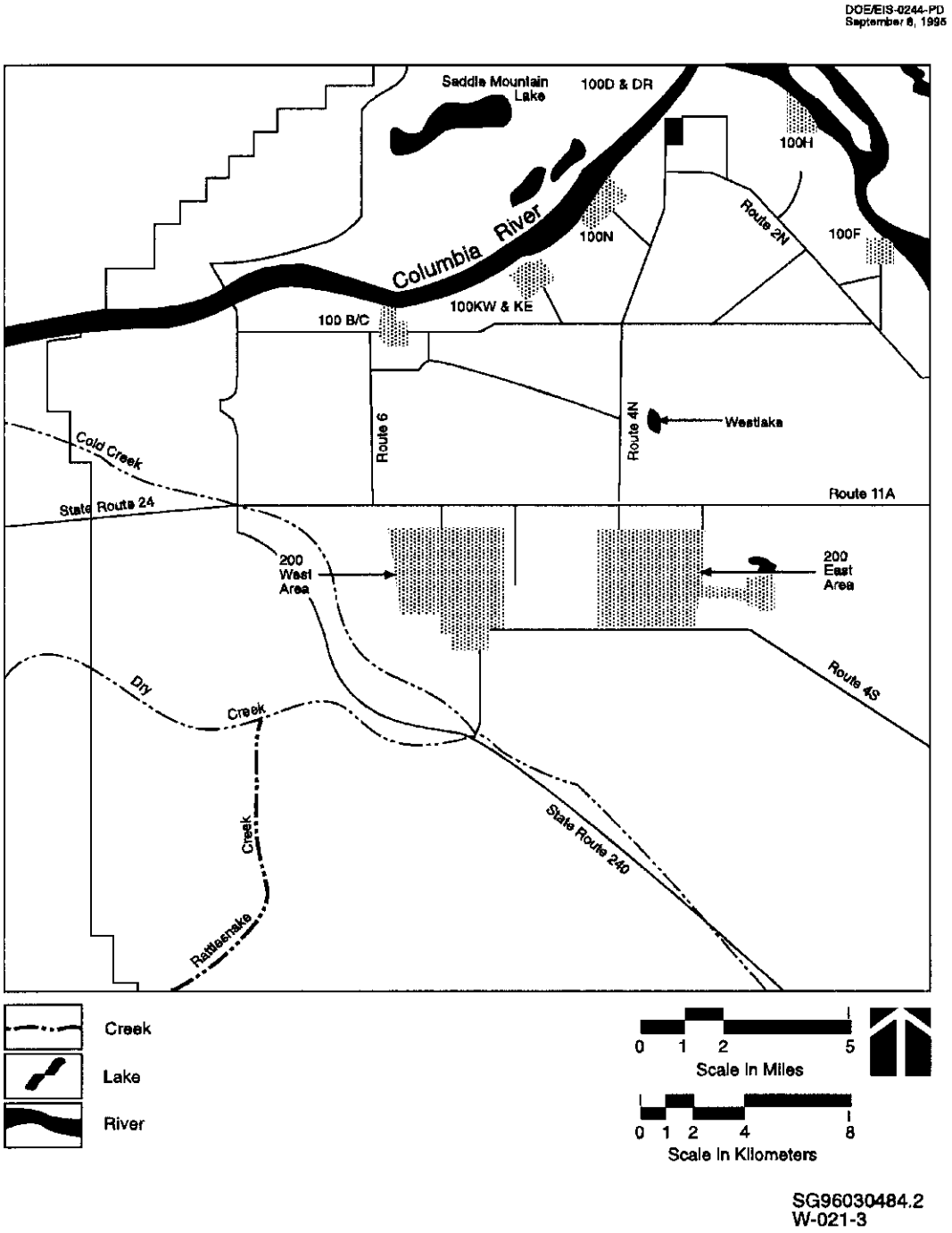
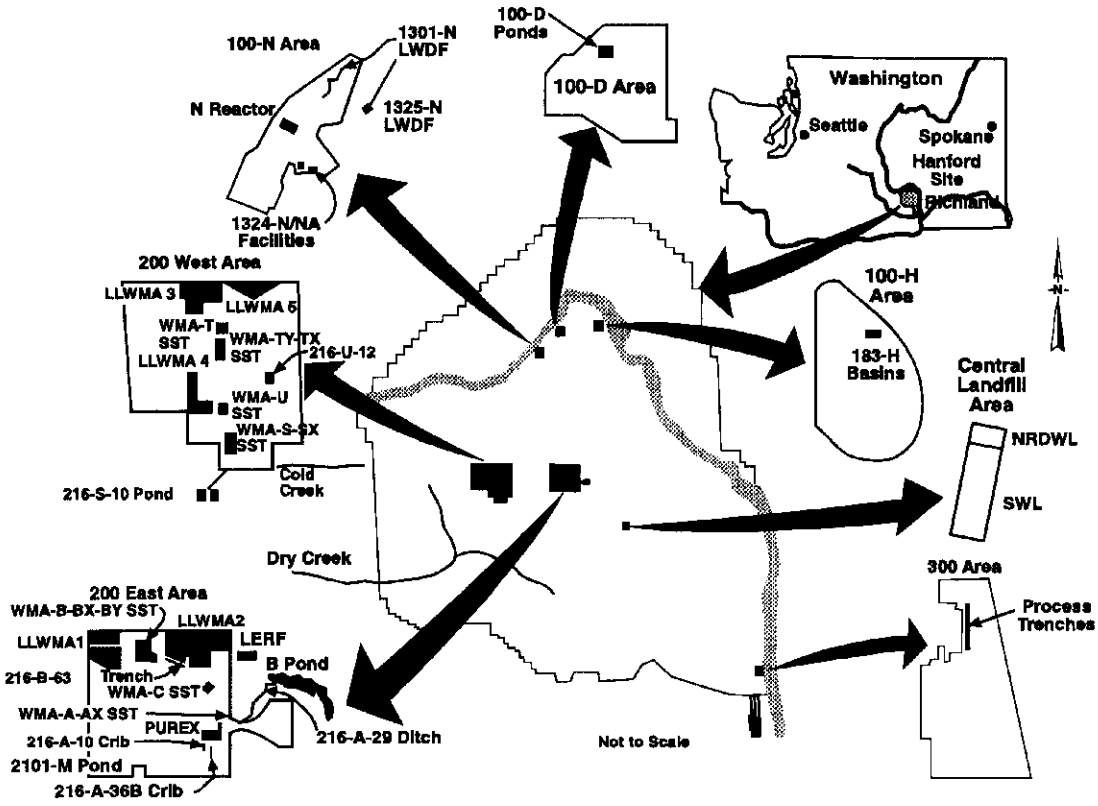


Figure 3-15. Surface Water within the Hanford Site Boundary.
(Extracted from the Quarterly Report of RCRA Groundwater Monitoring Data for Period January 1 through March 31, 1995).
(Sheet 2 of 2)



LERF	Liquid Effluent Retention Facility	PUREX	Plutonium-Uranium Extraction (Plant)
LLWMA	Low-Level Waste Management Area	SST	Single-Shell Tank
LWDF	Liquid Waste Disposal Facility	SWL	Solid Waste Landfill
NRDWL	Nonradioactive Dangerous Waste Landfill	WMA	Waste Management Area

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Figure 3-16. Topographical Map for Plutonium Finishing Plant Vicinity.

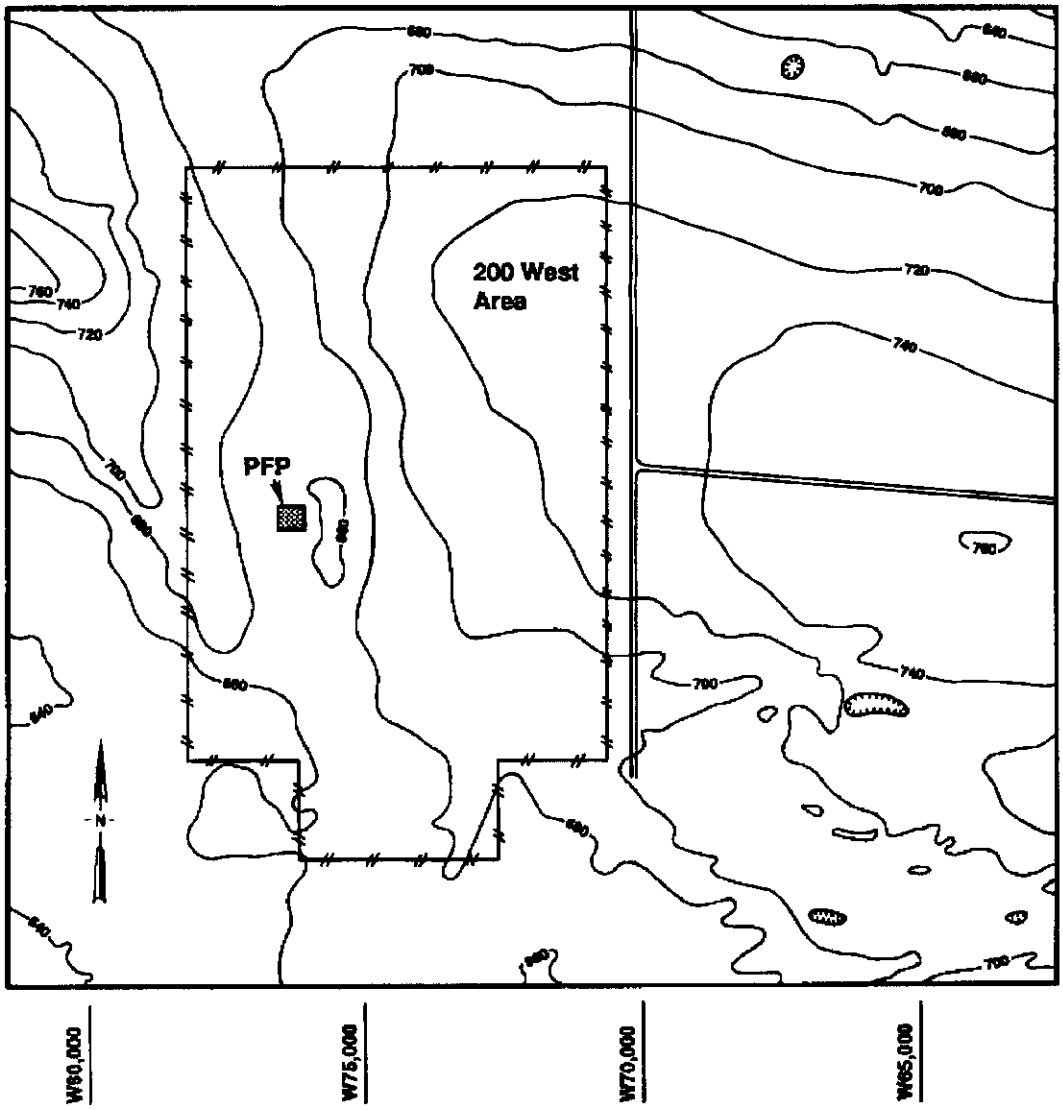


Figure 3-17. Pasco Basin Geologic Setting.

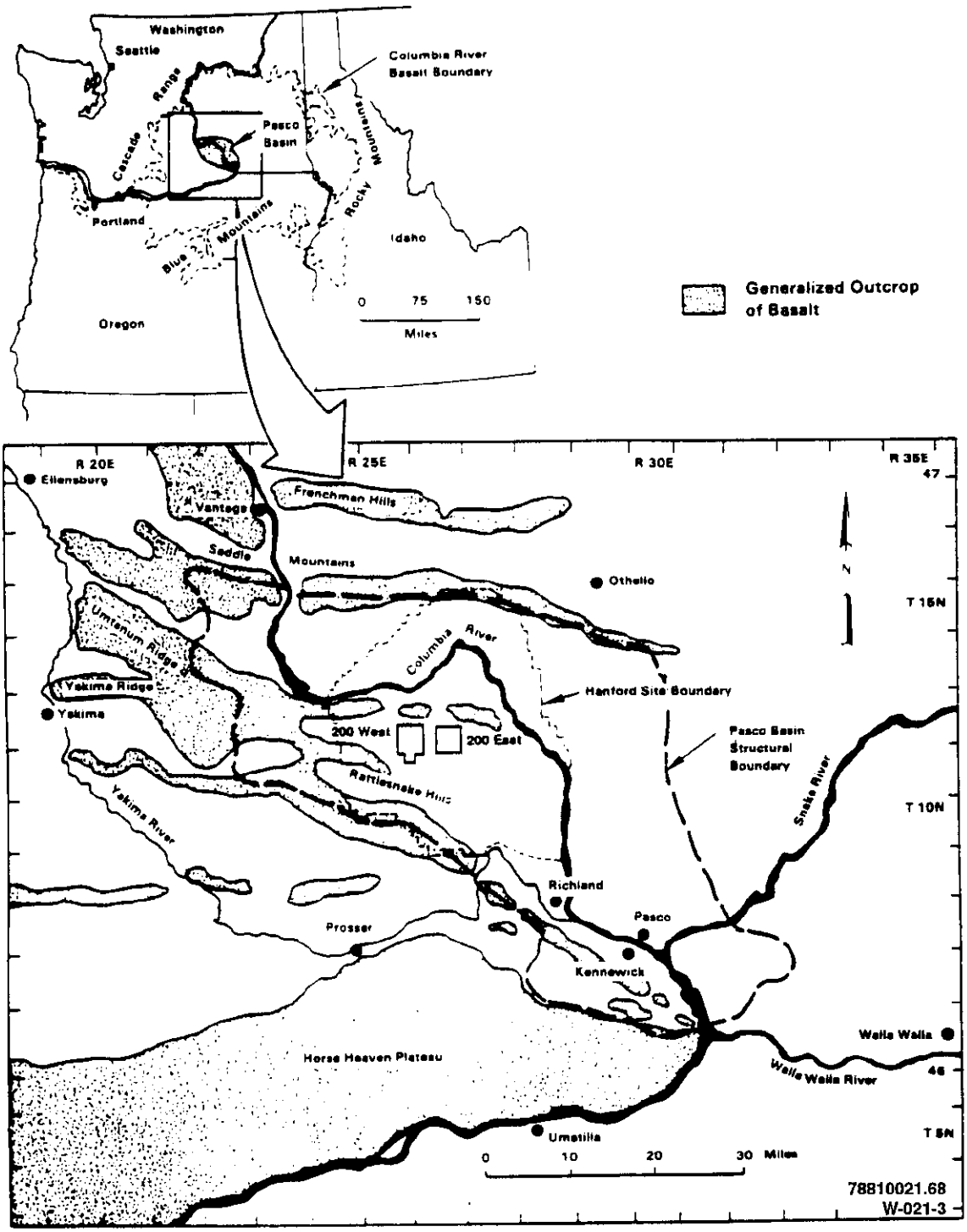


Figure 3-18. Approximate Location of Major Drainage Divides on the Hanford Site.

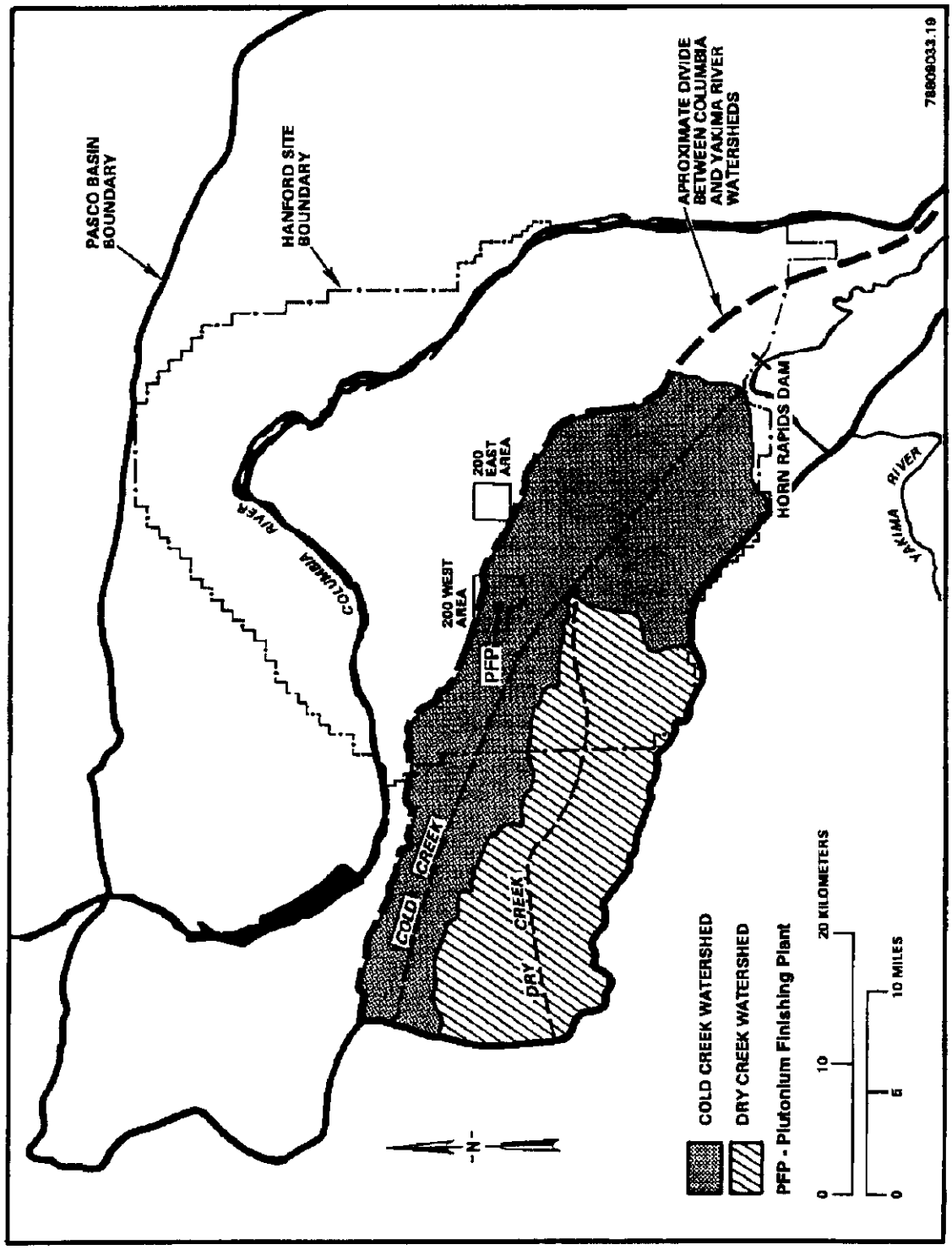
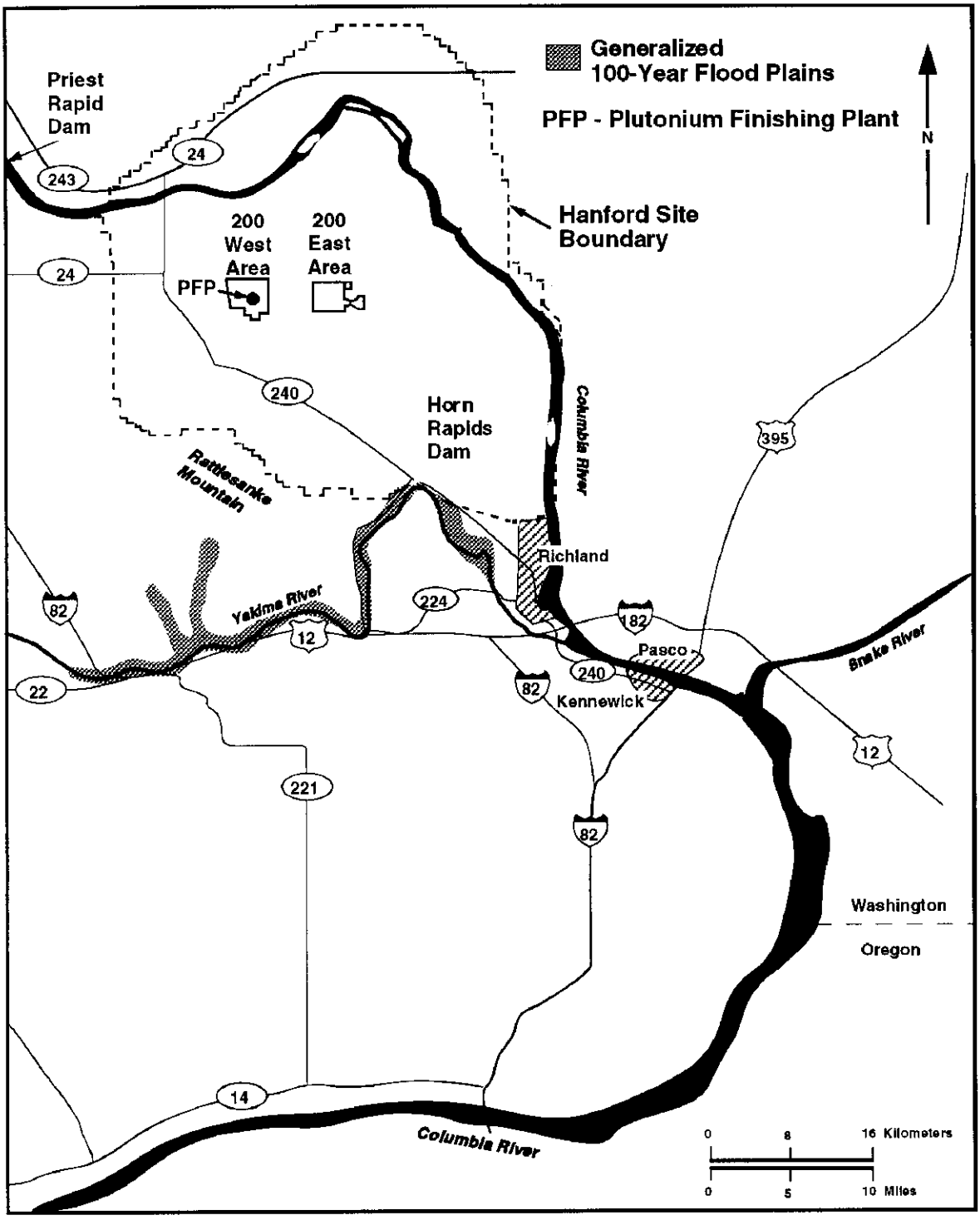


Figure 3-19. Flooded Areas Resulting from a 100-yr Flood of the Yakima River in the Vicinity of the Hanford Site.



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Figure 3-20. Setting of the Pasco Basin.

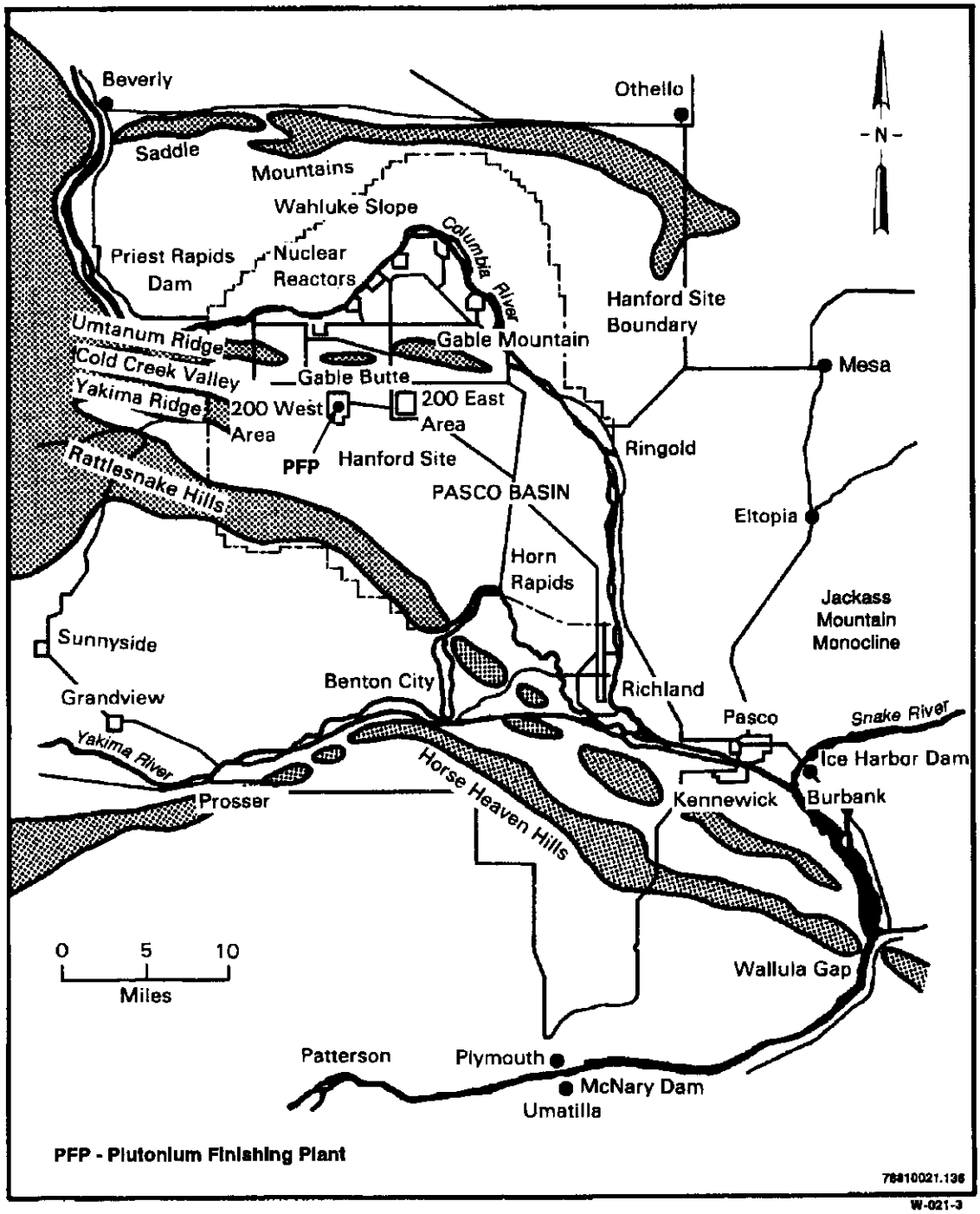


Figure 3-21. Potentiometric Surface Map of the Rattlesnake Ridge Aquifer within the Hanford Site.

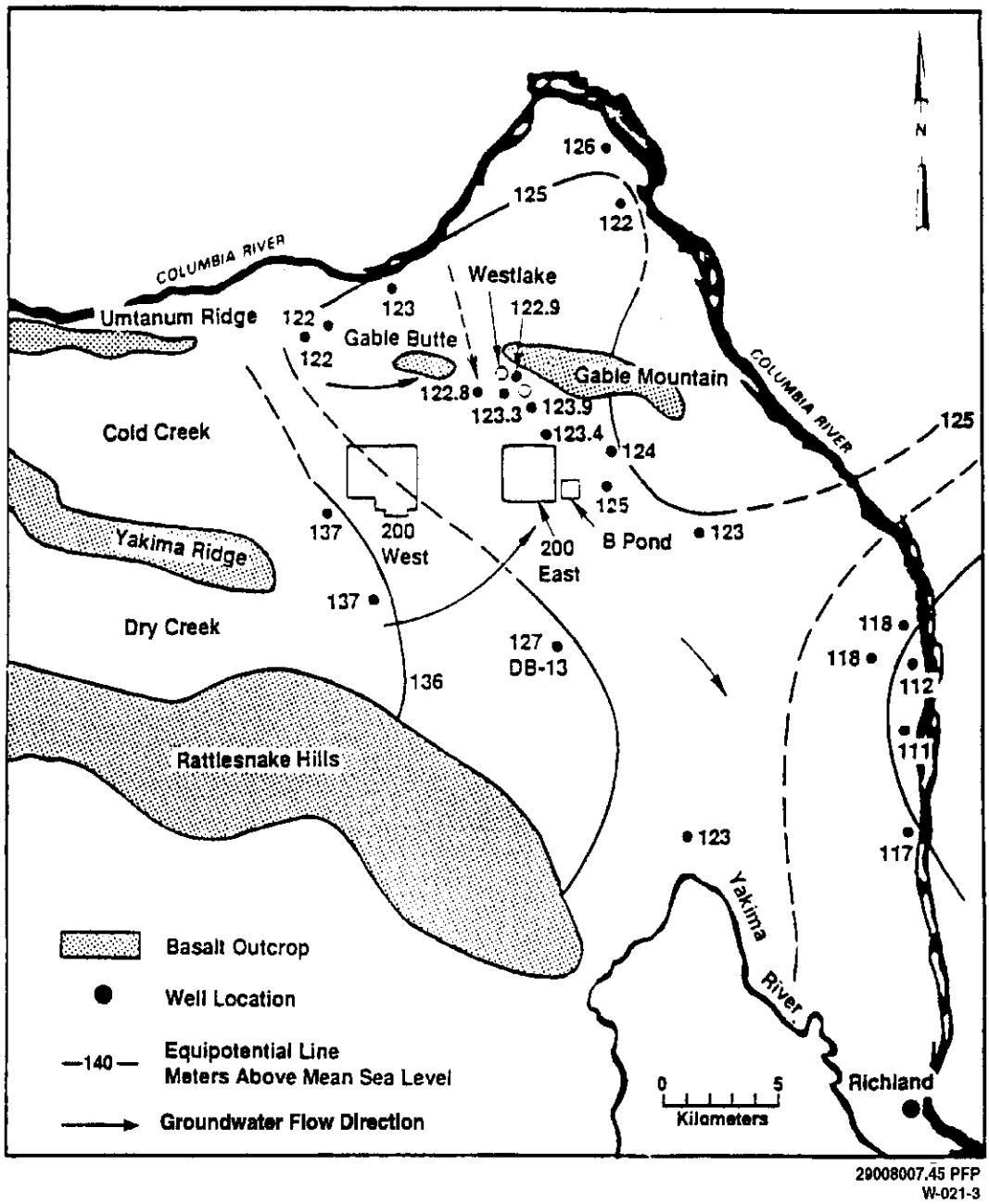


Figure 3-22. Hanford Site Water Table Map, December 1986.
(Adapted from Schatz and Green 1986)

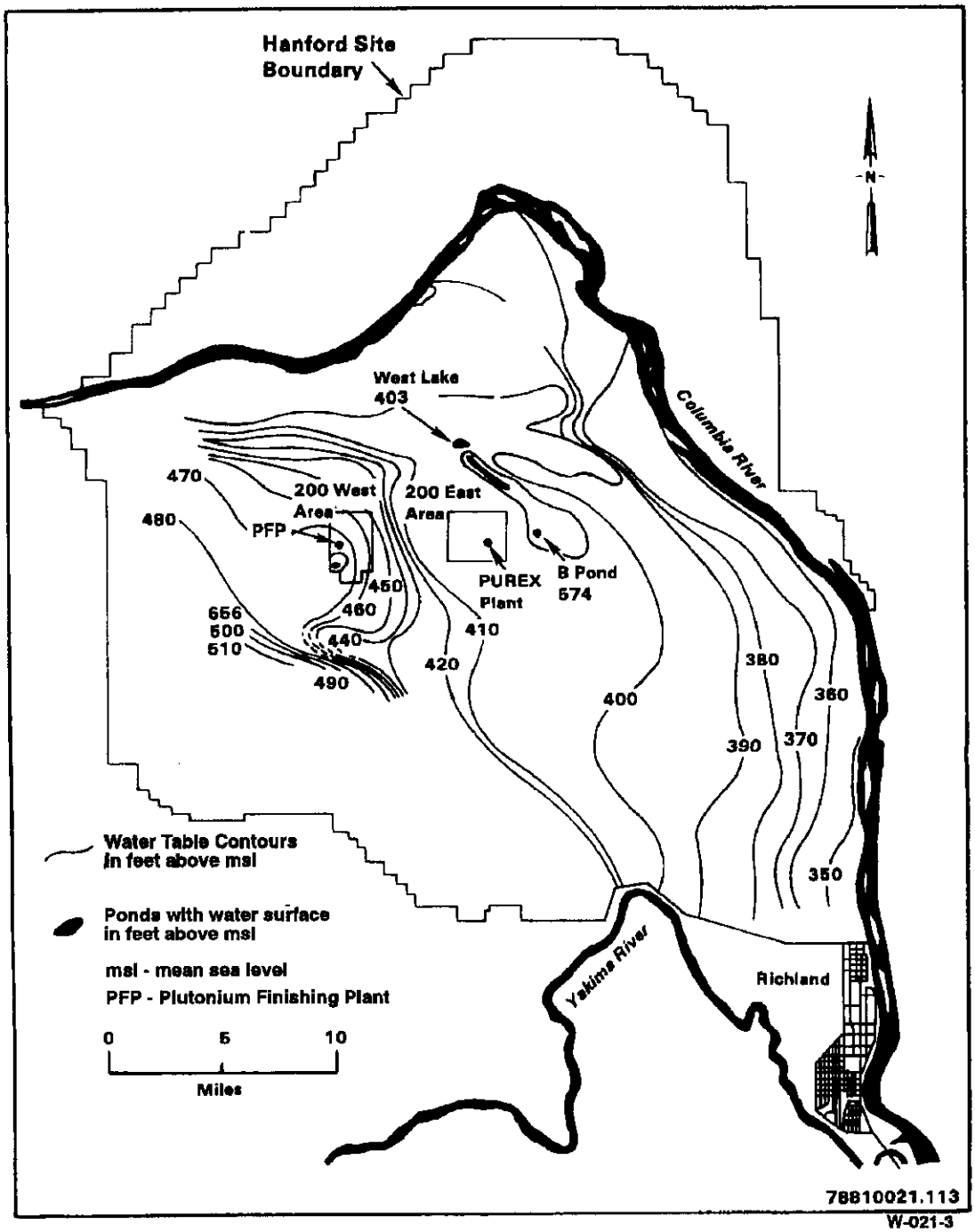


Figure 3-23. Vertically Averaged Hydraulic Conductivity Distribution in Unconfined Aquifer.

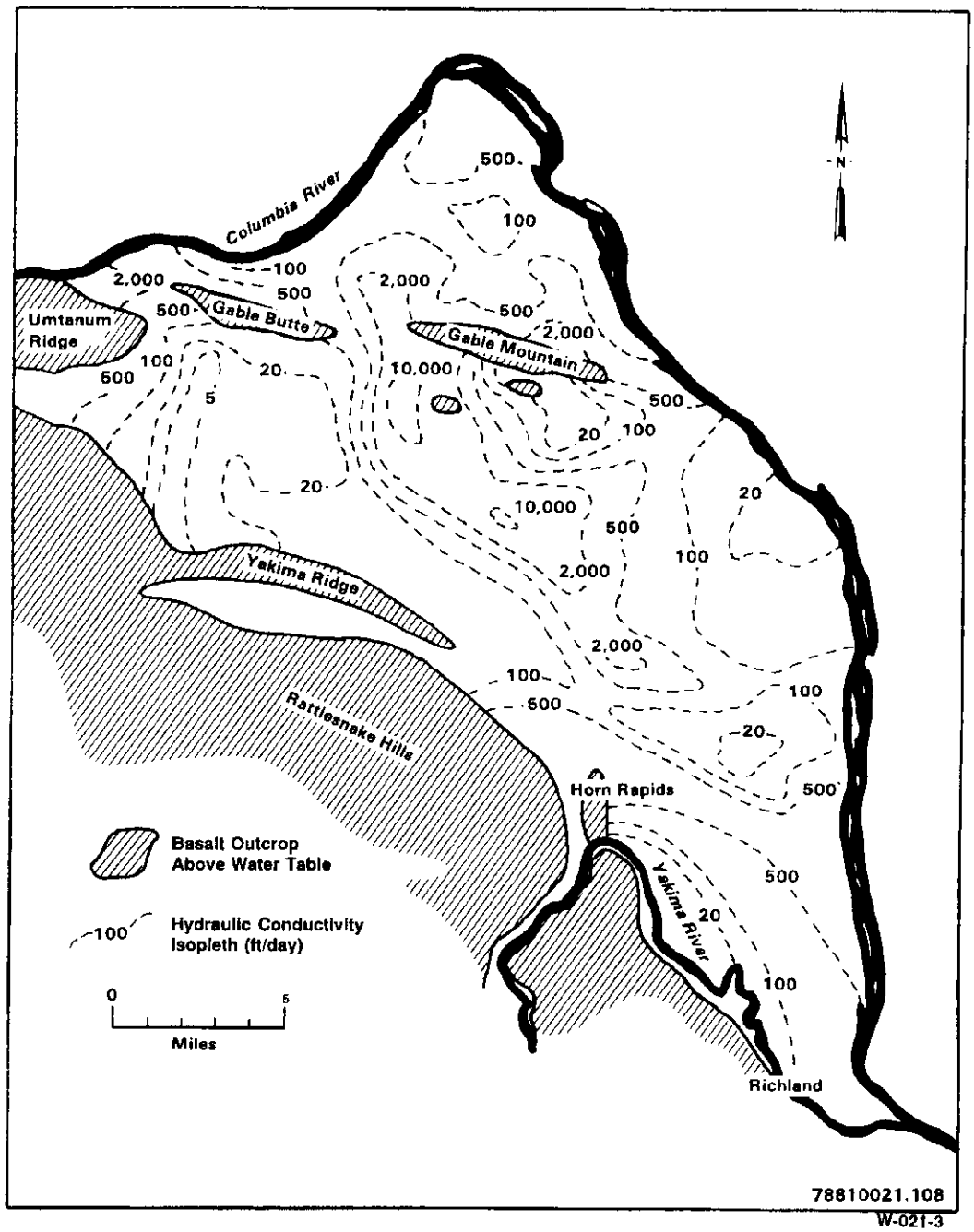


Figure 3-24. Generalized Hanford Groundwater Flow System.

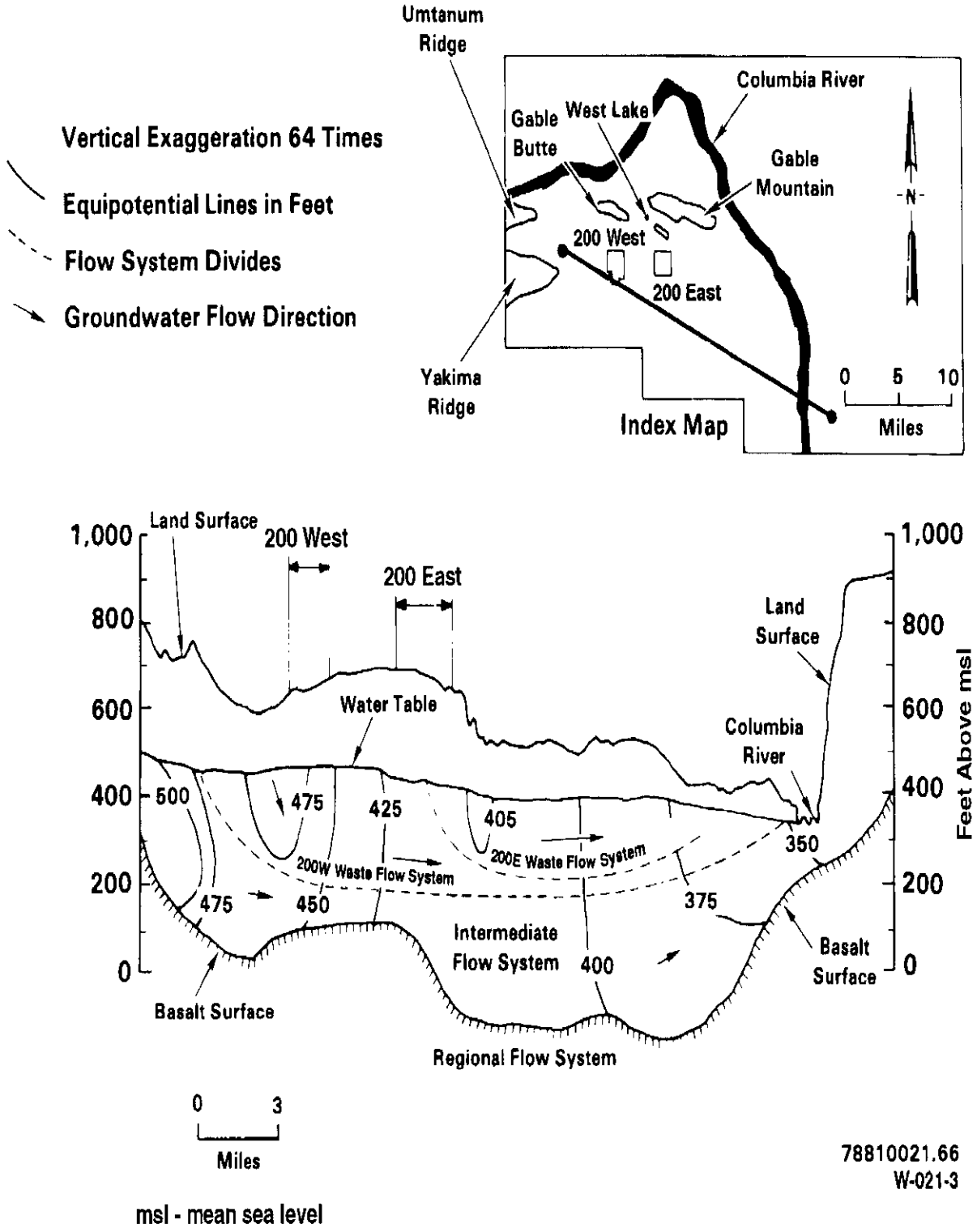


Figure 3-25. Well Location Map for the 200-West Area (Including Groundwater Monitoring Network Surrounding Plutonium Finishing Plant Facilities)

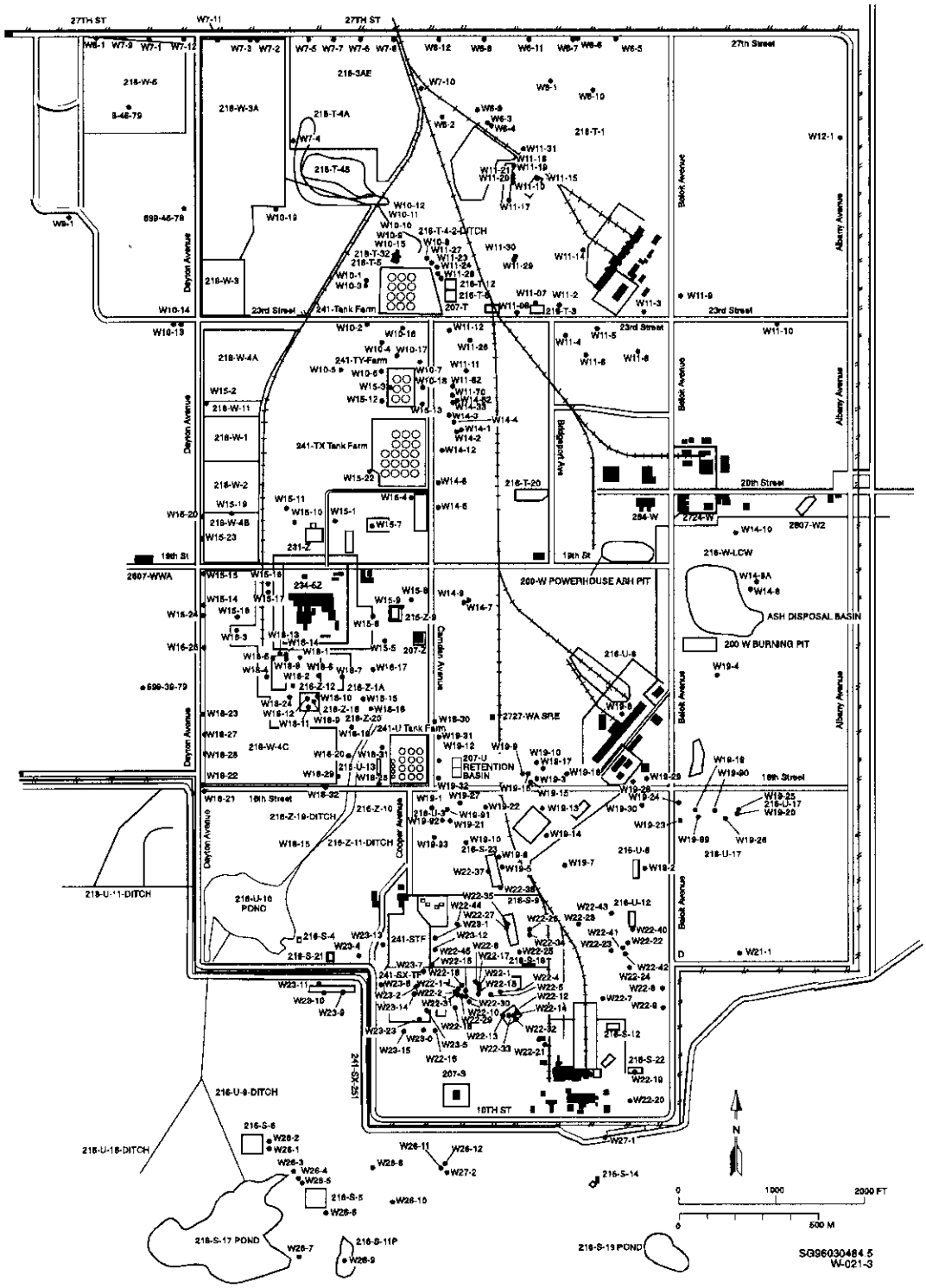


Figure 3-26. Hydrograph of Well Near Plutonium Finishing Plant. (Well 299-W15-17)

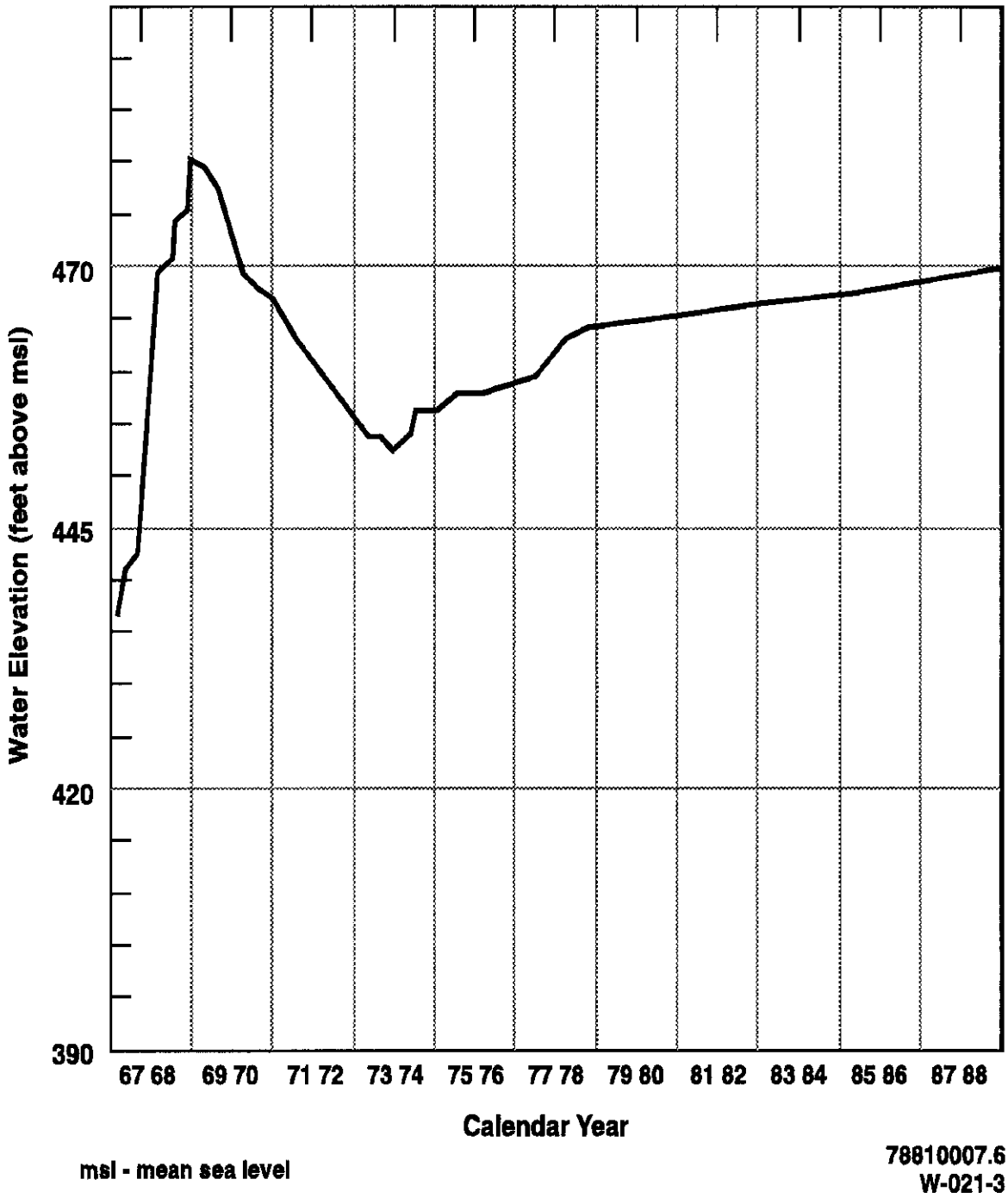


Figure 3-27. Distribution of Carbon Tetrachloride in the Unconfined Aquifer in the 200-West Area, 1994.

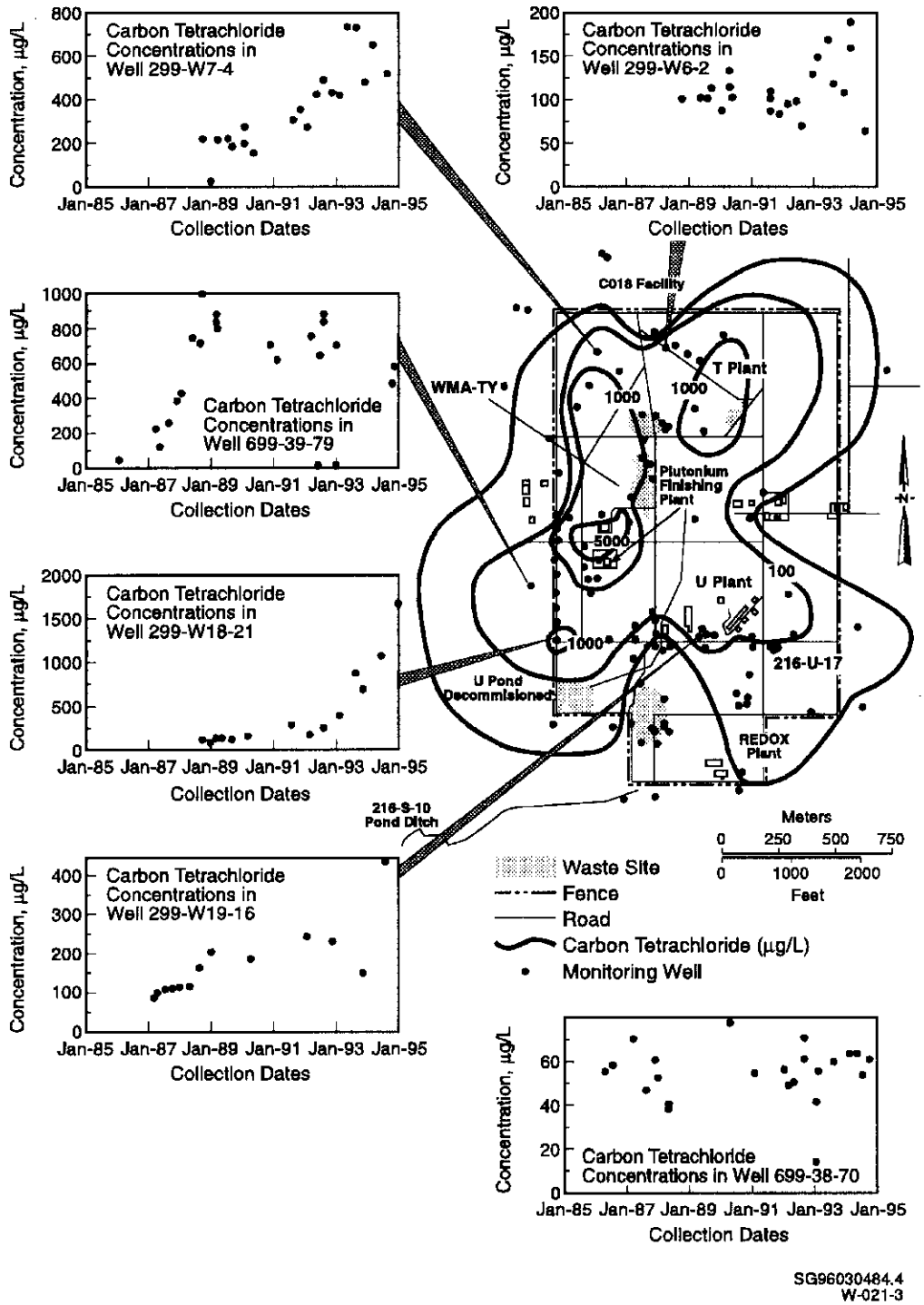


Figure 3-28. Topographic Map of the Region Surrounding the Plutonium Finishing Plant.

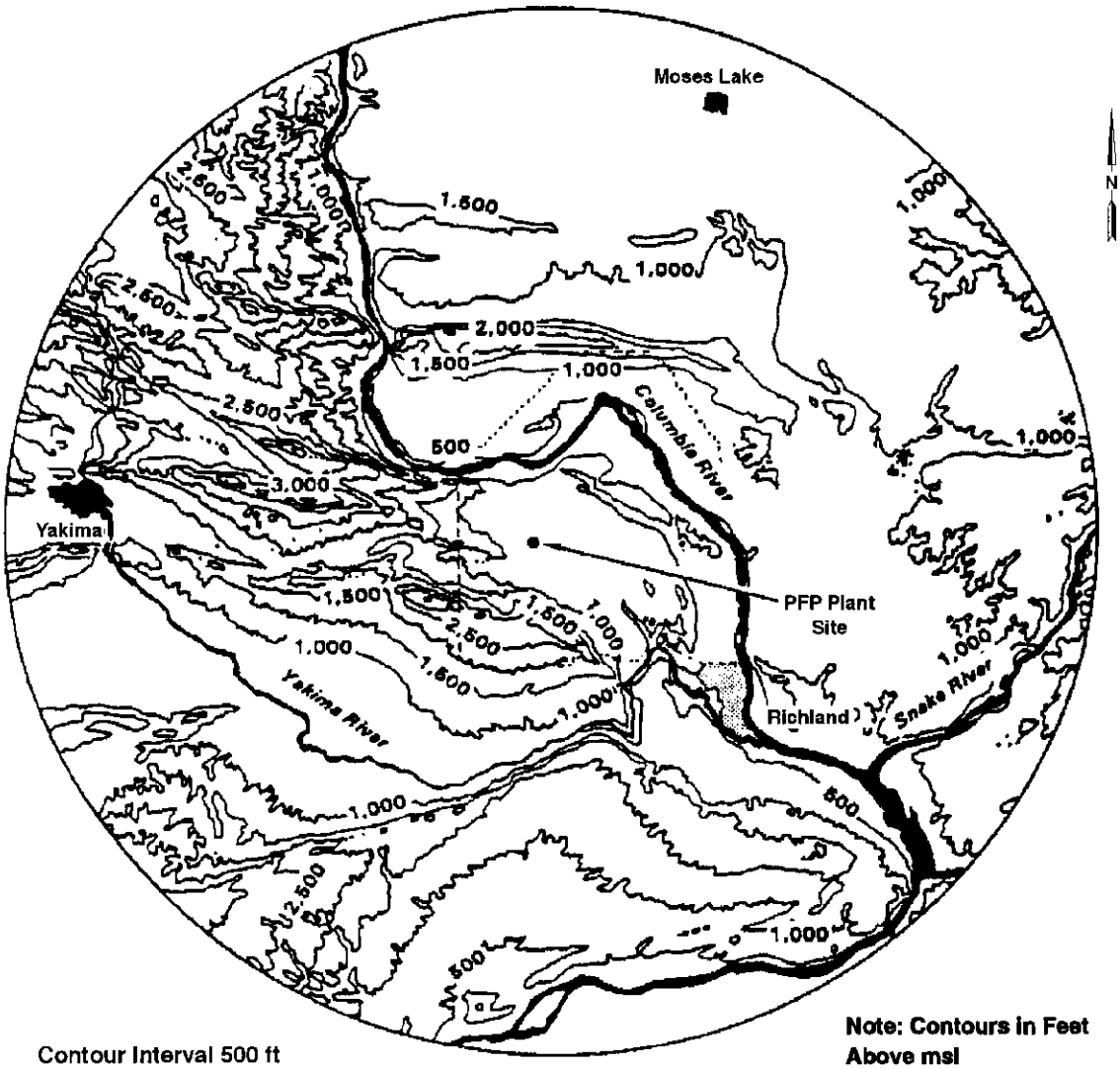
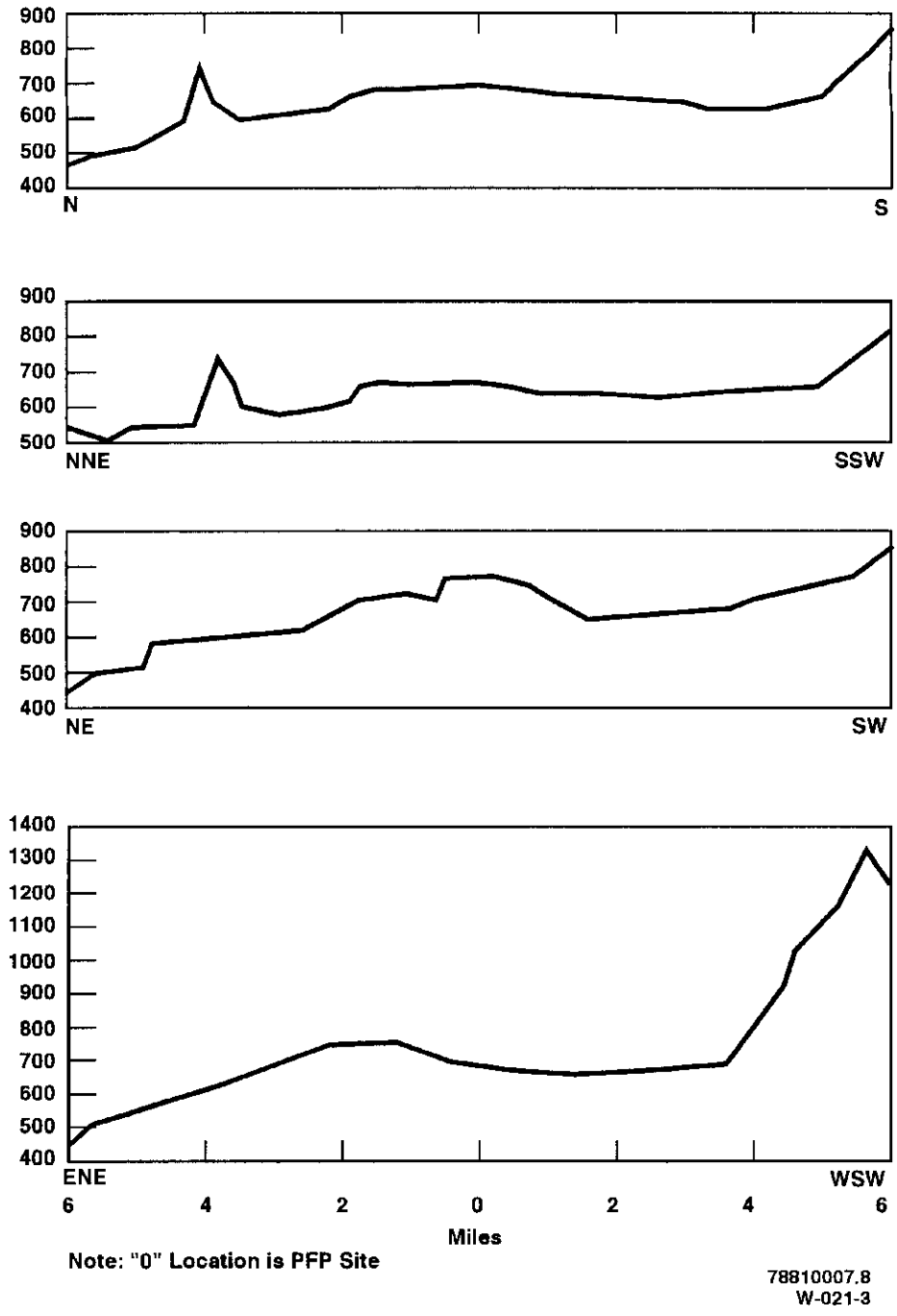
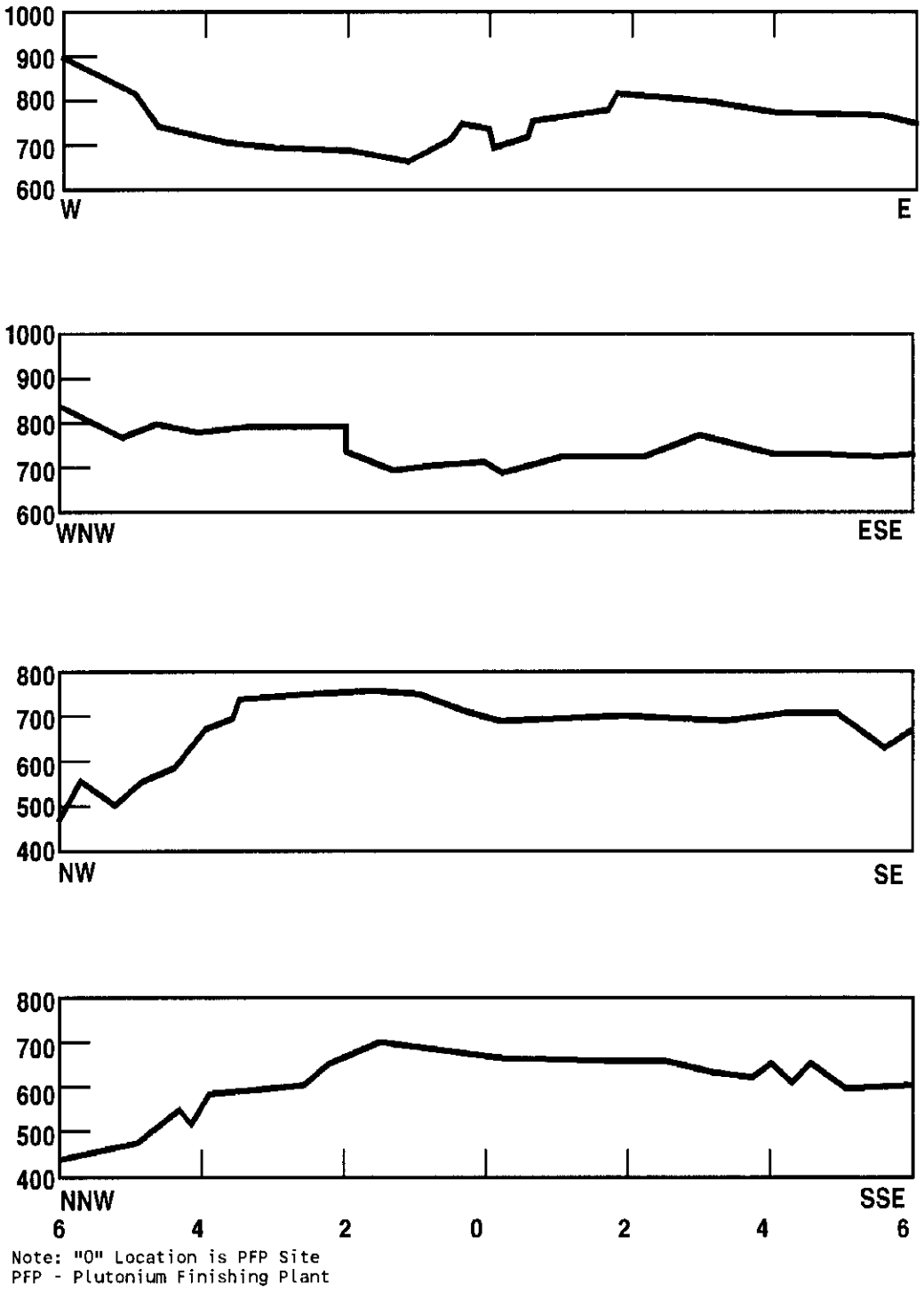


Figure 3-29. Topographic Cross Sections of the Ground Surface Surrounding the Plutonium Finishing Plant.
(Sheet 1 of 2)



PFP - Plutonium Finishing Plant

Figure 3-29. Topographic Cross Sections of the Ground Surface Surrounding the Plutonium Finishing Plant.
(Sheet 2 of 2)



Note: "0" Location is PFP Site
PFP - Plutonium Finishing Plant

Figure 3-30. Physiographic Provinces.

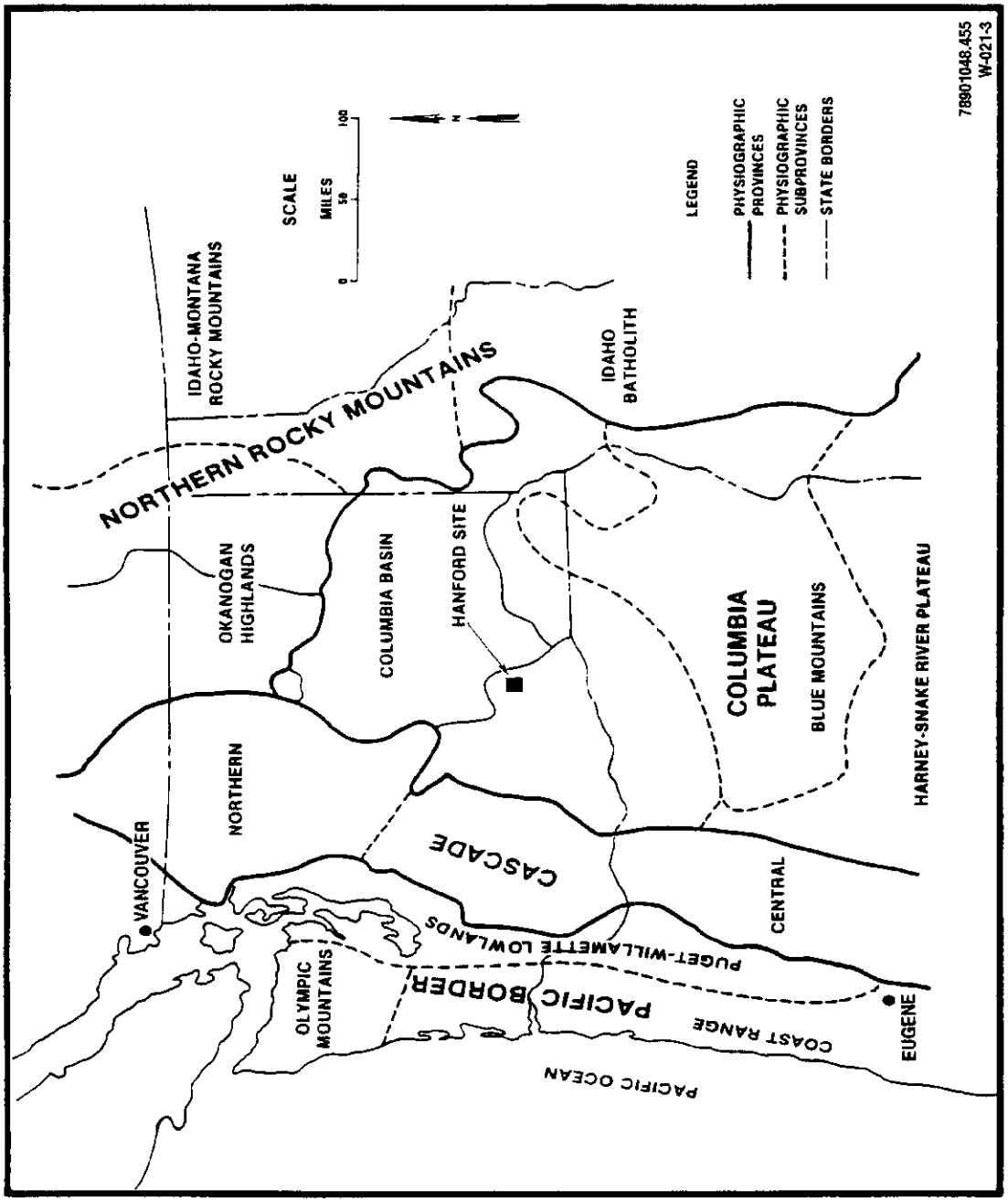
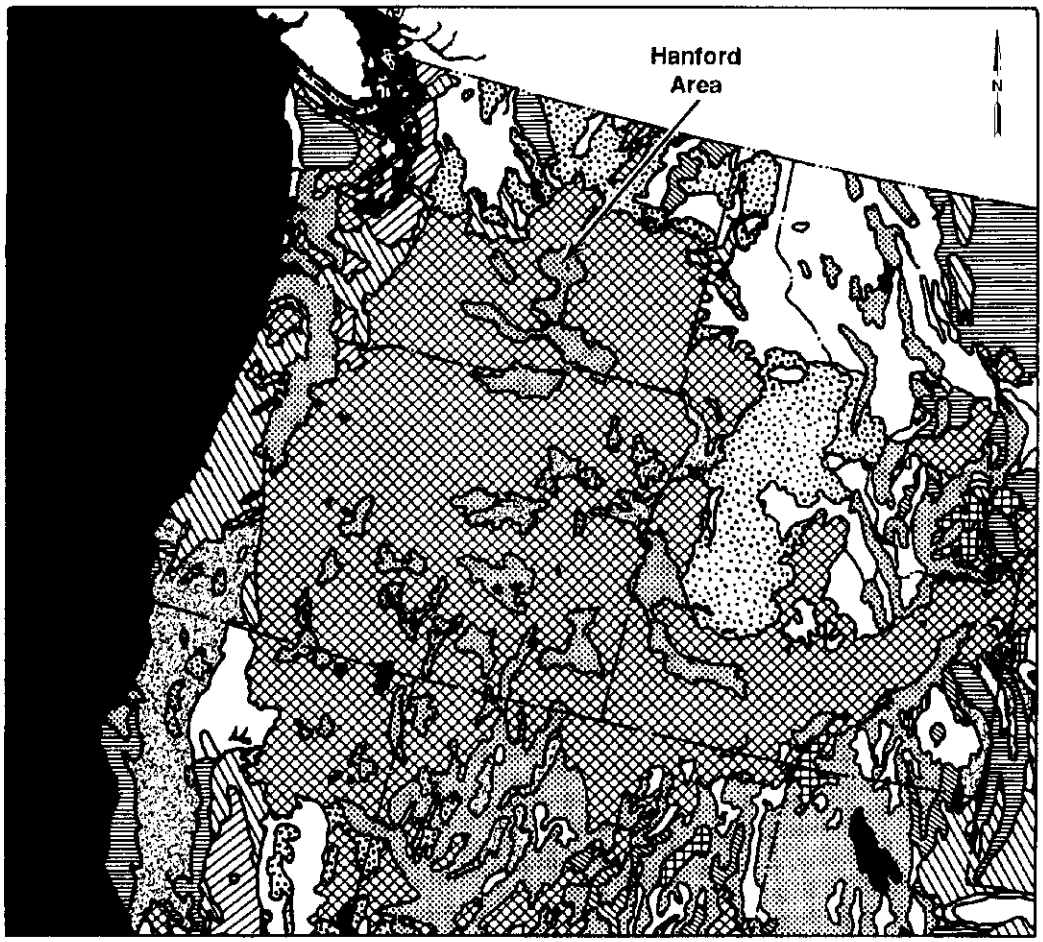


Figure 3-31. Regional Geological Map.



Sedimentary Rocks

- Quaternary: Recent and Pleistocene
- Upper Tertiary: Pliocene and Miocene; in western states include recent and Pleistocene
- Lower Tertiary: Oligocene, Eocene, and Paleocene
- Cretaceous: In parts of Rocky Mountains and Alaska includes Jurassic and Triassic
- Jurassic and Triassic
- Upper Paleozoic: Permian, Pennsylvanian, and Mississippian; in parts of Rocky Mountains and Alaska includes middle and lower Paleozoic
- Middle Paleozoic: Devonian and Silurian
- Lower Paleozoic: Ordovician and Cambrian
- Younger Precambrian

Volcanic Rocks

- Quaternary and Tertiary: Includes small areas of intrusive rocks

Intrusive Rocks

- Lower Tertiary, Mesozoic, and Paleozoic; chiefly Granitic rocks, lower Tertiary and Mesozoic

Igneous Metamorphic

- Older Precambrian Metamorphic and Igneous rocks

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Figure 3-32. Regional Tectonic Map.

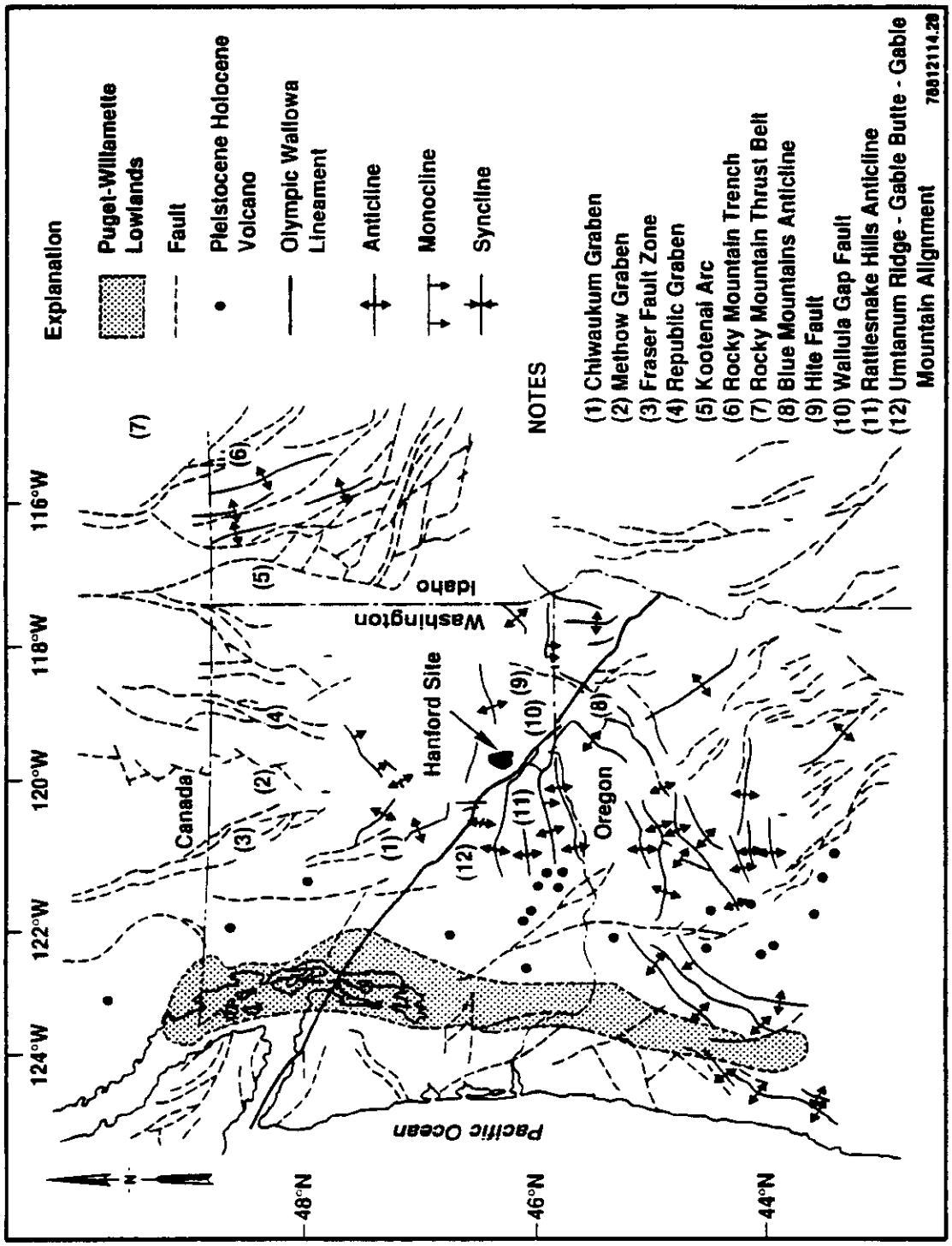
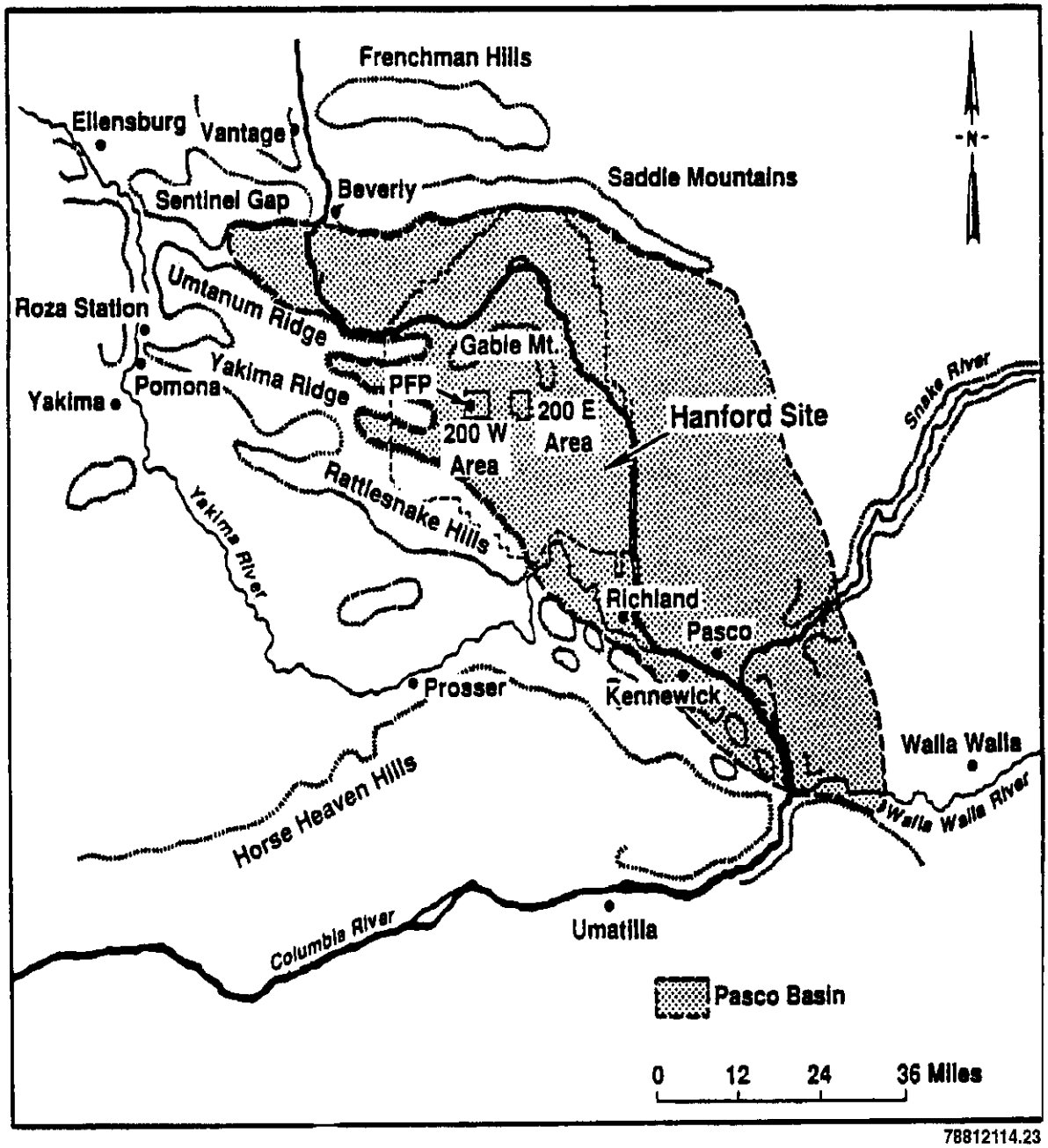


Figure 3-33. General Location of the Columbia Basin Physiographic Subprovince.



PFP - Plutonium Finishing Plant

Figure 3-34. Surface of Basalt in Pasco Basin.

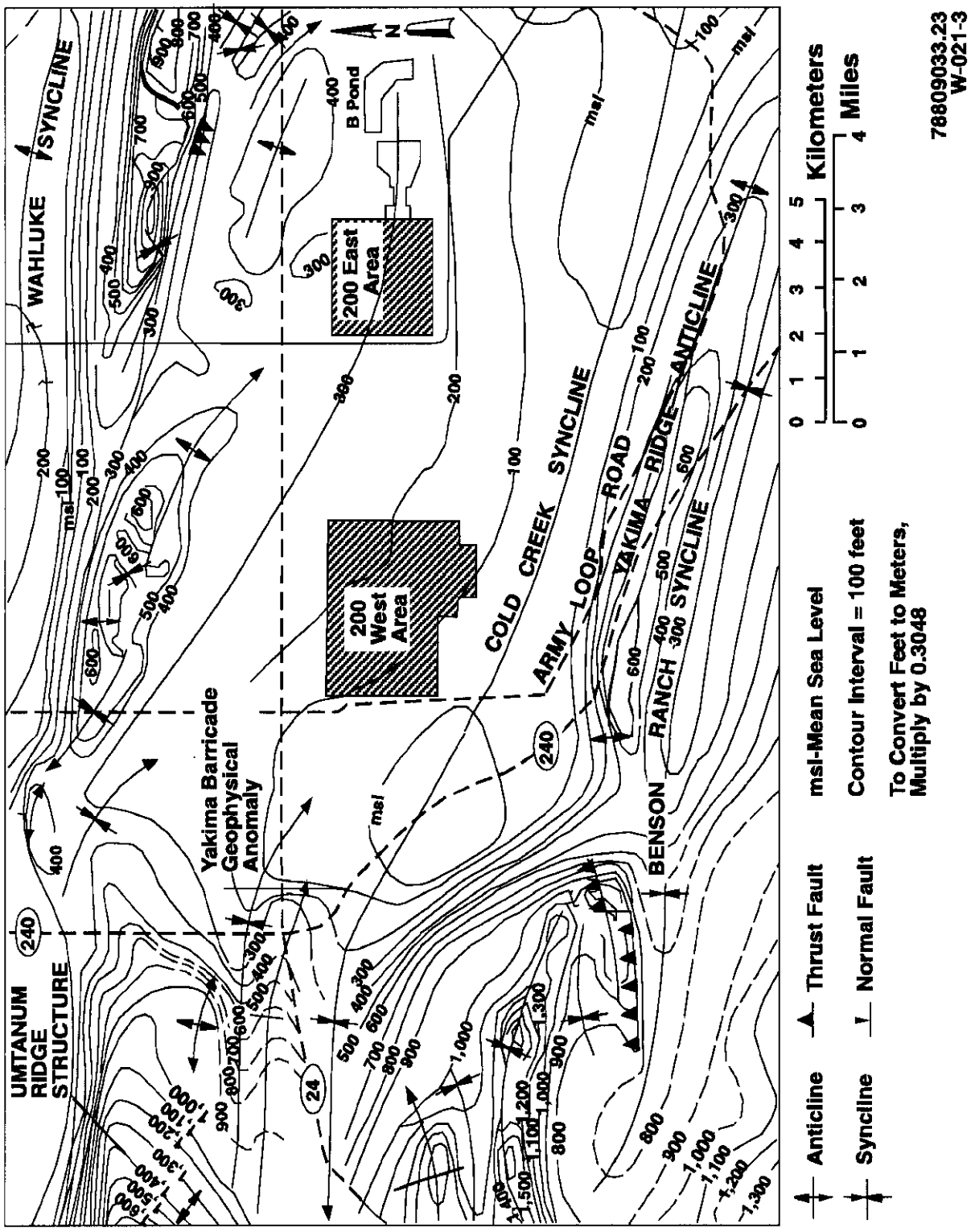


Figure 3-35. Geological Cross Sections of the Pasco Basin.

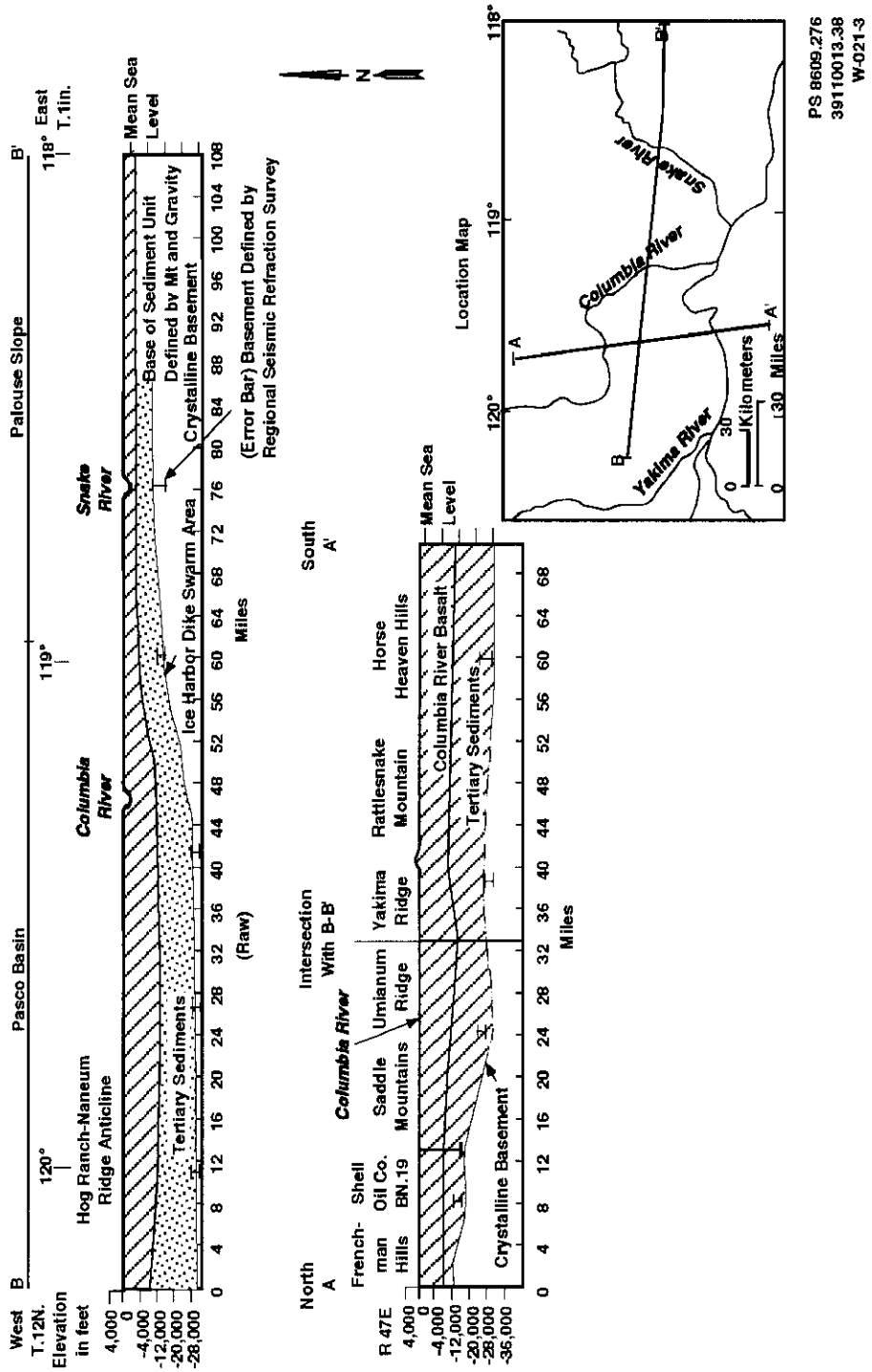


Figure 3-36. Columbia Basin Structural Elements.

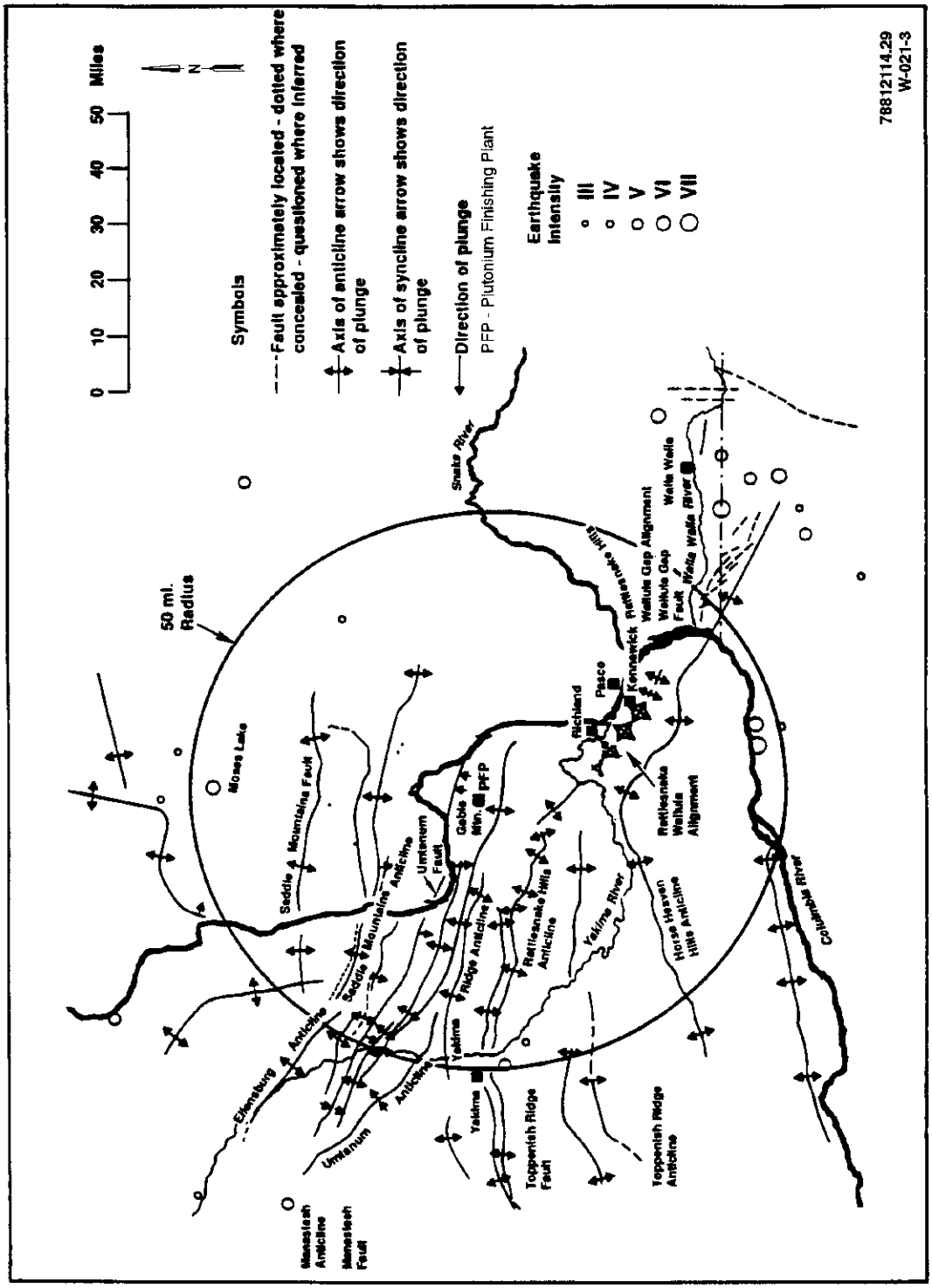
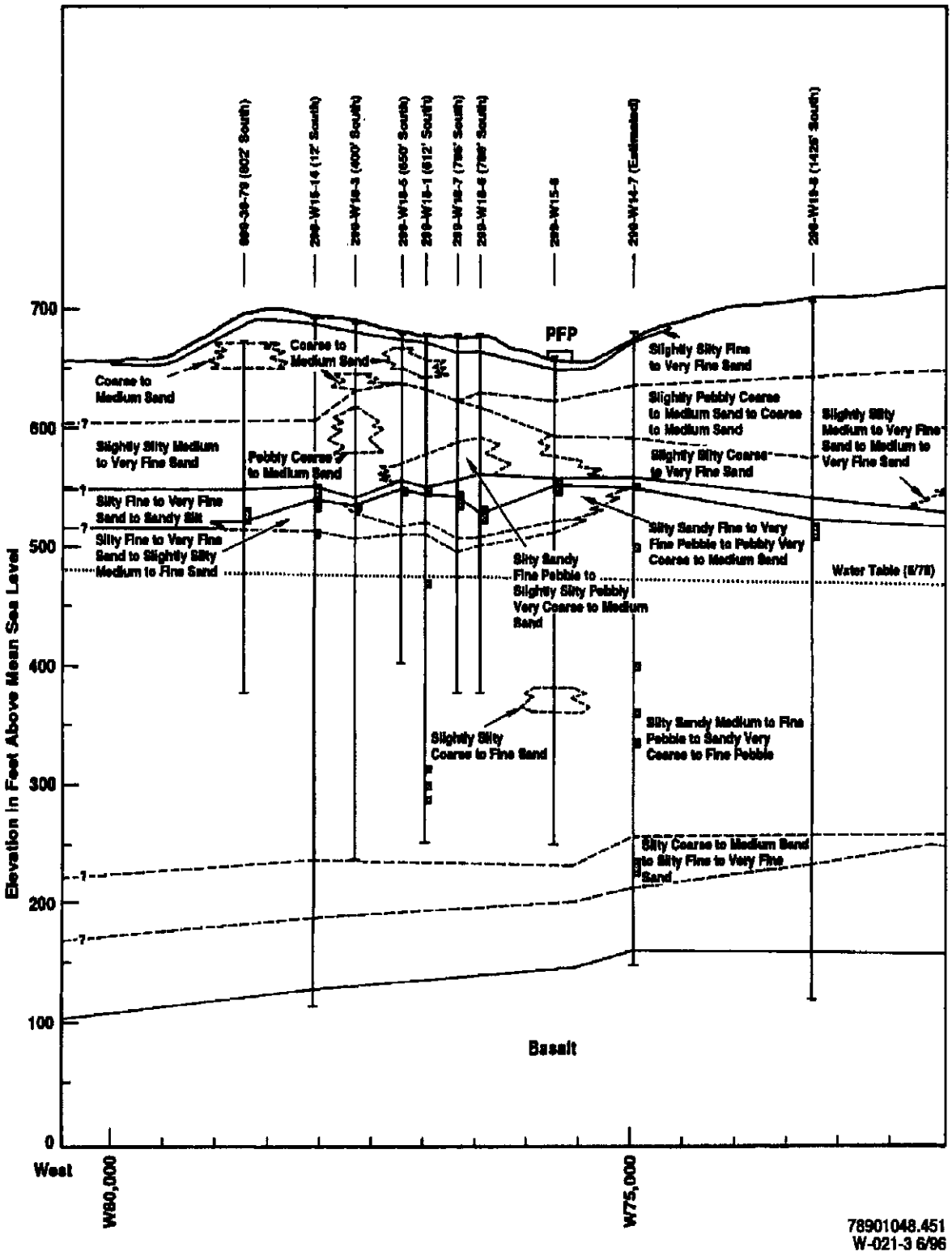


Figure 3-37. Generalized Geologic Cross Section.



PFP - Plutonium Finishing Plant

Figure 3-38. Northwest Volcanoes Closest to the Hanford Site.

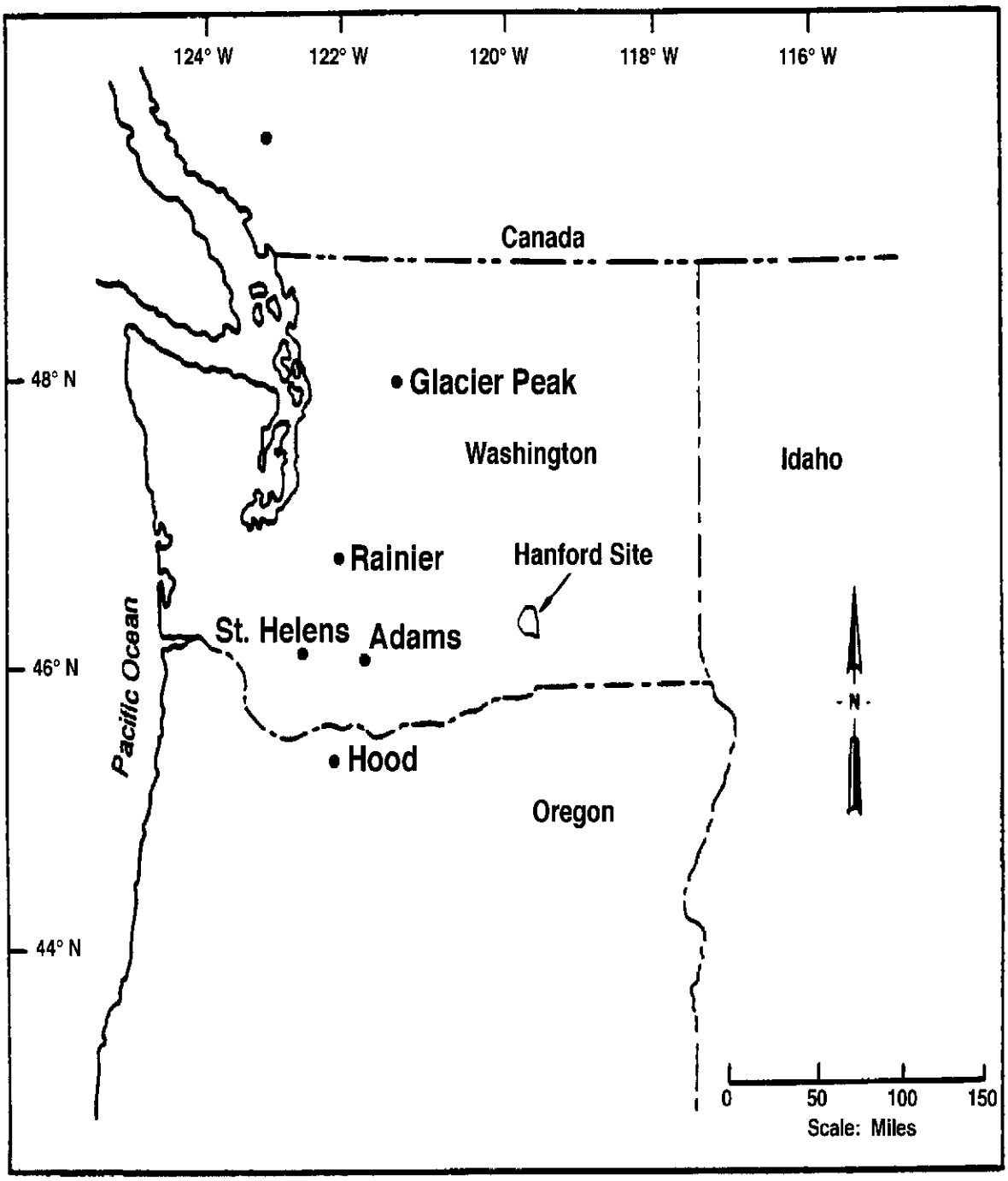


Figure 3-39. Uncompacted Bulk Density as a Function of Distance from the Volcano for Ash Erupted from Mt. St. Helens on May 18, 1980.

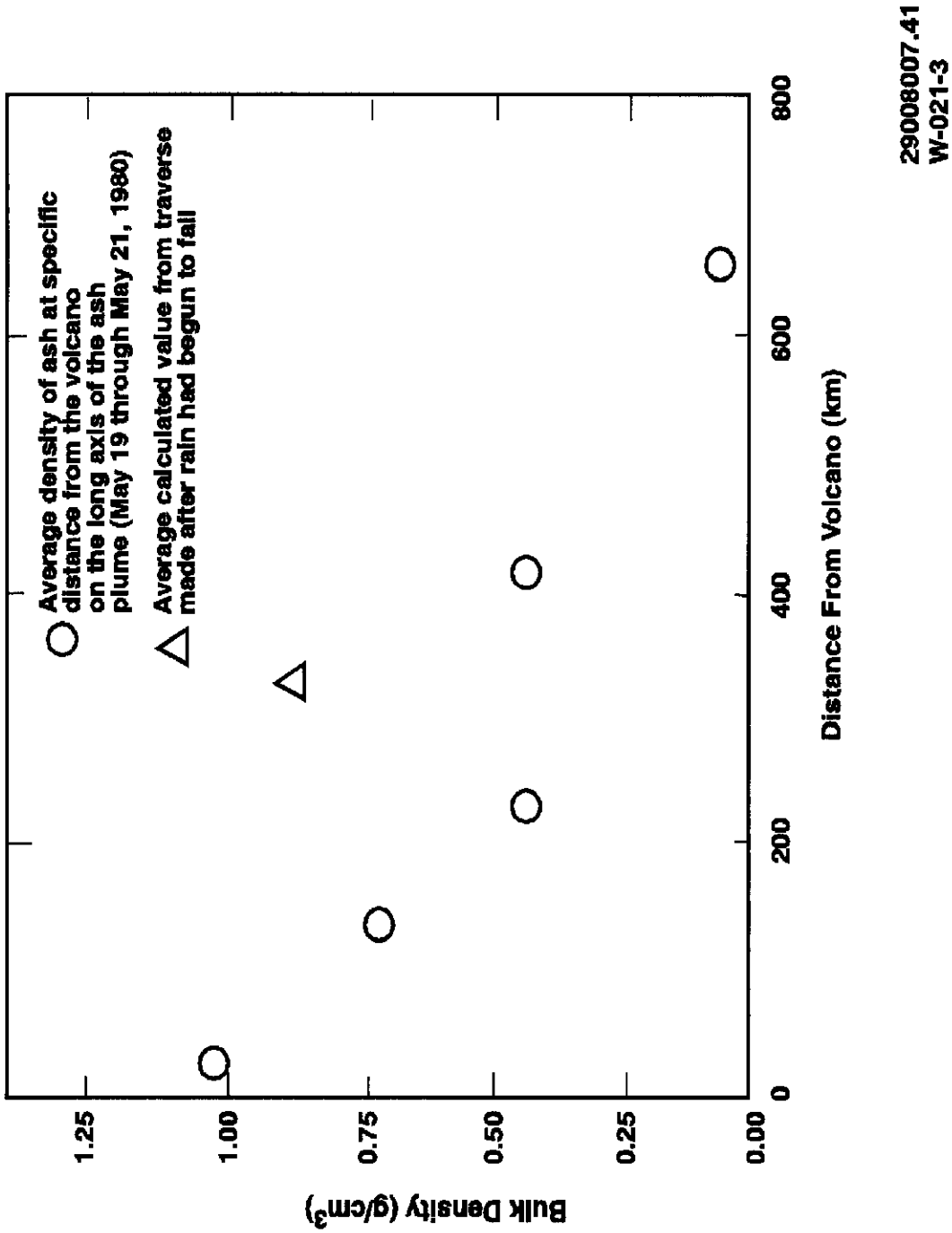


Figure 3-40. Ash Pattern from Postulated Mt. Adams Eruption.

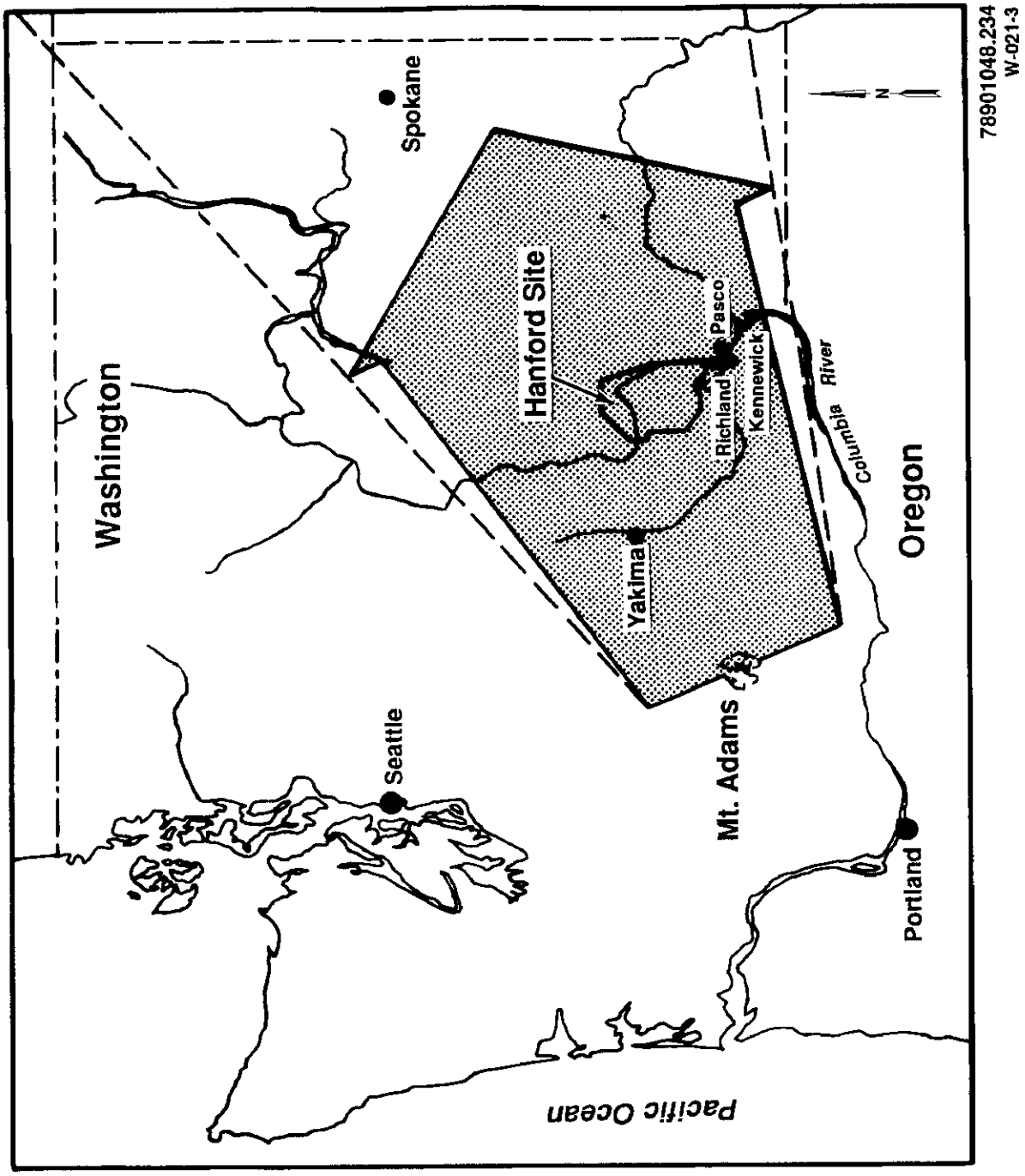
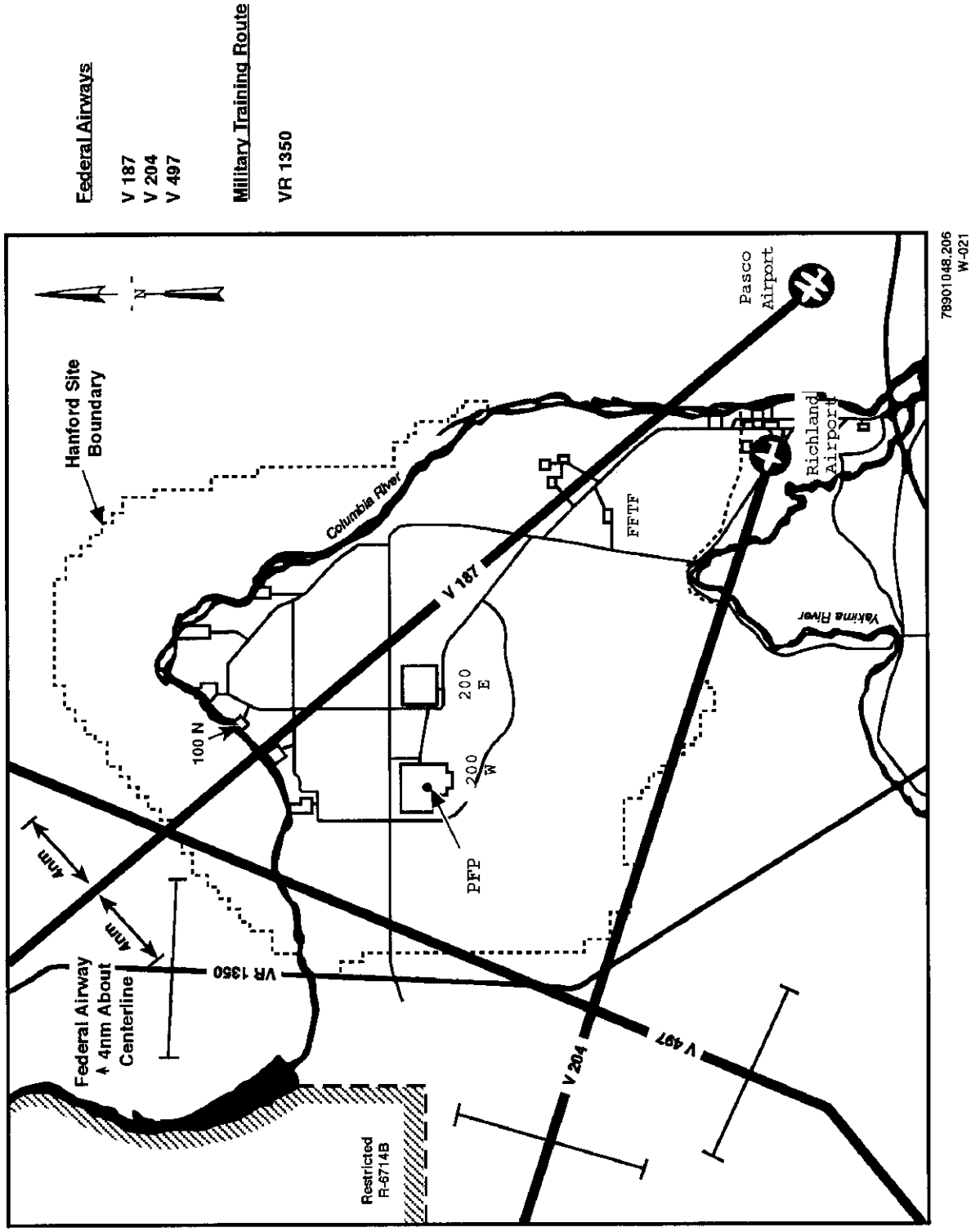


Figure 3-41. Federal and Military Airways in Relationship to Plutonium Finishing Plant.



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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 4.0

PRINCIPAL DESIGN CRITERIA

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 4.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) includes modifications for the following:

- Changing the terminology for the back-up power systems to standby power systems
- Change the Building 232-Z and Building 241-Z stack cams from safety class to safety significant designation
- Incorporation of the Magnesium Hydroxide Precipitation Process
- Incorporation of the Bagless Transfer System

Other minor changes include editorial changes and additional clarifications.

It is noted that various sections of Chapter 4.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner located in the Plutonium Process Support Laboratories. Operation of either the production calciner or the laboratory calciner for solution stabilization is not authorized at this time. If necessary, the related portions of Chapter 4.0 will be updated prior to initiation of operations.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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4.0 PRINCIPAL DESIGN CRITERIA

The Plutonium Finishing Plant (PFP) (originally referred to as the 234-5 Building) was conceived and designed under Project C-198 before 1948 and its construction was completed in 1949. Additional facilities have been designed and constructed from 1949 to the present (the latest major building being the 243-Z Building, finished in 1994). In each case, the facilities were designed in accordance with the codes and standards of the time. The history of the available codes, standards, and guides are shown in the design and construction time line (Figure 4-1). For many of the older facilities, it is not practical to define the original design criteria used, as the design specifications for these facilities were not properly or consistently documented during that time period. Additional information concerning the design and construction dates of specific buildings is presented in Chapter 5.0.

The original PFP design criteria are assumed to be based on DuPont design criteria for explosives-manufacturing plants. It is assumed that following the change of the Hanford Site contractor from DuPont to General Electric (G.E.) in 1945, G.E. Hanford Company retained much of the personnel and design philosophies of DuPont and used these resources in the design and construction of the original PFP facility (the 234-5Z Building).

The U.S. Department of Energy (DOE) Order 5481.1B, *Safety Analysis and Review System* requires that an evaluation of facilities be made against current DOE design criteria (this order is currently undergoing the process to be canceled; DOE Orders 420.1 and 5480.23 would serve as compliance documents for evaluation of facilities). Current principal design criteria, for existing structures, systems, and components and for the purposes of this final safety analysis report (FSAR), are defined as those criteria contained within DOE Order 6430.1A, *General Design Criteria*. New structures, systems, and components will be designed and evaluated in accordance with HNF-PRO-097, "Engineering Design and Evaluation". This order also requires adherence to other applicable DOE orders (e.g., 5480 series) and to other national codes and standards.

4.1 DESIGN CRITERIA CONFORMANCE

The PFP was evaluated against the design criteria of DOE Order 6430.1A using a methodology similar to the Systematic Evaluation Program (SEP) developed through the U.S. Nuclear Regulatory Commission (NRC), for principal design criteria with an emphasis on safety-related design criteria. The SEP was developed by the NRC in cooperation with commercial reactor operators to evaluate older operating nuclear facilities that were designed and built before the establishment of DOE Order 6430.1A. The SEP thereby allowed safety design reviewers to confirm and document a facility's safety design relative to DOE Order 6430.1A safety design criteria. The selected criteria approved by Westinghouse Hanford Company (Westinghouse Hanford) management for incorporation into this FSAR included all Section 99 elements and those special elements in Section 1300 which referred to plutonium handling, storage, or processing. These criteria were structured to the Regulatory Guide 3.39 (NRC 1986) requirements.

Evaluation of the PFP conformance to DOE Order 6430.1A is provided in *Preliminary Evaluation of PFP Conformance to DOE Order 6430.1A General Design Criteria* (WHC 1990). Conformance to these safety criteria ensures that the operation of the PFP will not contribute to an unacceptable onsite or offsite consequence. The nonconforming items are evaluated in Attachment II of WHC (1990). The attachment also notes Chapter 9.0 evaluations if a potential onsite/offsite consequence issue is involved.

This engineering study was a preliminary assessment of the PFP conformance to DOE Order 6430.1A, required by DOE Order 5481.1B. The assessment evaluated conformance of the PFP to design criteria having a potential safety boundary impact. The following two assessments were made of the PFP in this study.

- An initial conformance assessment identified conforming, nonconforming, and not applicable items, categorized their safety implications and consequences, and set a confidence level for these decisions.

- A further assessment evaluated nonconforming items for acceptance or upgrading. Best engineering judgement was used in evaluating nonconforming items to ensure that deviations from general design criteria did not compromise the PFP safety boundary. In many instances, the rationale for acceptance or upgrading was based on safety analysis techniques defined in WHC-CM-4-46, *Safety Analysis Manual*. Approved risk acceptance criteria are defined for offsite and onsite consequences resulting from routine operations, abnormal events, and design basis accidents (DBAs) for both radioactive and toxic chemical releases. However, nonconforming items that adversely impact facility workers or ground water/soil contamination did not have approved risk acceptance criteria. Best engineering judgement was used to evaluate these kinds of impacts.

4.1.1 Nonconformance to Design Criteria

Existing facilities (such as the PFP) that cannot be shown to conform with the design requirements contained in DOE-RL (1993) may be evaluated to the site-specific and less conservative natural phenomena hazards defined in WHC-SA-0606A *Natural Phenomena Hazards, Hanford Site, Washington* (Tallman 1989). If evaluation using site-specific natural phenomena hazards cannot show an existing facility to be in conformance with the acceptance criteria, then the methods for evaluating existing structures defined in *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards*, UCRL-15910 (Kennedy et al. 1990) may be used. Potential options for existing facilities include the following:

- Conducting a more rigorous evaluation to reduce conservatism that may have been introduced by simplified evaluation techniques; alternatively, a probabilistic assessment of the facility may demonstrate that the performance goals for the facility may be met

- Strengthening the facility to provide resistance to hazard effects that meet the guidelines

- Changing the use of the facility, provided there is an adequate technical basis, so that the facility falls into a hazard category governed by less stringent requirements.

If an existing facility is close to meeting the guidelines, a slight increase in the annual risk to natural phenomena hazards may be allowed for less than 20 yr. Hazard exceedance probabilities of twice the recommended values may be used for wind and seismic loads, or alternately, permitting calculated inelastic demand to exceed capacity by no more than 20% may be allowed. Relief for flood evaluation is not permitted. Earthquake and wind loads for the reduced hazard probabilities may be obtained from Tallman (1989).

In general, PFP facilities found to be nonconforming to specific DOE 6430.1A design criteria were found acceptable as is based on (1) showing that the nonconformance is low risk by use of relevant analysis scenarios and consequences performed for the nonconforming facilities, and (2) operational safety requirements necessary to maintain the plant safety envelope (WHC 1990).

All modifications and upgrades identified in WHC (1990) have been either completed or determined by further evaluation to be unnecessary.

4.2 PURPOSE OF PLANT

The primary purposes of the current PFP complex are listed below:

- Plutonium material shipping/receiving/storage
- Remote Mechanical A (RMA) and Remote Mechanical C (RMC) Line operations
    - Reactive plutonium-bearing material stabilization
    - Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner
    - Other RMA and RMC Line processes
- Laboratory support
- Facility cleanout operations
- Radioactive waste handling.

Various plutonium-bearing materials were produced during previous PFP operations. This inventory of plutonium is in the form of pure and mixed oxides, fluorides, metal, polycubes, oxalates, silicates, and organic-based sludges and residues. Reactive plutonium-bearing material must be stabilized before long-term storage to prevent the formation of excessive hydrogen or nitrated organic compounds. Plutonium stabilization is conducted in selected gloveboxes in the 234-5Z Building. The principal plutonium material storage vaults are in the 2736-Z Building, and shipments (oxide or metal forms) are prepared or received in the 2736-ZB and 2736-ZC facilities. Nitrate solution

storage is provided in the 234-5Z Building. Developmental work involving plutonium materials is conducted in the laboratories within the 234-5Z Building.

4.2.1 Plant Feed

The feed for the stabilization processes comes from material stored in the plant. This material is composed of by-product from former production campaigns, research scrap, and shipments received from offsite. The isotopic distribution of the PFP plutonium inventory is documented in *Technical Basis for Characterization of Plutonium for PFP Safety Analyses* (Crowe and Szempruch 1994). The PFP may receive additional onsite or offsite shipments of plutonium-bearing materials for storage.

The original PFP mission was to supply plutonium metal for national defense. Plutonium metal was processed at the PFP and shipped in large quantities during the 1950's and 1960's. Virtually all of this plutonium is characterized as containing nominally 6% or less of the ^{240}Pu isotope. Similar metal production was done for several years in the 1980's.

In the 1960's, the PFP plutonium processing changed. Demands for plutonium metal declined while research in power technology indicated that plutonium oxide could be used as fuel. Later research demonstrated how to use plutonium oxide as a fuel for breeder reactors. The predominant product form from the PFP changed from a single, metallic piece (weighing about 2 kg) to a fine, powder oxide. Demands for the oxide powder increased from grams for research to thousands of kilograms for reactor fuel. In the late 1960's and 1970's, the PFP processed almost all of the plutonium oxide used in this country, including thousands of kilograms for Fast Flux Test Facility (FFTF) reactor cores.

Production strategies for the oxide dictated scheduling between metal production campaigns. They also included a degree of overproduction to allow for process losses, out-of-specification product, and requests for kilogram quantities of plutonium oxide for research efforts. Storage of production overrun materials became common.

The completion of the Plutonium Reclamation Facility (PRF) in the 1960's provided the PFP with plutonium scrap recovery capability. Plutonium scrap from military applications as well as from commercial and breeder reactor research was returned to the Hanford Site for the recovery of plutonium. Because the Hanford Site was the DOE scrap-management site and the envisioned supply site for DOE breeder reactor fuel, the PFP received virtually all plutonium with greater than 6% ^{240}Pu content from both domestic and foreign sources. The scrap, which had a wide variety of chemical and physical forms, was added to the growing inventory of plutonium metal and oxide stored at the PFP.

During the 1960's and 1970's, other changes occurred that ultimately impacted isotopic composition of the plutonium stored at the PFP. The declining demand for plutonium metal caused N Reactor production to change from nominal 6% ^{240}Pu to nominal 12% ^{240}Pu. The 12% ^{240}Pu material was used for breeder reactor research and FFTF cores. Commercial nuclear reactors and some government experimental reactors produced plutonium with higher ^{240}Pu content.

Changes in production demands and capabilities at other DOE sites caused large segments of the DOE inventory to be relocated. The inventory was shipped to the PFP because of available storage space and anticipated breeder reactor program needs. Plutonium handling or processing of 15% to 18% ^{240}Pu material was not uncommon, and some small lots in excess of 40% ^{240}Pu were processed at the PFP. This material is part of the current inventory of thousands of containers in storage vaults.

The current plutonium inventory is a collection of individual items and not a continuous spectrum of a single product line. The plutonium in each inventory container is unique because of its creation in a particular reactor environment and its chronological history of processing and storage. Individual containers may have similar plutonium isotopic distributions because they have a common history, were part of a common process blend lot, or purely from coincidence.

The present plutonium inventory at the PFP comprises more than 8,000 items. Accountability methods and records requirements over the years have changed. This has resulted in an inventory database that ranges from detailed isotopic information for some items to only the total plutonium mass and an indication of ^{240}Pu content for others. The present PFP plutonium inventory shown in Table 4-1 was derived from current inventory records. For cases in which the database did not contain isotopic information, the plutonium material accountability personnel provided an estimate of the total inventory of each isotope. Past laboratory data and hard copy records were used to determine an estimate of the isotopic content of each package. Estimates and professional judgements were used to assign isotopic values to materials of common origin or process lot. The plutonium inventory was separated into groups, or "bins," based on the percent of ^{240}Pu. The bins typically spanned a 3% range.

The isotopic distribution of the current plutonium inventory determined as described above is shown in Table 4-2. Some 400 kg of plutonium in clad nonirradiated FFTF fuel pins and assemblies is not included in the table because this material is relatively "clean" (lower activity) and is not considered dispersible. Inclusion of the plutonium from the FFTF fuel in the database would reduce the calculated unit doses and, from the standpoint of safety analysis, would not be conservative. In addition, EBR II reactor spent fuel stored in the 2736-ZD vault is not included as dispersible inventory in the table.

Nondestructive analysis (NDA) of shipments and periodic vault inventory verifications have been performed at the PFP for more than a decade using gamma spectroscopy to determine isotropic concentrations of plutonium. The vault verification program includes randomly selecting a number of items from the inventory and nondestructively verifying contents. The shipping NDA measurements verify the composition of material shipped into and out of the PFP. Additional measurements are made for items created during PFP operations. In all, about 4,700 items have been measured during the past 8.5 yr. The results of these measurements have been maintained by the PFP laboratory analysts in a historical database.

This database, referred to in this document as the NDA verification database, validated the inventory estimate and assessed the distribution of individual isotopes and their net effect on calculated potential doses in

safety analyses; however, because the database is a record of "all" measurements, it includes duplicate measurements and counts of standards made for quality control purposes. These data were deleted from the database before use in this evaluation because they do not represent items in the inventory. Some of the database items were analyzed when shipped in and again when shipped out. Counting these items in the estimate is not appropriate because these items no longer are in the inventory, therefore, they were deleted from the database. The plutonium isotopic distribution of the NDA database is shown in Table 4-2. The remaining mass of plutonium and number of items measured are also shown in Table 4-2, columns 2 and 3. The correspondence between the NDA verification database and the current PFP inventory is shown in the comparison of the isotopic composition of the individual bins in Table 4-1 and 4-2.

4.2.2 Plant Product and Byproducts

The only product generated by active PFP processes is stabilized plutonium-bearing material. This material is handled, packaged, and stored in accordance with process descriptions contained in Chapter 6.0, Sections 6.1, 6.3, and 6.4.

Former products of the PFP processing facilities were: (1) the purified plutonium nitrate from PRF, which was sent primarily to the RMC Line, (2) plutonium metal (weapons grade) from the RMA and RMC Line, and (3) plutonium oxide powders from the RMA Line. The specifications for these products are shown in Table 4-3.

4.2.3 General Plant Functions

The PFP functions are as follows:

- Perform stabilization of reactive plutonium-bearing materials
- Perform stabilization of plutonium-bearing solutions
- Manage the plutonium inventory at the Hanford Site including receipt, analysis, storage, and shipment
- Conduct development work involving plutonium material.

Utilities and support functions are discussed in Chapter 5.0. The process systems are described in Chapter 6.0. Effluent and waste handling functions are discussed in Chapter 7.0.

4.3 STRUCTURAL AND MECHANICAL SAFETY CRITERIA

The building structures and mechanical systems at the PFP were designed by the Architect and Engineer before today's stringent requirements for resistance to natural force events. Construction for the 234-5Z, 241-Z, 291-Z, and 2902-Z (water tower) Buildings began in 1948. The design requirements of this time period considered static loads, vertical live loads,

and dead loads. During this period, the Hanford Site was designated as a low intensity, minimum occurrence earthquake zone.

From 1949 to 1968, the Hanford Site chemical processing (CP) structures were designed for static, vertical live, and dead loads in accordance with the UBC, which included seismic provisions (see Chapter 5.0, Section 5.2, for more details on the original design criteria of specific PFP buildings). Lateral wind forces related to areas and lateral earthquake forces related to the mass of structures were specified according to the UBC provisions that designated the Hanford Site as seismic zone 2.

Since 1973, critical structures, facilities, and equipment at the Hanford Site have been designed and/or analyzed for the combination of dead, live, and operating loads plus seismic forces from a maximum credible earthquake, as defined in Section 4.3.5.

The current criteria for natural phenomena design are presented in this section as the appropriate design basis for evaluating existing facilities and future modifications and additions. DOE Order 6430.1A states in Section 0101-1 that for existing facilities, original design criteria apply to the structure in general and that modifications are to comply with current criteria. The ability of existing facilities to withstand the stresses derived from current design loading criteria (or the consequence of failure to do so) is detailed in Chapter 5.0, Section 5.2.

General criteria for structural and mechanical safety are defined in DOE Order 6430.1A.

4.3.1 Wind Loading

The PFP is classified as a high-hazard nonreactor nuclear facility in accordance with Kennedy et al. (1990). Wind design criteria are in accordance with *Hanford Plant Standard, Standard Arch-Civil Design Criteria*, "Design Loads for Facilities," SDC 4.1, Revision 12 (DOE-RL 1993). Evaluation methodology and site-specific criteria are obtained from Kennedy et al. (1990). The Hanford Site is considered Exposure Category C with an importance factor of 1.0. See Chapter 5.0, Section 5.2, for a discussion of specific building wind loading criteria.

4.3.1.1 Design Wind Velocity. The original design criteria did not utilize a design wind velocity but defined a resultant applied force in pounds per square feet. The current criteria comes from DOE-RL (1993) and Kennedy et al. (1990). The current criteria from DOE-RL (1993) is as follows.

- Nonreactor safety class 1 (Kennedy et al. 1990) structures, systems, and components (SSCs) (now referred to as Safety Class SSCs) are designed for wind loads in accordance with ASCE 7-88. High-hazard facilities as defined in Kennedy et al. (1990) are designed to a wind having an annual probability of 1×10^{-4}.
- Fastest-mile speed at a height of 10 m = 90 mi/h.

4.3.1.2 Basis for Wind Velocity Selection. The basis for the 90-mi/h design wind velocity identified in Section 4.3.1.1 is Kennedy et al. (1990),

Table 5-e, "Recommended Basic Wind Speeds for DOE Sites." This correlates with the wind history described in Chapter 3.0, Section 3.3.1.

Compliance with design criteria is analyzed in Section 5.2 and in Chapter 9.0.

4.3.2 Tornado Loadings

Analysis of the effects of the design basis tornado (DBT) on nonreactor nuclear facilities (such as the PFP complex) is not required based on current design criteria stated in DOE-RL (1993).

- The design basis wind velocity is a function of the Safety Class of the structures. ". . .according to probabilistic hazards studies, the controlling load for nonreactor structures at the Hanford Site is from extreme wind."

- Nonreactor Safety Class 1 structures, systems, and components (now Safety Class SSCs) are to withstand the effects cited previously for reactor facilities with three exceptions: (1) Safe Shutdown Earthquake (SSE) is identified as the Design Basis Earthquake (DBE), (2) Operating Basis Earthquake (OBE) is not required, and (3) DBT is replaced by Design Basis Wind.

This correlates with Kennedy et al. (1990), Section 5.2.4 and Table 5-1, which states that the Hanford Site should be designed for extreme wind and not tornado.

4.3.3 Water Level (Flood) Design

There is no possibility of PFP structural failures due to high flood water level. Therefore, the calculation of dynamic water force design loads due to maximum flood level is not necessary.

The lowest elevation within the PFP complex (bottom of the tunnel level in 234-5Z Building) is approximately 666 ft above mean sea level (msl). The probable maximum flood level of the Columbia River at the 100-N Reactor site would be at an elevation of 423 ft. In addition, the probable maximum 24-h precipitation of 11 in. during a million-year period would not result in any flooding due to the natural drainage of the soils (see Chapter 3.0, Sections 3.4.2 and 3.4.3 for details).

4.3.4 Missile Protection

The original designs of the 234-5Z, 232-Z, 236-Z, 241-Z and 242-Z Buildings did not incorporate criteria for missile protection. The design of the 2736-Z and 2736-ZB Buildings incorporated criteria for wind generated missiles. The only other source of externally generated missiles is the gas storage bottles located outside the 234-5Z Building, but within the 2734-Z structure designed for that purpose.

No significant potential for internally generated missiles has been identified except in the 236-Z and 234-5Z Buildings.

4.3.4.1 Missile Barriers and Loading. Those PFP buildings that contain plutonium inventory have been evaluated for extreme-wind and/or tornado-generated missiles are identified in Chapter 5.0, Section 5.2, and Chapter 9.0, Section 9.2.5.

The 236-Z process cell wall (2-ft-thick concrete) design is based on radiation protection but is sufficiently thick to provide missile protection from very low probability deflagration in the concentrators located in the cell. Other deflagrations considered capable of generating missiles involve flammable gas cylinders.

4.3.4.2 Missile Selection. The criteria for extreme-wind generated missiles are provided in DOE-RL (1993) as follows:

- Missile (horizontal)--2-in. by 4-in. plank, weight 15 lb, velocity 50 mi/h (73.5 ft/s), 50-ft maximum trajectory height
- Vertical missile velocity is 2/3 of the missile horizontal velocity.

The gas bottle missile is considered a standard high-pressure gas bottle for analysis purposes.

4.3.5 Seismic Design

This section presents the generic seismic design criteria relevant to the PFP structures. Chapter 5.0, Section 5.2, presents building-specific discussion of the seismic design and analyses performed on major PFP structures.

Original Criteria. Original seismic design criteria for the PFP facilities are assumed to be based on UBC requirements applicable at the time of construction or modification at both the Hanford Site and at the General Electric Laboratory at Schenectady, New York. The 234-5Z, 241-Z, 2902-Z, and 291-Z Buildings are assumed to have been designed in accordance with the UBC of 1946. The 232-Z, 236-Z, and 242-Z Buildings are assumed to have been designed in 1959 and 1960 in accordance with applicable Hanford Plant Standards and the UBC of 1958 and 1961. The 2736-Z Building is assumed to have been designed in 1969 in accordance with Hanford Plant Standards, general criteria for the storage of plutonium (Brecke 1969) and the UBC of 1967. The 2736-ZB complex is assumed to have been designed in 1979 in accordance with *General Design Criteria, Plutonium Facilities* (ERDA 1974), Hanford Plant Standards and the UBC of 1976. Facility additions and alterations since June 1981 have been designed in accordance with DOE Order 6430, 6430.1, or 6430.1A, as applicable, DOE Order 5480 series and Hanford Plant Standards (DOE-RL 1993).

Current Criteria. Each PFP structure is placed into the applicable facility use category based on the function of the structure in accordance with UCRL-15910 (Kennedy et al. 1990). Based on the facility use category descriptions given in Kennedy et al. (1990), the PFP confinement structures are classified as High Hazards Facilities. It should be noted that

UCRL-15910, "High Hazard Category," is equivalent to DOE Order 6430.1A, "Nonreactor Safety Class 1." The performance goal for High Hazard Category structures is to provide very high confidence that radioactive materials are confined during and following a natural phenomena hazard occurrence. Maintaining confinement of hazardous materials requires that damage be limited in confinement barriers such that they remain functional. Structural members and components should not be damaged to the extent that breach of the building envelope is significant. Hanford Site procedure HNF-PRO-704, *Hazard and Accident Analysis Process*, provides the necessary guidance to determine the safety categorization of SSCs (Table 4-4). These safety SSCs are then used to determine the applicable and relevant design criteria (Table 4-5).

Current seismic design criteria for evaluation of the PFP facilities are based on DOE-RL (1993) and Kennedy et al. (1990). Additional DOE orders and national consensus codes and standards applicable to the PFP buildings are presented in Table 4-5.

Criteria for the safety categorization of SSCs are found in Section 4.4.

4.3.5.1 Input Criteria. Seismic hazard models for the Hanford Site is presented in *Evaluation of Seismic Hazard for Non-Reactor Facilities at Hanford Reservation, Hanford Washington* (Woodward-Clyde 1989). This study is used to characterize the earthquake hazard at the Hanford Site by use of a frequency plot that gives the return period or annual probability of exceedance of different peak ground accelerations of the site. These curves were derived from a combination of recorded earthquake data, estimated earthquake magnitudes of known events for which recorded data are not available, review of local geological investigations, and use of expert judgment by seismologists familiar with the region (see Chapter 3.0, Section 3.6 for details of these data).

4.3.5.1.1 Design Response Spectra. For nonreactor nuclear safety class SSCs the safe shutdown earthquake (SSE) is identified as the design basis earthquake (DBE), and design for the operating basis earthquake (OBE) is not required in DOE-RL (1993). The Hanford Site design/evaluation earthquake response spectra for the design ground motion of the DBE are shown in Figure 4-2. These response spectra are applied for the horizontal direction in the free field at the top of the ground surface. The maximum free-field surface acceleration is 0.20 g for Safety Class 1 SSCs (now Safety Class SSCs) (see Figure 4-2), and 0.12 g for Safety Class 2 SSCs (now Safety Significant SSCs) (see Figure 4-3). For vertical motion, the response spectra are taken at approximately two-thirds of the response spectra for the horizontal motion over the entire range of frequencies (DOE-RL 1993).

4.3.5.1.2 Design Response Spectra Derivation. The design/evaluation spectra generally have the shape shown in Figure 4-2. This shape is similar to that for an actual earthquake, except that peaks and valleys that occur with actual earthquake spectra are smoothed out. Also, the design/evaluation spectra include motions from several potential earthquakes such that they are broader in frequency content than spectra computed for actual ground motion. Such simplified spectra shapes are necessary in order to provide practical input for seismic analyses. Because the design/evaluation spectra are smoothed and broadened relative to actual earthquake spectra, a design/evaluation spectrum tends to be a conservative representation of actual earthquake amplification that might occur (DOE-RL 1993). The DBE response spectra shape

is the median Newmark and Hall response spectra for a sediment site (Newmark and Hall 1978). The earthquake records, damping value comparisons, and the system period intervals at which the spectra values were calculated are discussed in N. M. Newmark Consulting Engineering Service (1973).

Acceleration sensitive equipment such as relays, contactors, motor starters, and switches that require functional operability during a seismic event must also be evaluated with mounting point spectra that accommodate small-magnitude near-field high-frequency earthquake spectra (see Figure 4-4) (DOE-RL 1993). The critical damping values used for seismic natural phenomena hazard analyses of the PFP Safety Class 1 and 2 (now referred to as Safety Class and Safety significant) structures in analyses prior to 1996 are provided in Kennedy et al. (1990) and are presented in Figures 4-2 and 4-3. These critical damping values conform to *Damping Values for Seismic Design of Nuclear Power Plants*, Nuclear Regulatory Commission Regulatory Guide 1.61 (NRC 1973).

Building-specific discussions of analyses are presented in Chapter 5.0, Section 5.2.

4.3.5.2 Seismic System Analysis. The seismic system analysis applicable to SSCs within the PFP complex is described in Kennedy et al. (1990). Kennedy et al. (1990) provides guidance and criteria for design of facilities or evaluation of existing facilities to ensure that DOE facilities are adequately constructed to resist the effects of earthquakes. These guidelines generally provide procedures for the evaluation of facility response to hazard loads and an assessment of whether or not a computed response is permissible.

Numerous static and dynamic seismic analysis methods have been used in the design and evaluation of the PFP facilities. The performance of a facility subjected to a natural phenomena earthquake hazard depends not only on the level of hazard selected for design or evaluation, but also on the degree of conservatism used in the design or evaluation process. Conservative, simplified design or evaluation approaches are well established, extensively documented, and commonly practiced. Median design or evaluation approaches are currently controversial, not well understood, and seldom practiced. Less conservative, more exact/rigorous dynamic analyses are well documented and are often, by necessity, used in the evaluation of existing facilities. For instance, preliminary (conservative) seismic analysis of the 234-5Z Building indicated that the DBE motions might produce nonlinear response and possible structural distress. It was recognized, however, that the building had considerable capacity to resist DBE loads in the nonlinear range. Therefore, a rigorous linear and nonlinear finite element seismic analysis was performed. This analysis demonstrated that the 234-5Z Building was capable of resisting DBE motions without collapse (Price 1989).

Seismic analysis/design information specific to major PFP structures is presented in Section 5.2.

4.3.5.3 Seismic Subsystem Analysis. The seismic analysis applicable to the PFP subsystems (such as equipment and piping) is described in UCRL 15910 (Kennedy et al. 1990). Special considerations of the seismic resistance capacity of equipment and piping are provided in DOE Order 6430.1A.

Because the PFP facilities house hazardous operations and materials, the seismic adequacy of equipment and piping is as important as that of the building. As part of the DOE Natural Phenomena Hazards Project, practical guidelines for the support and anchorage of many equipment items that are likely to be found in DOE facilities have been developed. These guidelines primarily address equipment strengthening and upgrading to increase the seismic capacity of subsystems in existing facilities.

A brief, general discussion of factors to be considered in the design or evaluation of equipment, piping, and other nonstructural elements is presented in the following (DOE Order 6430.1A).

- Equipment or piping supported within a structure respond to the motion of the structure rather than the ground motion. Equipment supported on the ground or on the ground floor within a structure experiences the same earthquake ground motion as the building.

- Equipment or piping supported at two or more locations within a structure are stressed due to both inertial effects and relative support displacements.

- Equipment or piping may have either negligible interaction or significant coupling with the response of the supporting structure. With negligible interaction, only the mass distribution of the equipment should be included in the model of the structure and the equipment may be analyzed independently. With strong coupling, or if the equipment mass is 10% or more of the structure story mass, the equipment should be modeled along with the structure model.

- Many equipment items are inherently strong enough to remain invulnerable to earthquakes, if adequately anchored.

- Elements attached to the floors, walls, or ceilings of a building (e.g., mechanical equipment, ornamentation, piping, nonstructural partitions) respond to the motion of the building in much the same manner that the building responds to the earthquake ground motion. However, the building motion may vary substantially from the ground motion. The high-frequency components of the ground motion tend to be filtered out at the upper levels in a building, while the components of ground motion that correspond to the natural periods of vibrations of the building tend to be magnified. Elements that are rigid and rigidly attached to the structure will experience forces in the same proportion to the mass as the forces on the structure. Elements that are flexible and have periods of vibration close to any of the predominant modes of the building vibration will experience forces in a proportion substantially greater than the forces on the structure.

In summary, the seismic evaluation of equipment and piping necessitates the development of floor response spectra representing the input excitation. Once seismic loading is established, seismic capacity is determined by analysis, testing, or through the use of seismic experience data.

An evaluation of all applicable safety SSCs in the PFP complex to the Hanford Site DBE is documented in Ocoma et al. (1988).

Additional seismic analyses of PFP SSCs are discussed in Chapter 5.0, Section 5.2.

4.3.6 Roof Loads

Current dead, live, snow and volcanic-ashfall loading criteria are provided in DOE (1993). In summary, the current loading criteria are as follows.

- Dead loads - Consideration shall be given to provide for an additional roof load of 10 to 20 lb/ft^2 to accommodate future ceiling and roof equipment loading for all categories of SSCs.

- Live loads - Roof live loads shall be in accordance with ASCE 7-88 (ASCE 1988) for all categories of SSCs.

- Snow loads - Snow loads shall be in accordance with ASCE 7-88 (ASCE 1988). Fifteen lb/ft^2 shall be used as the ground snow load, but in no case shall roof loads be designed for less than 20 lb/ft^2 snow load for all categories of SSCs. In accordance with UBC, snow loading is not to be combined with roof live loads. SSCs outside of structures are to be designed for snow loads.

- Volcanic-ashfall loads - All new SSCs and modifications or additions to existing Safety Class 1 SSCs (now referred to as Safety Class SSCs) are required to meet the design ashfall criterion of 24 lb/ft^2. Additional load for ashfall is not required for Safety Class 2, 3, or 4 SSCs (Safety Significant SSCs). Ashfall loads are to be combined with snow or roof live loads.

4.3.7 Soil Loads

Subsurface conditions of the PFP were determined by approved field and laboratory means that adequately disclose soil and groundwater conditions (URS 1980). Data and other information obtained from prior subsurface investigations were used, supplemented by additional investigations at the specific location as deemed necessary by design professionals (DOE 1993). A bibliography and brief summary of geotechnical studies performed at Hanford (which includes a summary of a geotechnical investigation of the PFP site) has been documented in WHC-SD-GN-ER-30009, *Bibliography and Summary of Geotechnical Studies at the Hanford Site* (Giller 1992).

4.3.7.1 Soil Load Criteria. Soil load criteria for Safety Class 1, 2, and 3 SSCs (now referred to as safety class, safety significant,and general services SSCs) are presented in DOE-RL (1993). In summary, this document states that the effect of dynamic earth pressures shall be considered in the design of Safety Class 1 and 2 (now referred to as safety class for all Safety Class 1 and some Safety Class 2) below-grade SSCs. Safety Class 3 (now referred to as safety significant) SSCs are not required to be evaluated for dynamic soil loads. These dynamic soil properties for the PFP site are identified in Giller (1992) and are presented in Figure 4-5.

For non-safety category SSCs, the allowable soil pressure from the UBC may be used for design where precise soil bearing information is not available. These values are considered to be acceptable for undisturbed soil.

4.3.8 Process Equipment Derived Loads

The design codes and standards for modified or new SSCs (except piping system modifications will be done to the code-of-record) in the PFP complex are identified in Table 4-5. The codes and standards originally applied (code-of-record) to a facility or an SSC will continue to apply for maintenance activities until the facility or SSC is modified (WHC-CM-4-46).

Structural and piping acceptance criteria used for seismic analyses and all component modifications are contained in DOE-RL (1993) and Kennedy et al. (1990) and are also identified in Table 4-5. The safety categorization of components of gloveboxes and process equipment that were not known were conservatively assumed to be Safety Class 1 (now Safety Class).

The impact of accidents and natural forces events on the confinement barriers is analyzed in Chapter 9.0, Section 9.2.

4.3.9 Combined Load Criteria

The original combined loads criteria combined static, vertical live and dead loads, and wind loadings.

Current criteria for load combinations are provided in DOE (1989) Paragraphs 0111-99.0.4 and 0111-99.0.8. More specific criteria for combinations of designed loads are provided in DOE-RL (1993) and are summarized below.

- Load combinations and allowable stresses for load conditions that include live load, dead load, snow load, and normal operating loads for all SSCs are stipulated in the UBC.

- Load combinations and allowable stresses for load combinations that include normal operating loads and natural phenomena hazard loads of extreme wind, earthquake, flood, and ashfall for all SSCs shall be in accordance with UCRL-15910 (Kennedy et al. 1990) and its reference documents.

- Application of these load combinations and acceptance criteria for supports and anchorage of SSCs is appropriate except that the absolute sum of loads shall be used. For the design of supports and anchorage of piping systems in new facilities, the use of a capacity of half of the allowable shall be considered. For subsequent evaluations of these supports in new facilities for the purpose of documenting as-built conditions and for the evaluation of supports in existing facilities, the allowable capacity shall be used.

Structural specifications for the PFP facilities are discussed in Chapter 5.0, Section 5.2.

4.3.10 Subsurface Hydrostatic Loading

Based on the siting criteria, no subsurface hydrostatic loading calculation is necessary. The water table under the PFP complex is at an elevation of 460 ±10 ft, although standard calculational methods for foundations assume total flooding for design purposes (see Chapter 3.0, Section 3.5, for more details concerning the subsurface hydrostatic characteristics of the Hanford Site). The bottom of the tunnel level in the 234-5Z Building is at an approximate elevation of 666 ft msl and is the lowest structural elevation in the complex.

Since an almost 200-ft elevation difference exists between the water table and the lowest structural point, subsurface hydrostatic loading is neither credible nor applicable.

4.3.11 General Criteria

General criteria for structural and mechanical safety are defined in DOE Order 6430.1A. Additional design criteria guidance for safety SSCs is provided in HNF-PRO-704 and also in Table 4-5.

4.4 SAFETY PROTECTION SYSTEMS

4.4.1 General

Siting selection of the PFP facility imposes no special design considerations other than those normally required for this type of plant.

The PFP process activities require special safety considerations in facility process equipment design. Potential hazards of normal process activities are discussed in Chapter 6.0.

There are no specific criteria to safely shut down the facility. Emergency ventilation blowers are actuated following loss of normal ventilation power. In all cases analyzed in this FSAR, temporary loss or shutoff of power to processing facilities results in a safe shutdown condition.

4.4.2 Protection by Multiple Confinement Barriers and Systems

At a nuclear facility, physical confinement barriers must be established to prevent an uncontrolled release of radioactive material to the environment and to prevent or mitigate the spread of contamination within the facility. These barriers are required between the environment and the areas of a nuclear facility that contain and/or have the potential to contain radioactive material. Such physical barriers (e.g., facility layout, primary and secondary process equipment systems and components, enclosures, ventilation and filtration systems) are referred to as confinement systems. This section provides the applicable criteria selected from DOE Order 6430.1A, required for the design, construction, and implementation of the confinement systems. See

Chapter 5, Section 5.2 and 5.4.1, and Chapter 8, Section 8.3, for details of the confinement in use at the PFP.

4.4.2.1 Confinement Barriers and Systems. The original criteria for the PFP facilities relied upon several layers of confinement barriers and systems to prevent and mitigate any potential uncontrolled release of radioactive material within the facilities and to the environment. The barriers are primarily the physical location of the facilities within the PFP complex, each facility's internal arrangement, enclosures that provide containment for the equipment, equipment that provides containment for the process, and the access barriers. The systems are primarily the multiple ventilation systems for maintaining positive pressures and flows from areas with minimum potential for containing radioactive material to areas with lower pressures and exhaust filters for containment of airborne particulates, administrative and access controls, and instrumentation to indicate potential breach of confinement.

The confinement design used for the PFP was influenced by many factors, including the type of material and inventory being confined, the type of process and design of the process system(s), the confinement of the process systems (e.g., canyons, gloveboxes, vaults, etc.), system interactions and dependencies (e.g., fire protection, ventilation, and emergency power sources), and facility siting.

The general concept of confinement for the PFP facilities features a system of primary, secondary, and tertiary confinement boundaries to minimize a release of radioactive material to the environment. The number of confinement barriers used, e.g., primary and secondary and/or primary alone, is based on the quantity of material at risk. For the purpose of the PFP facilities, these confinement boundaries are defined as follows.

1. Primary confinement--Primary confinement consists of barriers, enclosures, gloveboxes, piping, vessels, tanks, etc., that contain plutonium. The principal function of primary confinement is to prevent release of plutonium to areas other than where processing operations are normally conducted.

2. Secondary confinement--Secondary confinement consists of barriers and associated ventilation systems that confine potential release of hazardous material from primary confinement. Because plutonium processing in the PFP is normally conducted in gloveboxes (the primary confinement), the operating area boundary and the ventilation system serving the operating area serve as the secondary confinement system.

3. Tertiary confinement--Tertiary confinement is provided by the building walls and other outer structures of the facility. For some of the DBAs, it represents the final barrier to the potential release of hazardous material to the environment; for others (such as for high wind loads), it is the barrier protecting the rest of the facility from damage.

Current criteria for this facility are defined in *General Design Criteria* (DOE Order 6430.1A), *Environment, Safety, and Health Program for DOE Operations at RL* (DOE-RL Order 5480.1A), and the section(s) of DOE-RL (1994) pertaining to confinement barriers and systems. These orders contain

(1) criteria for confinement barriers, (2) design criteria for enclosures and equipment, and (3) guidelines for ensuring that as low as reasonably achievable (ALARA) objectives are utilized. DOE Order 6430.1A specifies selected ALARA objectives to be used in the design of confinement barriers and systems. These criteria and objectives ensure that the lowest practical levels of releases from the operation of the plant, the protection of the workers, the protection of the public, and the protection of the environment are maintained (see Chapter 8, Section 8.1, for details).

4.4.2.2 Ventilation Offgas. Criteria from DOE Order 6430.1A for ensuring capacity standards for normal and abnormal conditions, zone interface flow velocity and differential pressure (DP) standards, the flow pattern, and ensured continuity of operation under accident conditions and special control instrumentation include the following:

- Airflow patterns and velocity with respect to contamination control
- Minimum negative pressures at key points in the system to maintain proper flow control
- Interaction of offgas systems with ventilation systems
- Minimum filter performance with respect to particulate removal efficiency and maximum pressure drop
- Minimum performance of other radioactivity removal equipment
- Minimum performance of dampers and instrumented control
- Ensured continuity of operations under all credible operating conditions.

There is a distinct difference in zone definitions between that cited in the following set of criteria and that which is actually used throughout the PFP facilities; with the exception of PFP 2736-ZB Building. The PFP employs a reverse nomenclature for the zone definitions, compared to zones as defined in current criteria (i.e., the criteria assume that zone 1 is the zone of highest contamination [e.g., process enclosures, offgas systems], which correlates to the PFP zone 4). The PFP zone 1 normally does not have the potential for contamination (e.g., lunchrooms, administrative office areas, etc.), which correlates to the criteria in zone 4.

The zone definitions for the 2736-ZB Building adhere to current criteria, not the reverse nomenclature of zone definition as maintained in all other PFP facilities. Zone definitions are addressed in more detail in Chapter 5.0, Section 5.4.1.

Additional applicable criteria for ventilation and offgas systems are discussed in Chapter 8, Section 8.3.3.

4.4.3 Protection by Equipment and Instrument Selection

The original design criteria for equipment and instrumentation at the PFP were to provide operating safety, process control, and historical records.

Some of the original equipment and instrumentation were intended to serve more than one of these three functions.

Current criteria for this facility are defined in DOE Order 6430.1A. Refer to Section 4.4, for specific safety systems and related equipment.

Additional protective equipment requirements specific to the Hanford Site are defined in various site contractor procedures including HNF-PRO-704.

Current criteria for general instrumentation and control systems were selected to provide facility and environmental safety protection. An evaluation of these systems is provided in Chapter 5.0. Instrumentation and control systems that monitor or control safety class SSCs are safety classified according to HNF-PRO-704.

4.4.4 Nuclear Criticality Safety

This section describes the criteria used for establishing acceptable criticality safety control (CSC) and outlines the engineered and administrative controls used for prevention of criticality accidents.

The CSC criteria are established in HNF-PRO-537, *Criticality Safety Control of Fissionable Material*, HNF-PRO-334, *Criticality Safety General Requirements*, and DOE Order 5480.24, *Nuclear Criticality Safety*.

The criticality safety program applies to all processing, transfer operations, transport, and storage activities involving fissionable material.

A facility classification system is established in HNF-PRO-334. Under this system, the PFP is classified as a fissionable material facility and subject to all of the elements of the criticality safety program.

4.4.4.1 Control Methods for Prevention of Criticality. The following types of CSC are incorporated into the design, operation, and administration of the PFP, as required, based on the criticality safety evaluation (CSE).

1. Mass controls--Restrictions on the quantity of fissionable material permitted in individual units or in the total configuration.

2. Volume controls--Restrictions on fissionable material volumes, or container and vessel volumes; restrictions may be specific to compositions.

3. Geometry controls--Dimension and shape restrictions on equipment design provide inherently "geometrically safe" or "geometrically favorable" containers and vessels for fissionable materials. Includes floor areas allowed for leakage accumulations and geometrically favorable drain heights ("criticality drains").

4. Density controls--Restrictions on permitted concentrations of fissionable material dissolved or dispersed in another medium.

5. Areal density control--Restrictions on allowed fissionable mass per unit area of a large slab, as for the bottom of a glovebox or floor.

6. Enrichment controls--Restrictions on maximum relative fraction of fissionable isotope constituents in total heavy metal (U+Pu) concentration.

7. Moderation controls--Restrictions on allowed range of hydrogenous-material density relative to fissionable material density in moderator/fissionable mixture (H/X ratio) or on the total amount of moderating materials allowed.

8. Controls on material compounds and form--Restrictions on allowed composition (e.g., nitrates, oxides) and allowed physical state (e.g., metallic, salt-crystal, powder, solution) for fissionable materials at particular process stages, workstations, or storage locations.

9. Piece-count controls--Restrictions on the number of fissionable units or moderator units in a glovebox or array.

10. Interaction controls--Restrictions to minimize potential neutron interactions between various units, vessels, containers, and accumulations of fissionable materials; includes controls on spacing, arrangement, and/or shielding.

11. Reflection controls--Restrictions on the composition and/or configuration of reflector materials in proximity to fissionable configurations.

12. Absorber controls--Requirements defining need for solution concentration, distributions, minimums, and required permanence of neutron absorbers (such as boron and cadmium) used for criticality safety purposes.

13. Flow controls--Requirements for designed features or operational procedures that exclude or restrict the rate of flow of solutions in process pipelines. This category includes:

    - Nuclear blanks--Temporarily remove pipe sections
    - Inline orifices--Limit the maximum potential flow rate.

14. Placement or displacement controls--Requirements for fixtures or barriers that prevent positioning of fissionable units in particular locations or prevent motions of units from designated positions.

15. Chemistry controls--Restrictions on concentrations or specifications of the makeup of process chemicals incorporated with the fissionable materials in the processing streams. These controls are to ensure the intended physical and chemical forms of the fissionable material, to prevent material buildup (such as precipitation or internal refluxing in a solvent extraction column), and to ensure control of fissionable material concentration.

4.4.4.2 Error and Contingency Criteria. Criticality prevention is based on the double-contingency principle that at least two unlikely, independent, and concurrent changes or contingencies must occur before criticality is possible.

Therefore, no single accident or error in process conditions can result in criticality. Judgment is required in determining whether two events are related and, consequently, whether they represent two contingencies or a single contingency. For example, exceeding storage limits and then flooding an area would constitute two independent events; however, fire and flooding from an automatic sprinkler system would be considered a single event. Anticipated or expected events are not considered contingencies but are analyzed as part of the base condition or as part of a single contingency based on multiple errors.

In evaluating compliance with the double-contingency principle, the CSE must show that an acceptable margin of subcriticality will be retained after any foreseeable contingency, including allowance for calculational bias and statistical uncertainty.

The application of these criteria to facility operations is covered in Sections 6.2.9, 6.3.9, 6.4.1.9, and 6.5.1.9.

4.4.4.3 Verification Analysis. The design or modification of processes, systems, and equipment for handling of fissionable material receives independent nuclear criticality safety (NCS) review, analysis, and approval. This includes equipment and systems whose performance affects NCS (e.g., fire sprinkler systems in areas containing fissionable materials). The Quality Assurance (QA) organization independently verifies equipment dimensions and installations that are essential to criticality safety.

Analytical techniques that are used to determine criticality safety limits are validated by comparison of calculated values with the results of criticality experiments in accordance with ANSI/ANS 8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*. The CSEs are documented and independently reviewed in accordance with ANSI/ANS 8.19, *Administrative Practices for Criticality Safety*.

4.4.5 Radiological Protection

The radiation exposure of Hanford Site employees, visitors, and members of the general public originating from PFP operations are to be controlled to levels that are ALARA. The HSRCM-1, *Hanford Site Radiological Control Manual* (DOE-RL 1994), HNF-PRO-159, *ALARA Program Description* and HNF-PRO-1618, *ALARA Management Commitment Policy* describe the organizational structures and the methods for controlling and ensuring that human exposures to hazardous substances and conditions are maintained ALARA.

The PFP Safety organization conducts periodic assessments and appraisals of PFP operations. These provide independent radiological control assessment to ensure that the applicable radiological safety standards are being followed and comply with DOE orders.

The design philosophy used throughout PFP is based on the conservative premise that any exposure of personnel to possible internal plutonium depositions should be avoided, if at all possible. All new and modified facilities/systems/equipment are designed in accordance with accepted radiological design principles, including ALARA. The process equipment was designed to provide total containment of airborne activity, completely

separating the atmospheres exposed to possible plutonium contamination from air breathed by operating personnel. Since operations performed in the different building spaces have varying potentials for external contamination spreads, a high degree of compartmentalization has been provided to isolate various spaces in the event of a contamination incident.

The general design criteria are those specified in DOE Order 6430.1A. In some cases more restrictive criteria, specified in Hanford Site Contractor guides and policies and DOE control manuals, are applicable.

Specific design recommendations of the PFP have evolved as a result of past operating experience. Lead plate shielding, lead glass panels, and lead-loaded gloves are used in gloveboxes to reduce whole-body and extremity exposures. Gloveboxes are used in cases where handling of bare material is required. Examples of other design recommendations are as follows.

- Ventilation systems should be designed to ensure control of airborne contaminants even if normal airflow patterns may be disrupted such as an open access port. This system also must maintain airflows from lowest to highest contamination potential and filter all exhaust from zones 3 and 4 to ensure minimal escape of radioactive materials.

- Gloveports should be strategically located to permit quick servicing of glovebox equipment.

- Interior surfaces of gloveboxes should be designed to minimize material buildup.

- Operation and control of certain process equipment, valving, and material transfers should be remote from the glovebox interior, thereby reducing extremity and whole-body exposure.

- A vacuum cleaning system should be used in certain gloveboxes for removal of residual powders. This would reduce exposure to operations and maintenance personnel.

- Supply airflow in radiation zones within process area should be from ceiling to floor to maintain clean air in the breathing zone.

- Sargent™ gloveports should be used on certain gloveboxes to provide a greater degree of containment during glove change activities than conventional gloveports.

- Air sampling, radiation monitors, and communications systems should be provided to assist in controlling the release of radioactivity to the environment and providing notification of an off-normal situation at the facility. All of the monitors should have local alarms while some also should have remote alarming features.

- Radioactive materials within the process areas should be confined as close to the point of origin as practicable through the use of HEPA filters installed on the exhaust ducts of hoods and gloveboxes.

See Chapter 8 for details of the radiation protection program and associated systems.

4.4.5.1 Access Control. Multiple barriers (also referred to as "access control zones") limit access to radiation areas to only fully qualified workers. These barriers afford enhanced radiation protection, contamination control, and physical security.

General access control criteria are provided in DOE Order 6430.1A. Other specific criteria are listed below.

- The area within the site boundary is enclosed by an agricultural-type fence (minimum of three strands of barbed wire on metal posts) and posted to legally prohibit trespassing.

- For effluent control purposes and protection of the general public, and in accordance with *10 Code of Federal Regulations* (CFR), Part 100.3(a), the area within this boundary fence is considered an "exclusion area."

- Adequate emergency exits are provided. All locking personnel emergency doors are equipped with panic hardware on the inside and alarms that sound when opened.

The HSRCM-1, Part 3 (DOE-RL 1994), specifies that access to any controlled area where radioactive materials or elevated radiation fields may be present are clearly and conspicuously posted. The HSRCM-1 (DOE-RL 1994) defines four levels of radiation areas and five levels of contamination areas that must be posted (see Table 4-6).

4.4.5.2 Shielding. Shielding criteria considered here are applicable to radiation protection utilized at the PFP.

- General--The plutonium facility is designed to minimize personnel exposure, provide adequate radiation monitoring and alarm systems, and accommodate health physics activities. Physical safeguards (e.g., remote handling, equipment layout, shielding) provide primary radiation protection assurance; secondary radiation protection is provided by administrative controls.

- Shielding design--Shielding is designed to meet the exposure goals set forth in 10 CFR 835, Subpart C, "Standards for Internal and External Exposure," (DOE 1993) consistent with ALARA. The PFP also complies with HSRCM-1 (DOE-RL 1994) administrative control levels, which are more restrictive than the requirements identified in 10 CFR 835. See Chapter 8, Section 8.3.2, for details.

- ALARA--Analyses require evaluation of the cost of radiation reduction in dollars per man-rem and limits reduction to a reasonable cost.

Concrete, lead, leaded glass, masonite, polycarbonate/acrylic, and water are the principal shielding materials used in plutonium handling areas throughout the PFP complex.

4.4.5.3 Radiation Monitoring Systems. Radiation detection and alarm instrumentation is provided to warn plant personnel of significant increases in radiation levels of airborne contamination in normally accessible spaces and of above-normal amounts of radioactivity released in effluents.

The guidelines for placement and sampling intervals of fixed head samplers (FHS) and continuous air monitors (CAM) are based upon *Hanford Site Radiological Control Manual*, HSRCM-1 (DOE-RL 1994). These requirements specify that the monitoring systems are placed at strategic locations to detect and evaluate airborne contamination at workstations. These monitoring systems are required for sampling airborne contamination levels that may exceed 10% of the applicable derived air concentration (DAC) guides. Primarily, these monitoring systems consist of FHSs and alpha CAMs (See Chapter 8, Sections 8.3.4 and 8.3.5, for details of the radiation detection and alarm instrumentation system).

The gaseous effluent from the PFP complex are monitored by CAMs with local and remote alarm capability and record samplers. The liquid effluent monitors are designed with a record sampler. The alarm set points for these effluent monitors are well below release criteria to provide early warning of effluent releases. See Chapter 8.0, Section 8.3.5, for discussion of alarm set points for CAM systems. See Chapter 7.0, Section 7.2, for additional details of the effluent monitors.

The criticality alarm system (CAS) radiation detection equipment installation is based upon American National Standards Institute (ANS)/American Nuclear Society (ANS) Standard 8.3 as implemented by *Criticality Safety General Requirements* (HNF-PRO-334), *Definition and Means of Maintaining the Criticality Detectors and Alarms Portions of the PFP Safety Envelope* (HNF-SD-CP-SDD-003), and *Nuclear Alarm Manual for the Plutonium Finishing Plant* (HNF-IP-1115). See Chapter 8.0 Section 8.3.4 for discussion of the CAS system.

Survey instruments are located throughout radiation areas within the PFP complex where radioactive materials are processed, handled, transported, or stored as required in DOE Order 6430.1A. The PFP uses radiation detection instrumentation designed for survey of personnel, equipment and process areas. These instruments provide both audible and gauge or dial outputs when contamination is detected. These instruments play an important role in contamination control and personnel safety.

4.4.6 Fire and Explosion Protection

4.4.6.1 Original Criteria. The original design criteria for the PFP fire protection systems were based primarily on their action in relation to the plutonium product. Systems were designed and components selected to minimize the spread of product and prevent displacement of materials.

The current fire protection philosophy in all the buildings used for the process, handling, or storage of plutonium products minimizes the amount of combustible material to the extent practicable within the structures and in the operation of the plant (see Chapter 5, Sections 5.2 and 5.4.11). In addition, the number, type, and location of ignition sources is carefully

controlled. Criteria related to limitation of product spread and displacement (criticality potential) continue to be important.

4.4.6.2 Current Criteria. DOE Order 6430.1A embodies general criteria for design and construction of DOE facilities. Criteria in DOE Order 6430.1A are given for fire and explosion protection.

4.4.6.3 Additional Criteria. The DOE Order 5480.7A, *Fire Protection* (which has been replaced by DOE Order 440.1 and so is currently being removed as a compliance order for the site contractor) defines criteria for an "improved risk" level of fire protection sufficient to attain DOE objectives. The following criteria apply to the design of fire protection systems.

4.4.6.3.1 Public Safety and Hazards to Life. These criteria are directed toward having no threats to the public health and welfare and no undue hazards to life from fire.

The procedures *Fire Protection Program Overview*, (HNF-PRO-340), *Fire Protection Policy Statements* (HNF-PRO-341), and *Responsibilities* (HNF-PRO-342) provide guidance so that buildings comply with the Life Safety Code (NFPA 101) and DOE Order 5480.7A, and therefore meet the intent of OSHA requirements. Where noncompliance with some "Life Safety Code" provisions may be required for public safety, as with containment structures, additional protective systems are maintained.

The following restrictions are intended to reduce potential for fast-spreading fires:

- Materials of unusual fire characteristics, such as exposed urethane foams, are prohibited for interior finish
- Materials developing large quantities of toxic products of combustion are prohibited for interior finish
- Where hazardous materials (such as flammable liquids or explosives) are used, special protection features are installed.

The facility containment systems are designed to preclude an offsite release of hazardous amounts of toxic materials under maximum credible fire conditions.

Exhaust and ventilation systems, including filters, are protected or isolated from the effects of a credible fire to the extent that hazardous amounts of toxic materials or combustion products will not escape.

Natural or artificial means of controlling liquid runoffs from a credible fire are provided so that contaminated or polluting liquids will not escape the site, including potentially contaminated water resulting from fire fighting operations.

4.4.6.3.2 Unacceptable Program Delays. The design of the facility is such that the maximum credible fire will not result in loss of use of a vital facility for longer than an acceptable shutdown period as defined by the program senior official.

4.4.6.3.3 Property Damage Limitation. Property damage is limited in accordance with the following three categories.

- Category 1--When the maximum possible property loss is in the range of $1,000,000 to $25,000,000, an automatic fire protection system shall be provided that will limit the probable loss to the lower figure.

- Category 2--When the maximum possible property loss is in the range of $25,000,000 to $50,000,000, a redundant protection system is provided, even in the failure of the primary system, that should limit the loss to the lower figure.

- Category 3--When the maximum possible property loss exceeds $50,000,000, redundant systems are provided as in 1 and 2, above, and a failure-proof type of fire protection system, such as blank walls or physical separation, is provided to limit the maximum property loss to $75,000,000.

4.4.6.3.4 Higher Standard of Protection. A higher standard of protection, usually including some form of automatic protection, is justified by certain additional considerations. In general, probable loss should be limited to $250,000 in such cases. The following points should be considered in evaluating the need for automatic fire extinguishing systems:

- Vital property (including contents) that may have long lead time for replacement, significant public visibility, or sensitivity

- Effect on current process

- Favorable cost versus benefit ratios

- Effect of a facility on an adjacent or included facility

- Future increased risk or conversion to other uses.

4.4.6.3.5 Essential Elements of an Improved Risk Facility. An improved risk facility is characterized by a sufficiently high level of fire protection to fulfill requirements for insurability by the Factory Mutual System, industrial-risk insurers, or other private industrial fire insurance companies that limit their underwriting to the best protected class of industrial risks. A basic requirement is the provision of automatic fire extinguishing systems in all areas subject to serious property damage or business interruption losses as a result of fire. The primary requirement for qualifying for an improved risk rating is tangible evidence of continuing sincere interest by management and employees in minimizing losses from fire and related perils.

The DOE facilities qualifying as improved risks will incorporate the following physical improvements and internal programs and maintain records for appraisal of the programs.

1. Review of plans before contemplated construction to ensure adequacy of fire risk appraisal and protection and follow up review to ensure that fire protection features are provided.

2. Regular self inspections, tests, fire loss potential reviews, and appraisals to identify the nature, location, and severity of fire risks (injuries, dollar loss, programmatic interruption, release of toxic and radioactive materials) as well as to determine adequacy of fire loss control devices and activities.

3. Periodic audits by outside fire protection authorities such as contractor facility appraisals by field fire protection engineers.

4. Plans, procedures, devices, and trained personnel adequate to permit controlling any credible fire emergency that may arise at the facility.

5. Limitation by physical means (e.g., geographic isolation, fire walls, fire doors, draft barriers) of areas that can be directly damaged in the event of a single fire.

6. Quality construction that, in most cases, is defined as fire resistive or noncombustible type buildings with segregation or isolation of particularly hazardous operations.

7. Enclosures of adequate fire resistant construction for stairways, elevators, ducts, and other openings coupled with fixed or manual devices (such as self-closing doors or dampers, draft stops, or water curtains) to control or limit both vertical and horizontal fire spread potentials.

8. Protection of special hazards by isolation, segregation, or use of special fire control systems (e.g., automatic sprinklers, inert gas flooding, explosion suppression) together with devices (e.g., relief valves, filters, roof hatches, scuppers, blast walls) for limiting or controlling damage potentials of fire, hazardous smoke, gases, and water runoff, or other occurrences that may reasonably be anticipated during a fire emergency.

9. Adequate, reliable fire protection water supplies and distribution systems coupled with adequate hydrants, inside standpipes, and other devices to facilitate use of such water during fire emergencies.

10. Adequate automatic and manual means for detecting and reporting incipient fires, including, but not limited to, watchman service.

11. Adequate sprinkler protection for all combustible construction or occupancies where potential losses exceed departmental criteria.

Currently the PFP does not fully comply with all criteria established for an improved risk facility. Project B-631 was initiated to rectify the existing deficiencies. The duct level is now fully covered by automatic sprinklers. New fire-rated doors were installed where needed. In addition, a major upgrade was done on the fire alarm system to provide supervisory capability and ensure spare parts availability. Project B-631 was completed in 1995.

4.4.7 Materials Handling and Storage

4.4.7.1 Fuel Handling and Storage. In addition to plutonium-bearing materials, spent nuclear fuel and unirradiated fuel are stored at the PFP. Spent nuclear fuel is contained in three EBR-II storage casks that are stored in the 2736-ZD Building (refer to Chapter 5.0, Section 5.2.8.5, for a description of the 2736-ZD facility). All necessary shielding and containment is provided by the casks themselves. The EBR-II casks were relocated from a Hanford Site solid waste management burial ground to 2736-ZD to use security measures in place at the PFP to comply with DOE Order 5632.1C, *Protection and Control of Safeguards and Security Interests*.

Unirradiated FFTF fuel is temporarily stored in vault 192-A. The fuel consists of driver fuel assemblies (DFAs) stored in radial reflector shipping containers (RRSCs) and fuel pins stored in Model 60 shipping containers.

Criteria for handling and storage of the plutonium feed and product materials are discussed in Section 4.3.7.3.

4.4.7.2 Radioactive Waste Treatment. The criteria pertinent to the design and operation of radioactive waste treatment facilities are from DOE Order 6430.1A.

Radioactive waste generated at the PFP is either transferred as a liquid to the underground liquid storage tanks via the 241-Z facility or packaged as solid waste for interim or long-term storage. Guidelines and requirements applied to facility design and operation are listed below.

1. Facility design ensures that all ventilation air and gaseous effluents are exhausted through a ventilation system designed to remove particles (see Chapter 5.0, Section 5.4.1, Chapter 7.0, Section 7.1, and Chapter 8.0, Section 8.3.3., for more details).

2. All exhaust ducts (or stacks) that could contain plutonium provided with two monitoring systems. One system is a CAM type and the other is an FHS. Each monitoring system is powered by the same energy source as the motive power for the effluent exhaust or be connected to a standby power source (see Chapter 5, Sections 5.4.1 and 5.4.10, Chapter 7.0, Section 7.1, and Chapter 8.0, Sections 8.6.1 and 8.8, for more details).

3. All liquid industrial wastes are collected and transferred to liquid waste treatment systems. Provisions are made for retention systems for potentially contaminated waste streams (see Chapter 7.0, Section 7.2, for more details).

4. Process waste storage tanks and transfer lines are designed and constructed so that they are fully inspectable and so that any leakage will be detected and contained before escape to the environment (see Chapter 5.0, Section 5.4.9, and Chapter 7.0, Section 7.2, for more details).

5. Federal, state, and local codes regarding discharge of sanitary wastes are met. There are no interconnection between the sanitary waste systems and the plutonium handling area. The sanitary waste

is sampled for radioactivity (see Chapter 5.0, Section 5.4.9, and Chapter 7.0, Section 7.2, for more details).

6. Consideration is given to converting liquid wastes to solid forms (see Chapter 7.0, Section 7.5).

Additional guidance for control of radioactive wastes is given in HSCRM-1 (DOE-RL 1994), HNF-PRO-455, *Solid Waste Management*, and HNF-PRO-456, *Water Quality Program*.

4.4.7.3 Storage Facilities. Plutonium storage facilities are designed per DOE Order 6430.1A to provide confinement of radioactive materials under normal operations, anticipated operational occurrences, and DBA conditions. The design ensures that releases to the environment do not exceed the guidelines outlined in the DOE Order 5400 series. Additional guidance is given in HSRCM-1 (DOE-RL 1994).

Guidelines and requirements applied to facility design and operation are listed below.

1. Plutonium containers in which gas buildup can occur are designed to prevent leakage of gas over the maximum storage period or are vented to prevent an accumulation of explosive gases; however, such venting must not permit spread of contamination.

2. The maximum allowable self-heating (decay heat) for the containers are specified, as well as the design requirements for cooling (in terms of the required vault ambient temperature, active cooling systems, etc.).

3. Plutonium-bearing or -contaminated material are packaged in a closed metal container. Combustibles within the container shall be minimized.

4. Provisions are made to periodically monitor and check storage facilities and containers to ensure continued integrity of containment.

5. When required by the form or hazard potential of the stored material, provisions are made to monitor for contamination or loss of primary containment upon entering the plutonium storage facility.

6. Criteria for determining the suitability of plutonium containers (such as external and internal corrosion rate) are developed and documented. All containers are periodically inspected against these criteria. The time between inspections may vary depending upon container quality and type.

4.4.8 Industrial and Chemical Safety

Design criteria governing industrial safety are specified in DOE Order 6430.1A. Many of these safety considerations overlap those discussed in Section 4.3.5. Electrical services design criteria have not been included because NRC Regulatory Guide 3.39 (NRC 1986) does not include these criteria

in Chapter 4. However, the Preliminary Evaluation of PFP Conformance to DOE Order 6430.1A *General Design Criteria* (WHC 1990) does evaluate electrical services design criteria.

Industrial and chemical safety is ensured by virtue of a rigorous safety program in effect at the PFP. Industrial hazards encountered during plutonium handling operations that do not lead to an engineering solution are controlled in accordance with HNF-MP-003, *Integrated Environment, Safety and Health Management System Plan* and are described in Chapter 6.0. Other requirements and recommendations are listed below.

1. Fire protection and alarm systems are incorporated into the facility to protect operating personnel. Life safety code requirements of NFPA 101 are used in the layout of the building walls, doors, stairwells, and other access features (*Life Safety Code*, NFPA 101) (see Sections 4.3.6 and 5.4.11).

2. Electrical systems are designed in accordance with the *National Electrical Code* (NFPA 70).

3. Compressed gas system designs minimize hazards to building personnel. Pressure relief systems are provided which relieve to the HVAC exhaust or outside. Flammable air systems relieve only to the outside of the facility to limit the possibility of an explosion inside the facility. The use of compressed gas cylinders within buildings are limited to those situations in which piped systems are impractical. Installations met the requirements of WHC-CM-4-40 and WHC-CM-1-10 and meet the current requirements of HNF-PRO-087, *Storing, Using and Handling Compressed Gases.*

4. Valves, dampers, and electrical switches used for system shutoff and subsystem isolation provided with visual indicators for component status and with features to permit the use of mechanical locking devices to facilitate "lock and tag" operations.

5. Piping systems are labeled to indicate the contents and normal flow directions of the fluids.

6. Elevators are designed in accordance with ANSI A17.1, *Safety Code for Elevators, Dumbwaiters, and Escalators.*

7. Pressure systems are designed in accordance with ANSI B31.1, *Power Piping.*

8. Equipment containing PCB are not specified for use in the facility.

9. Piping system design and materials selection are based upon fluids to be conveyed, operating pressure of the system, corrosive nature of the fluids, and hazards posed to operations and maintenance personnel. While metal piping systems are generally preferred, glass, ceramic, and plastic piping systems may be acceptable for certain use, but only in accordance with the requirements of the Uniform Plumbing Code and/or ANSI B31.1.

10. Features are provided in the design to safely handle and store working amounts of required chemicals. Bulk quantities of chemicals are stored in a separate facility designed explicitly for bulk chemical storage as required by industrial safety practices. Controls for personnel protection as required by Hanford Site contractor procedures and the Occupational Safety and Health Administration requirements (i.e., 29 CFR 1910.1200) are imposed if hazardous chemicals are used. Disposal of chemicals are in accordance with WAC-173-303, *Dangerous Waste Regulations*, and Chapter 7.0, Section 7.3.

11. Oxygen monitoring equipment with alarms to alert personnel are provided in areas where oxygen deficiency potential exists.

12. The design of lifting and rigging equipment are in accordance with the requirements of DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (DOE-RL 1992). Appropriate requirements are applied to the design, operation and maintenance of overhead cranes and hoists.

13. Industrial noise protection for employees are in accordance with the requirements of Hanford Site contractor procedures.

14. Nonflammable hydraulic, lubricating, cooling, etc., fluids are used in plutonium handling areas.

15. Physical barriers for isolation between incompatible chemicals, materials, and processes are provided.

4.5 CLASSIFICATION OF SAFETY STRUCTURES, SYSTEMS, AND COMPONENTS

This section describes the criteria for the identification and safety classification of SSCs.

DOE Order 6430.1A states that special facility SSCs are to be designed, fabricated, erected, and tested to standards and quality commensurate with the hazards and potential consequences associated with both the facility and the role of each SSC in mitigating the consequences of DBAs. These items shall be identified as safety class items. Safety class items are SSCs, including portions of process systems, whose failure could adversely affect the environment or the safety and health of the public. Specific aspects of safety class criteria are discussed in DOE Order 6430.1A.

The PFP uses more stringent criteria for the identification and designation of safety class SSCs, as outlined in HNF-PRO-704. DOE Order 5480.23 requires that facilities identify safety class and safety significant SSCs and these identified SSCs are reported under DOE Order 232.1, *Occurrence Reporting and Processing of Operations Information*.

4.5.1 Definition of Safety Structures, Systems, and Components

HNF-PRO-704 uses the two general designations of safety SSCs listed below.

- Safety class SSCs--prevent or mitigate the release of hazardous materials to the public that would otherwise exceed the offsite radiological risk guidelines, or prevent accidental nuclear criticality.

- Safety significant SSCs--prevent or mitigate releases of radiological materials to onsite workers and toxic chemicals to the offsite public and onsite workers. This includes barriers that are judged to contribute substantially to defense-in-depth independent of quantitative analysis. Safety significant also describes worker safety SSCs that protect the facility worker from serious injury due to hazards not controlled by institutional safety programs.

4.5.1.1 Safety Structures, Systems, and Components Criteria. Designation of safety SSCs is done by use of criteria presented in HNF-PRO-704. A listing of these criteria is provided in Table 4-4. The methods and procedures for identifying safety class and safety significant SSCs are presented in HNF-PRO-704.

4.5.2 Design Criteria

Guidance for the replacement and modification of existing safety class SSCs to safety SSCs, as well as design criteria that apply to new SSCs to determine whether such SSCs are safety class, is provided in HNF-PRO-704. The codes and standards that should be addressed to determine applicable and relevant requirements are provided in Table 4-5 (note that only the applicable and relevant portions of any specific code or standard are to be applied to the design process).

Deviations to DOE Order 6430.1A design criteria are justified in the following manner (HNF-PRO-704):

- Evaluate and document in safety documentation that requires the DOE Richland Operations Office (DOE-RL) approval, except where Section 0101-2 requires DOE Headquarters (DOE-HQ) approval

- Substantiate design deviations in the safety equipment list (SEL)

- Document in the applicable functional design criteria, or in accordance with the exceptions process of HNF-PRO-116, where advance planning and approvals are warranted.

4.5.3 Requirements

1. SELs are used to identify:

   - The safety SSCs and their designations

   - The safety functions maintained or performed by the safety SSCs

   - The SSC design attributes required to perform or maintain their safety functions

- Configuration identifiers
- Calculations and reference documentation used for safety SSC identification and designation.

2. Safety SSCs that fall into more than one category are assigned to the highest applicable classification.

3. Documents that define or change the design bases, performance requirements, regulatory requirements, codes, and standards of safety class SSCs are assigned "approval designators"in accordance with HNF-PRO-233, *Review and Approval of Documents*.

4. The QA program requirements are applied to safety SSCs.

5. Design criteria for safety SSCs are in accordance with criteria identified in Table 4-5.

6. For new projects or facilities, safety SSCs are identified as early in the design phase as practical. An SEL is included in the FSAR and is updated annually.

4.5.4 Safety Systems and Related Equipment List

Tables 4-7 and 4-8 show the safety classifications for SSCs at the PFP. Table 4-7 provides the safety classifications as determined for the PFP prior to installation of the Production Vertical Denitration Calciner (VDC) process for stabilization of plutonium-bearing solutions. The classifications in Table 4-7 are not affected by installation of the Production VDC process. Table 4-8 shows the safety classifications for equipment associated with the Production VDC process. Operation of the Production VDC is not authorized and the related safety classifications will be reevaluated prior to initiation of operations. Other than the safety class designation associated with Building 234-5Z Building HEPA filters and related ducting, which are already identified as safety class in Table 4-7, the only safety class item required by the Production VDC process is the glovebox criticality drain as shown in Table 4-8. Otherwise, the only classification of selected items related to Production VDC operations is safety significant which is due primarily to their function of providing worker protection or defense-in-depth. For reactive plutonium-bearing material stabilization operations, no additional items have been identified requiring safety classification other than those already classified in Table 4-7.

Tables 4-7 and 4-8 were prepared based on the definitions identified in Chapter 4.0, Section 4.5.1, the accident safety analysis provided in Chapter 9.0 and the system design description (SDD) documents (HNF-SD-CP-SDD-003; HNF-SD-CP-SDD-004; HNF-SD-CP-SDD-005; HNF-SD-CP-SDD-006; HNF-SD-CP-SDD-007; HNF-SD-CP-SDD-008; HNF-SD-CP-SDD-009; HNF-SD-CP-SDD-010; HNF-SD-CP-SDD-011; HNF-SD-CP-SDD-013; WHC-SD-CP-SDD-015; HNF-SD-CP-SDD-017; HNF-SD-CP-SDD-021; HNF-SD-CP-SDD-024; also see *Safety Systems and Related Equipment*, FH 2000).

The safety classifications for SSCs associated with the Laboratory Prototype Calciner are shown in the laboratory calciner addendum to this FSAR.

The basis for the classification of SSCs for the prototype calciner and the related PFP SDDs are identified in the addendum. The laboratory calciner is not currently authorized for operation.

The safety classifications for SSCs associated with the Magnesium Hydroxide Precipitation Process are shown in the related addendum (Carson 2000) to this FSAR. The basis for the classification of SSCs for the process and the related PFP SDDs are identified in the addendum.

The safety classfications for SSCs associated with the Bagless Transfer System (BTS) are shown in the calculation notes (FH 2000a) for the BTS. The basis for the classification of SSCs for the BTS and the related PFP SDDs are identified in the calculation notes.

4.6 DECOMMISSIONING

As technology advances and missions change, facilities and equipment become obsolete. Because special handling is required for the disposal of radioactive SSCs, the decontamination and decommissioning (D&D) program has been developed to ensure disposition in a manner that minimizes risk to employees, the general public, and the environment.

The specific objective of D&D operations is to remove contaminated PFP facility components and dispose of them appropriately as transuranic (TRU) waste, low-level waste (LLW), or mixed waste. Contaminated PFP components may include process gloveboxes and associated electrical and piping systems, ventilation systems, vacuum systems, and drain systems.

DOE Order 430.1, *Life-Cycle Asset Management*, requires the development of a decommissioning turnover plan, a decontamination plan if appropriate for the facility, and the completion of a deactivation readiness review.

4.6.1 Original Criteria

No formal criteria for D&D were used in the original plant design.

4.6.2 Current Criteria

Current D&D criteria are described in DOE Orders 6430.1A for incorporation into new facility design.

4.6.3 Decontamination and Decommissioning Activities. The D&D of plutonium handling facilities can be divided into six basic operational activities:

1. Removal of significant quantities of plutonium material to interim storage
2. Decontamination of glovebox internals and equipment removal
3. Packaging for disposal
4. NDA of material prior to disposal
5. Removal of service piping/wiring
6. Removal of all equipment from facility.

The first five activities are terminal cleanout operations (TCO). The last one is strictly D&D activity.

Overall D&D operations extend from completion of TCO activities to disposition of D&D items as waste. At the beginning of D&D operations, a process facility: (1) will not contain accessible quantities of plutonium, (2) will be isolated from process piping and electric services, and (3) will remain connected to fire protection and ventilation services. Equipment will then be decontaminated, size reduced, and packaged in approved waste containers.

Placement of all items in 20-yr retrievable storage or burial grounds completes D&D activities.

Detailed discussion of the procedures to be followed on the PFP D&D activities may be found in *Plan of Approach to Selected Decontamination and Decommissioning of Plutonium Finishing Plant Facilities* (Rockwell 1983a) and *Plan of Approach to Selected Decontamination and Decommissioning: Process Control Plan* (Rockwell 1983b).

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Table 4-1. Isotopic Distribution of Plutonium at the Plutonium Finishing Plant Based on Inventory Records and Estimates.

Range (% ^{240}Pu)	Mass (g)	Number of items	^{238}Pu (%Pu)	^{239}Pu (%Pu)	^{240}Pu (%Pu)	^{241}Pu (%Pu)	^{242}Pu (%Pu)	^{241}Am (%Pu)
<3.99	8,166	23	0.00	96.89	3.04	0.05	0.00	0.02
4.00 to 6.99	1,470,646	3,202	0.01	93.43	6.04	0.25	0.04	0.16
7.00 to 9.99	63,808	419	0.01	91.10	8.35	0.43	0.10	0.61
10.00 to 12.99	477,026	2,195	0.07	86.68	11.88	0.93	0.19	0.73
13.00 to 15.99	109,272	235	0.52	81.05	14.92	2.39	1.15	2.50
16.00 to 18.99	1,295,254	1,440	0.16	81.17	17.01	1.11	0.57	1.68
>19.00	225,059	572	0.27	73.68	22.62	1.87	1.65	2.45
Total	3,649,231	8,086	--	--	--	--	--	--

Note: The percent plutonium (%Pu) is calculated on a per gram plutonium basis. The total for a row is greater than 100% because of the contribution of the ^{241}Am mass.

Table 4-2. Isotopic Distribution of Plutonium at the Plutonium Finishing Plant Based on Nondestructive Analysis (NDA) Verification Database.

Range ($\%^{240}Pu$)	Mass (g)	Number of items	^{238}Pu (%Pu)	^{239}Pu (%Pu)	^{240}Pu (%Pu)	^{241}Pu (%Pu)	^{242}Pu (%Pu)	^{241}Am (%Pu)	Age
<3.99	3,515	13	0.00	97.04	2.91	0.05	0.00	0.09	23
4.00 to 6.99	1,135,919	1,784	0.01	93.77	6.00	0.20	0.03	0.14	11
7.00 to 9.99	32,825	123	0.03	91.75	7.78	0.39	0.05	0.45	16
10.00 to 12.99	223,577	489	0.09	86.94	11.81	1.00	0.17	0.86	13
13.00 to 15.99	83,225	83	0.22	83.85	14.44	1.61	0.38	2.26	18
16.00 to 18.99	115,983	143	0.24	80.66	16.98	1.44	0.69	2.80	23
>19.00	56,568	87	0.30	72.87	23.14	1.90	1.79	4.05	24
Total	1,651,613	2,722	--	--	--	--	--	--	--

Note: The percent plutonium (%Pu) is calculated on a per gram plutonium basis. The total for a row is greater than 100% because of the contribution of the ^{241}Am mass.

Table 4-3. Plutonium Product Specifications.

1. Plutonium metal* (RMC Line)	
Chemical purity	
Plutonium assay	≥99.84 wt%
Atomic purity	
Atomic % plutonium	≥99.00
Isotopic purity	
^{238}Pu	<0.05 wt%
^{240}Pu	5.2 to 6.5 wt%
^{241}Pu	<1.0 wt%
Element impurity	
Gallium (Ga), aluminum (Al), and silicon (Si)	4(ppm Ga) + 10(ppm Al) + 10(ppm Si) ≤1,300
Americium	<200 ppm
Beryllium	<1 ppm
Boron	<5 ppm
Calcium	<500 ppm
Magnesium	<500 ppm
Carbon	<200 ppm
Cadmium	<10 ppm
Iron + Nickel	<400 ppm
Lithium	<10 ppm
Neptunium	<50 ppm
Thorium	<50 ppm
Uranium	<100 ppm
Tritium	<10 µCi/kg
Other	<100 ppm each
2. Plutonium nitrate (PRF)--	
Plutonium	= 250 to 375 g/L
Free acid	= 3.0M to 9.0M
Solids	= 0 to 1%
Organic	= 0 to 1%
Uranium	<1,700 µg/g Pu
Specific gravity	= 1.27 to 1.70

*Based on Rocky Flats specifications.

Table 4-4. Safety Structures, Systems, and Components Criteria. (2 sheets)

Structures, systems, and components (SSCs) that:		Safety SSC Designation	Previous Designation*
1.	Prevent or mitigate offsite dose in excess of 5 mSv (500 mrem) TEDE.	SC	SC-1
2.	Place or maintain an operating process in a safe condition that prevents or mitigates offsite dose in excess of 5 mSv (500 mrem) TEDE.	SC	SC-1
3.	Monitor the release of radioactive materials to the environment during and after accidents where the monitor's output initiates Emergency Response Plan or operator actions to place the operating process in a safe condition per criterion 2.	SC	SC-1
4.	Maintain double contingency protection against an accidental nuclear criticality.	SC	SC-1
5.	Support the safety function of a safety class SSC. This includes control and monitoring functions (operating air, electrical power, instrumentation, etc.).	SC	SC-1
6.	Prevent or mitigate a radiological dose or chemical exposure that challenges the risk evaluation guidelines of Appendix D.	SS	SC-1 or SC-2
7.	Place or maintain an operating process in a safe condition that prevents or mitigates consequences that exceed criterion 6.	SS	SC-1 or SC-2
8.	Prevent or mitigate exposure in excess of 50 mSv (5 rem) TEDE or an airborne chemical concentration in excess of ERPG-2 to facility operators who are relied on to achieve the safe condition of criterion 2 or 7.	SS	SC-1 or SC-2
9.	Monitor the release of radioactive and/or hazardous materials to the environment during and after accidents where the monitor's output initiates Emergency Response Plan or operator actions to place the operating process in a safe condition per criterion 7.	SS	SC-1 or SC-2
10.	Support the safety function of a safety significant SSC. This includes control and monitoring functions (operating air, electrical power, instrumentation, etc.).	SS	SC-1 or SC-2
11.	Prevent or mitigate an acute fatality to a facility worker or serious injury to a group of workers, except where the SSCs are controlled through an implemented institutional safety or radiation protection program.	SS	SC-3
12.	Provide defense-in-depth prevention or mitigation of an uncontrolled release of radioactive and/or hazardous material deemed significant in the safety analysis.	SS	N/A

* No longer applies to the designation of SSCs; used for existing SELs and reference documentation until they are revised.

NOTES

1. Consider initiating events with a frequency greater than 10^{-1} per year to be planned events and mitigate their consequences to within normal operational limits.

2. Where a postulated accident can cause multiple system failures, evaluate bounding consequences at a common receptor location. Select safety SSCs and determine residual consequences for the purpose of designating other structures or systems.

Table 4-4. Safety Structures, Systems, and Components Criteria. (2 sheets)

NOTES (continued)

3. For criteria 6-10, the previous designation was SC-2 except for cases where SC-1 designation was applicable to the prevention or mitigation of toxic chemical exposures in excess of the offsite risk guidelines.

4. Designate SSCs that may prevent the adequate function of safety SSCs through physical interaction (seismic, pipe whip, jet impingement, water damage, environmental changes, etc.) as the same level of importance as those potentially affected SSCs.

5. Water treatment systems that use chlorine are considered to pose a risk commonly accepted by the public, provided that their design is consistent with public water treatment plants. Do not designate such systems as SC or SS.

6. See Section 2.4 of HNF-PRO-704 for the procedural steps that this Table supports. In May 1995, this procedure descoped environmental and standard industrial SSCs from designation as safety SSCs. These and other balance-of-plant SSCs are considered to be "General Service" SSCs.

Table 4-5. Design Codes and Standards for Systems, Structures, and Components.

Category/application	General services	Safety significant	Safety class
Structural	UBC; ACI-318; AISC; UCRL-15910, AWS-D1.1	same as GS	ACI-349; ANSI-N690
	Guidance on applicable codes and standards is also provided by performance category per DOE-STD-1021		
Process equipment - vessels and tanks	ASME VIII; API; AWWA-D100; UL-58, -142	same as GS	ASME III[a]
Process equipment - piping and valves	UPC; ASME VIII; ASME-B-16.xx, B-31.1, B-31.3, B-31.9; AWWA, Hydraulic Institute Standards	same as GS	ASME III[a], ANSI-N278
Process equipment - pumps	API; ANSI/ASME 373.1M, 2M; ASME VIII; Hydraulic Institute Standards; AWWA; AFMBA	same as GS	ASME III[a]
Process equipment - heat exchangers	ASME VIII; TEMA; ASRAE	same as GS	ASME III[a]
Process equipment - ducts and fans	ASHRAE; SMACNA	same as GS	same as GS
Process equipment - pre- and HEPA filters	ASHRAE-52.68, ASME/ANSI-509, 510; Mil-F-51068C	same as GS	same as GS
Mechanical handling - cranes	CMAA; ANSI B30.xx; ASME NOG-1	same as GS	CMMA Nuclear Sections
Mechanical handling - other equipment	ANSI 16.xx; AISC	ANSI N14.6	same as safety significant
Electrical	NEC; NEXC; IES Lighting Handbook	IEEE-577	IEEE-308, -388, -379, -384, -603 (Section 5.8)
Instruments and controls	ISA; ANS-8.3, N42.18, N13.1	same as GS	ANSI-N320; ISA-S67.04; NQA-2; IEEE-627
Fire protection	NFPA	same as GS	same as GS
Chemical and toxicological hazards	OSHA; AICHE Safety Standards; ACGHI Requirements: NEPA	same as GS	same as GS
All applicable equipment	OSHA; UL; local and state standards; AWS; NEMA; ASTM; ANSI; NEPA	same as GS	same as GS

[a]ASME III or other comparable safety-related codes and standards that are appropriate for the system being designed.
[b]Standards in a lower safety category apply also to the higher safety categories unless otherwise listed.
[c]Codes and standards identified under "safety class" are invoked by DOE Order 6430.1A, and were developed specifically for commercial nuclear reactors. Their use for nonreactor applications requires judgement.
[d]Other criteria to be considered in design activities of the above will include such items as procurement levels, training, surveillance, in-service inspections, change control, maintenance, quality assurance, and NQA-1.
[e]The codes and standards identified in the table above apply to new facilities and modifications (except piping system modifications will be done to the code-of-record) and additions to existing facilities. The codes and standards originally applied (code-of-record) to a facility or an SSC will continue to apply for maintenance activities until the facility or SSC is modified.

Table 4-6. Criteria for Posting.

Radiation areas	
Area	Dose rate criteria
Radiation area	>0.005 rem/h and ≤0.1 rem/h at 30 cm
High radiation area	>0.1 rem/h at 30 cm and ≤500 rad/h at 100 cm
Very high radiation area	>500 rad/h at 100 cm
Hot Spot	5 times general area dose rate and >0.1 rem/h
Contamination areas	
Contamination	Contamination levels >1 time but ≤100 times 20 dpm/100 cm^2 (transuranic)
High contamination	Contamination levels >100 times 20 dpm/100 cm^2 (transuranic)
Fixed contamination	Removable contamination levels ≤ 20 dpm/100 cm^2 > 500 dpm/100 cm^2 (transuranic)
Soil contamination	Contaminated soil not releasable in accordance with DOE Order 5400.5
Airborne radioactivity	Concentrations ($\mu Ci/cm^3$) >10% of any DAC value

Table 4-7. Safety Systems and Related Equipment Safety Designation[1]
(4 sheets)

ITEM NO.	PARENT SYSTEM	SUPPORT SYSTEMS	FUNCTIONAL REQUIREMENTS	HNF-PRO-704 TABLE 5 CRITERIA
Safety Class (SC)				
1	Plutonium Building Structural Features: 232-Z, 234-5Z, 236-Z, 242-Z, 2736-Z, 2736-ZB. (HNF-SD-CP-SDD-007)	HVAC Supply Fan Seismic Shutdown System provides support for Item 1a. - See Item 7	1a: Seismic - Confine radiological releases, as defined in the accident analysis, during a seismic event. Building exterior surfaces and penetrations, and interior compartmentalization provide mitigation of Pu releases after a seismic event. However, the HVAC is assumed to fail during this event and the building structure is breached, but the building structure remains standing. The seismic accident analysis assumes this building breach and demonstrates that the system provides adequate mitigation to meet evaluation guidelines. The seismic shutdown system is considered a support system and provides necessary mitigation during this event. 1b: Non-Seismic - Confine radiological releases in all other accident scenarios in buildings. Building exterior surfaces and penetrations, and interior compartmentalization provide mitigation of release.	1
2		HVAC ductwork from HEPA filters to building exterior surfaces, including the HEPA filter frames.	Supports ability of building structure to provide radiological confinement for Item 1b. Confinement boundary from building structure walls to the HEPA filters includes this HVAC ductwork.	5
3		HEPA filters - See Item 5		
4	291-Z-1 Stack (HNF-SD-CP-SDD-006)		The stack must not fall on any of the buildings identified in Item 1, which could cause a loss of confinement. This is a 3/1 interference situation where possible failure of the stack may interfere with the confinement safety function provided by the buildings. Provides structural point to mount effluent monitoring system used to monitor accident conditions. Support system for Item 6. Provides elevated release point assumed during accident scenarios.	2,5
5	Final and Secondary HEPA filters: 234-5Z, 236-Z, 2736-Z, 2736-ZA, 2736-ZB, and 291-Z. (HNF-SD-CP-SDD-005).	Stack CAMs - See Item 6	Mitigate radioactive releases to protect onsite and offsite receptors. The filters provide part of the building confinement function, see Item 1b.	1

Table 4-7. Safety Systems and Related Equipment Safety Designation[1]
(4 sheets)

ITEM NO.	PARENT SYSTEM	SUPPORT SYSTEMS	FUNCTIONAL REQUIREMENTS	HNF-PRO-704 TABLE 5 CRITERIA
6	Effluent Stack Air Monitors and Alarms for: - 291-Z-1 for Buildings 234-5Z, 236-Z, 242-Z - 296-Z-5 for Building 2736-ZB - 296-Z-6 for Building 2736-Z (WHC-SD-CP-SDD-006)	291-Z-1 Stack - See Item 4	Monitor the release of radioactive materials to the environment during and after accidents (except for the seismic event) to initiate emergency response action or to initiate operator actions that will place or maintain the operating process in safe condition. Response to the seismic event is fully proscribed for evacuation and fail safe systems and does not require operation of the Effluent Stack Air Monitors and Alarms. Supports the final and secondary HEPA filter safety function by detecting a catastrophic filter failure.	3,5
7	HVAC Supply Fan Seismic Shutdown System (See Note 2 and *) (WHC-SD-CP-SDD-004)		Mitigate radiological release after a seismic event by shutting down the 234-5Z/236-Z ventilation supply fans, which prevents the facility from over-pressurizing. This system supports the confinement function of Item 1a. * Electrical supply to the seismic shutdown system is not SC because the system fails safe. In the event of a loss of power to the seismic shutdown system, the supply fans are deenergized.	2
8	Liquid Detector and Interlock in 26-in.-Hg Vacuum System (See Note 2 and *) (WHC-SD-CP-SDD-013)		Prevent criticality by detecting the aqueous solutions upstream of the geometrically non-favorable components of the 26-in.-Hg vacuum system and shutting down and isolating the system before solution reaches these components. * Electrical supply and compressed air supply to this system are not SC because the liquid detector and interlock fail safe. On loss of compressed air, the isolation valves close. On loss of electrical power to the detector and interlock circuits, the isolation valves close.	4
9	Glovebox Criticality Design Features (drains, sump discs, floor filler plates, sump raschig rings) (HNF-SD-CP-SDD-008)		Prevent criticality by maintaining a critically safe configuration.	4
10	Plutonium Vault Storage Arrays (racks, cubicles, pedestals)		Prevent criticality by maintaining a critically safe configuration.	4
11	Spill containment berm and spray shield for elevator hydraulic oil in Room 321		Prevent major oil fire and resultant facility damage by confining an oil spill.	1

Table 4-7. Safety Systems and Related Equipment Safety Designation[1]
(4 sheets)

ITEM NO.	PARENT SYSTEM	SUPPORT SYSTEMS	FUNCTIONAL REQUIREMENTS	HNF-PRO-704 TABLE 5 CRITERIA
	Safety Significant (SS)			
1	Criticality Alarm System (CAS) (See Note 2 and *) (HNF-SD-CP-SDD-003)		Prevent or mitigate radiation exposure to facility workers from criticality by warning personnel and causing their evacuation. *AC power is not SS due to DC power availability.	11
2	Plutonium Gloveboxes and Open Faced Hoods	Room CAMs - See Item 8	Prevent or mitigate radiation exposure to facility workers by minimizing contamination spread. Room CAMS used to monitor for safe working conditions around gloveboxes and hoods.	11
3	Public address function of the Private Automatic Exchange (PAX) System (HNF-SD-CP-SDD-009)		Mitigate the consequences of facility upset conditions by reliably notifying workers so that accidents can be controlled or workers can be evacuated. The PAX system backs up the Emergency Evacuation Alarms System, Item 9, as a defense in depth feature.	12
4	HVAC Exhaust System* (HNF-SD-CP-SDD-005)		Prevent and mitigate the release of radioactive materials that could expose facility workers by maintaining ventilation zone control (differential pressures). * This item provides a conservative, defensible position for the plant HVAC system that integrates the previously classified Emergency Exhaust System with the worker protection criteria of HNF-PRO-704.	11
5		Back-up Emergency Exhaust System	Supports the HVAC exhaust system function by providing a reliable source of exhaust HVAC flow in the event of a loss of electrical power.	12
6		HVAC Supply Fan Interlock with the Exhaust Fan System	Supports the HVAC exhaust system safety function by preventing the supply fans from running when the exhaust fans are deenergized.	10
7	Primary Pu Containers		Contain and isolate Pu from workers when stored outside gloveboxes.	8
8	Room CAMs - portable and fixed. Excludes CAMs associated with stacks, HEPA filters, and in-line duct or process monitors. (See Note 2) (HNF-SD-CP-SDD-011)	Standby Power System - See Item 10	Mitigate worker exposure to radioactive release by monitoring work areas and alerting facility workers to airborne radioactive concentrations exceeding limits. Facility workers initiate radioactive contamination control and protective actions upon alarm. Supports the safety function of gloveboxes and open faced hoods by monitoring parameters that indicate the gloveboxes and open faced hoods are, performing their radiological confinement function.	11, 10

Table 4-7. Safety Systems and Related Equipment Safety Designation[1]
(4 sheets)

ITEM NO.	PARENT SYSTEM	SUPPORT SYSTEMS	FUNCTIONAL REQUIREMENTS	HNF-PRO-704 TABLE 5 CRITERIA
9	Emergency Evacuation Alarms (See Note 2) (HNF-SD-CP-SDD-009)	PAX System - See Item 3 Standby Power System - See Item 10	Mitigate worker exposure to resulting from accident conditions by reliably warning facility workers of the upset condition and signaling appropriate facility worker response.	11
10	Standby Power System (See Note 3)		Provide backup electrical power to Room CAMs, Item 8, and the Emergency Evacuation Alarms System, Item 9 and power to public address system.	10
11	-241-Z Final and Secondary HEPA filters -232-Z exhaust HEPAs		Mitigate radioactive releases and provide part of the confinement boundary.	12
12	Effluent stack air monitors and alarms for: - 296-Z-3 for Building 241-Z - 296-Z-14 for Building 232-Z		Supports the final and secondary HEPA filter Safety function by detecting a catastrophic filter failure	5,9

Note 1: For safety systems and related equipment safety designations associated with the Laboratory Prototype Calciner, see the Laboratory Prototype Calciner addendum to this FSAR.

Note 2: The safety designation shown for each system only applies to those components of the system that: 1) perform the identified safety function, 2) monitor the critical operating parameters of the system (e.g., parameters such as flow or pressure), provide warning of malfunction of the system (alarms and indicator lights), or, 3) are necessary to place the system in a safe configuration (operational interlocks) are classified with the safety designation shown in the table. In addition, systems that ensure that the operational monitors, alarms, and interlocks function under adverse conditions (e.g., UPS or backup power systems for use during partial or complete loss of electrical systems) are assigned the same safety designation. The safety designation for these items is based on their function to alert personnel of off-normal conditions so appropriate actions can be implemented and to place systems in a safe mode to minimize the impacts of a malfunction.

Note 3: Standby Power System (SPS) includes diesel generators and select uninterruptable power supply systems (UPS). [See *Defining and Means of Maintaining the Standby Power System Portion of the PFP Safety Envelope*, HNF-SD-CP-SDD-024.

Table 4-8. Safety Classification for the Production Vertical Denitration Calciner Process (3 sheets)

ITEM	SAFETY CLASSIFICATION	SAFETY FUNCTION	RATIONALE	APPLICABLE HNF-PRO-704, TABLE 5 CRITERIA[1]
Safety Class (SC)				
Glovebox HC-230C-2 criticality drain and screen	Safety class	Prevent accumulation of critical solution volume and geometry in bottom of glovebox should tanks rupture and or water infiltrate glovebox.	Criticality drain prevents potential criticality which could cause serious worker exposure or fatality.	4
Safety Significant (SS)				
Calciner pressure relief device (PRV 230-6)	Safety significant	Prevent failure of the VDC from overpressurization.	Offgassing and flashing of water within calciner can result in pressurization of calciner due to a number of upset conditions. Pressure relief is set to relieve at 1.3 psi. Should the pressure relief device fail to relieve at lower pressures, catastrophic failure of calciner could result in hot Pu oxide, NOx, and steam being released to operating room due to failure of glovebox confinement boundary. Significant overpressurization of calciner poses serious health threat to multiple operators.	11
Calciner thermocouples and temperature control system for wall heaters; calciner high temperature alarm	Safety significant	Control temperature of calciner; protect structural integrity of calciner; annunciate on calciner high temperature to initiate shutdown of VDC heaters and calciner feed pump.	Loss of temperature control could result in significant structural degradation of calciner vessel and overtemperature condition in glovebox HC-230C-2. Glovebox loss of confinement accident poses significant health threat to multiple operators due to Pu inhalation hazard.	11
Glovebox high temperature alarm	Safety significant	Annunciate high glovebox temperature indicative of inadequate ventilation or loss of calciner temperature control; initiates shutdown of VDC heaters and calciner feed pump.	Same as above.	11
HC-230C-2 glovebox confinement structure and penetrations and ventilation exhaust ducting	Safety significant	Confine radiological and toxicological releases from glovebox vessels; prevent spread of Pu to room 230C.	Spread of Pu beyond glovebox boundary poses serious health threat to operators.	11
Vessels within Glovebox HC-230C-2	Safety significant	Provide criticality safe geometry.	Vessel geometry precludes criticalities for solutions containing less than 450 g-Pu/L. Criticalities can cause serious worker exposure or fatality. Vessel geometry provides defense-in-depth for criticality prevention.	12

Table 4-8. Safety Classification for the Production Vertical Denitration Calciner Process (3 sheets)

ITEM	SAFETY CLASSIFICATION	SAFETY FUNCTION	RATIONALE	APPLICABLE HNF-PRO-704, TABLE 5 CRITERIA[1]
Vacuum trap high level indication and vacuum system shutdown interlock in Glovebox HC-230C-2	Safety significant	Prevent liquid overflow into vacuum system	Portions of vacuum system are not criticality safe; shutdown interlock prevents potential criticalities in vacuum system which could result in serious worker exposure or fatality. Safety significant classification assigned because the glovebox vacuum trap high level interlock backs up a similar safety class feature in the plant vacuum system.	12
Transfer line encasement pipe (for transfer lines between Gloveboxes HC-227S and HC-230C-2)	Safety significant	Ensure leaks from primary transfer line drain to ventilated gloveboxes. Prevent spray or liquid leaks of Pu nitrate solutions into Zone 3 areas.	Encasement knocks down spray leaks and prevents liquid leaks to Zone 3 areas which are potentially occupied by workers. Airborne Pu poses serious health threat to facility workers.	11
Room 230C CAMs	Safety significant	Alert operators of presence of airborne radiological material in Room 230C.	Pu powder or aerosols spread beyond the Glovebox HC-230C-2 confinement boundary poses significant health threat to operators. CAMs are carefully located and calibrated to ensure adequate operator protection.	11
Dry Chemical Fire Suppression System	Safety significant	Prevent significant fire damage to glovebox confinement system.	Limited combustibles in Glovebox HC-230C-2 can be ignited. The dry chemical fire suppression system limits the magnitude of the fire and prevents spread of fire to the more combustible sections of the RMC line. Fires large enough to breach the confinement boundary of the glovebox pose significant health threat to operators.	11
Seismic shutdown interlock for VDC power, feed pump power, atomizing air feed, back pulsing air feed	Safety significant	Limit particulate and aerosol release from the VDC in a large seismic event that may fail the E-3 & E-4 exhaust system HEPA filters.	Without seismic shutdown, the VDC could pressurize and release significant quantities of PuO_2 powder or $Pu(NO_3)_4$ aerosols. As the seismic event could also cause the failure of the E-3 and E-4 ventilation system HEPA filters, the release from the pressurized VDC could result in a greater than 5 rem exposure to the maximum onsite receptor (see Section 9.1.10.1 and 9.2.9.4).	6

Table 4-8. Safety Classification for the Production Vertical Denitration Calciner Process (3 sheets)

ITEM	SAFETY CLASSIFICATION	SAFETY FUNCTION	RATIONALE	APPLICABLE HNF-PRO-704, TABLE 5 CRITERIA[1]
VDC low vacuum/feed pump shutdown interlock	Safety significant	Limit duration of pressurization events in the VDC; limit potential release of flammable organic vapors to the glovebox atmosphere should organic-containing material be injected into the VDC concurrent with a loss of vacuum event.	The low vacuum/feed pump shutdown interlock prevents multiple successive deflagrations in the VDC in the event organic containing material is injected into the calciner. The interlock also limits the quantity of organic gases/vapors that can be released into the glovebox atmosphere should organic-containing feed be injected into the calciner concurrent with a loss of process vacuum flow (See Section 9.2.9.1). The low vacuum/feed pump shutdown interlock limits the magnitude of potential organic deflagrations in the VDC and HC-230C-2 glovebox and thereby helps to ensure the integrity of the glovebox confinement boundary.	11

1. HNF-PRO-704, *Hazard and Accident Analysis Process*, Fluor Daniel Hanford, Inc., Richland, Washington.

Figure 4-1. Design and Construction Time Line for the Plutonium Finishing Plant Complex.

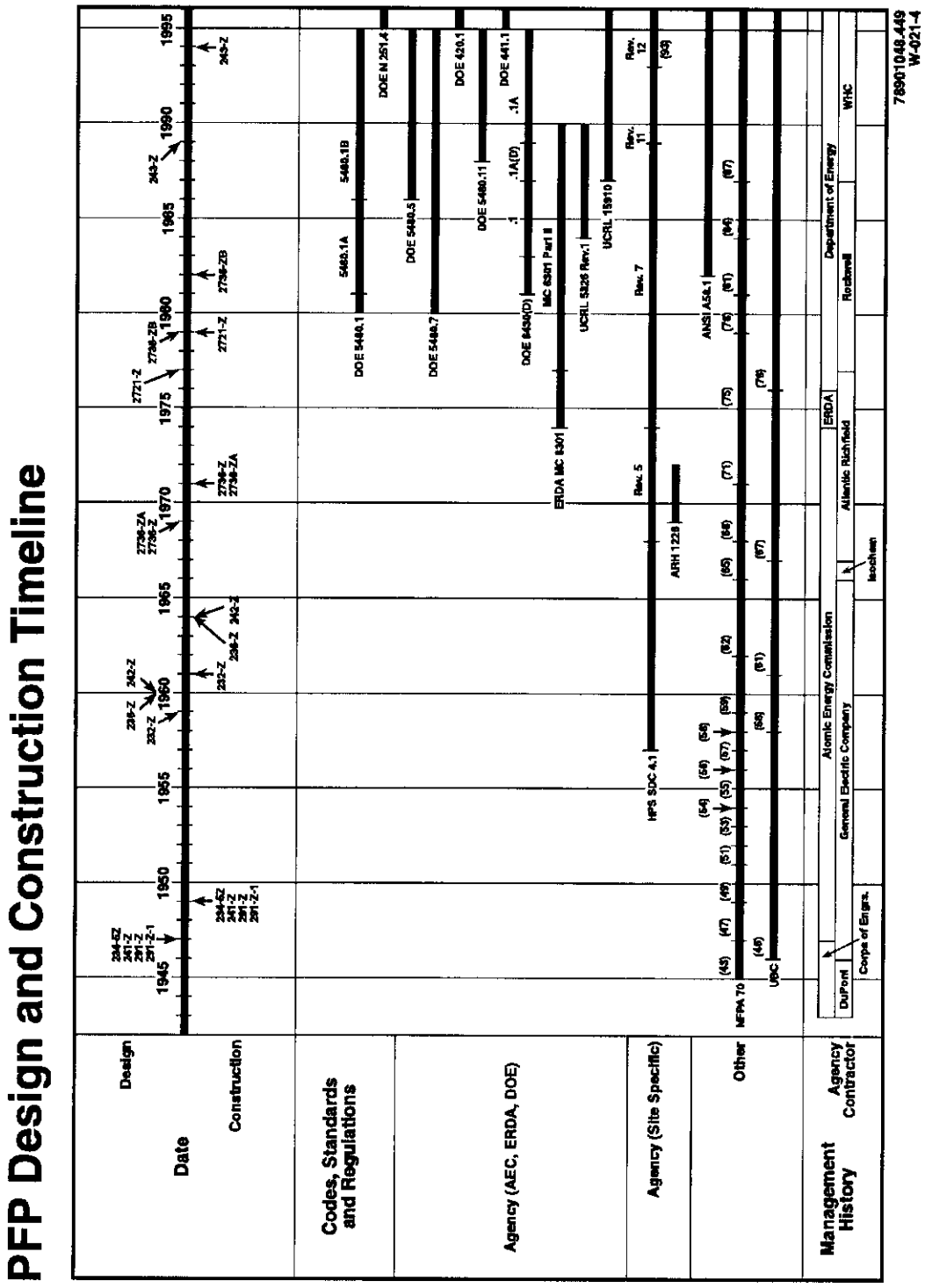


Figure 4-2. Response Spectra--Nonreactor Safety Class with 2%, 5%, 7%, and 10% Critical Damping at 0.20 g.

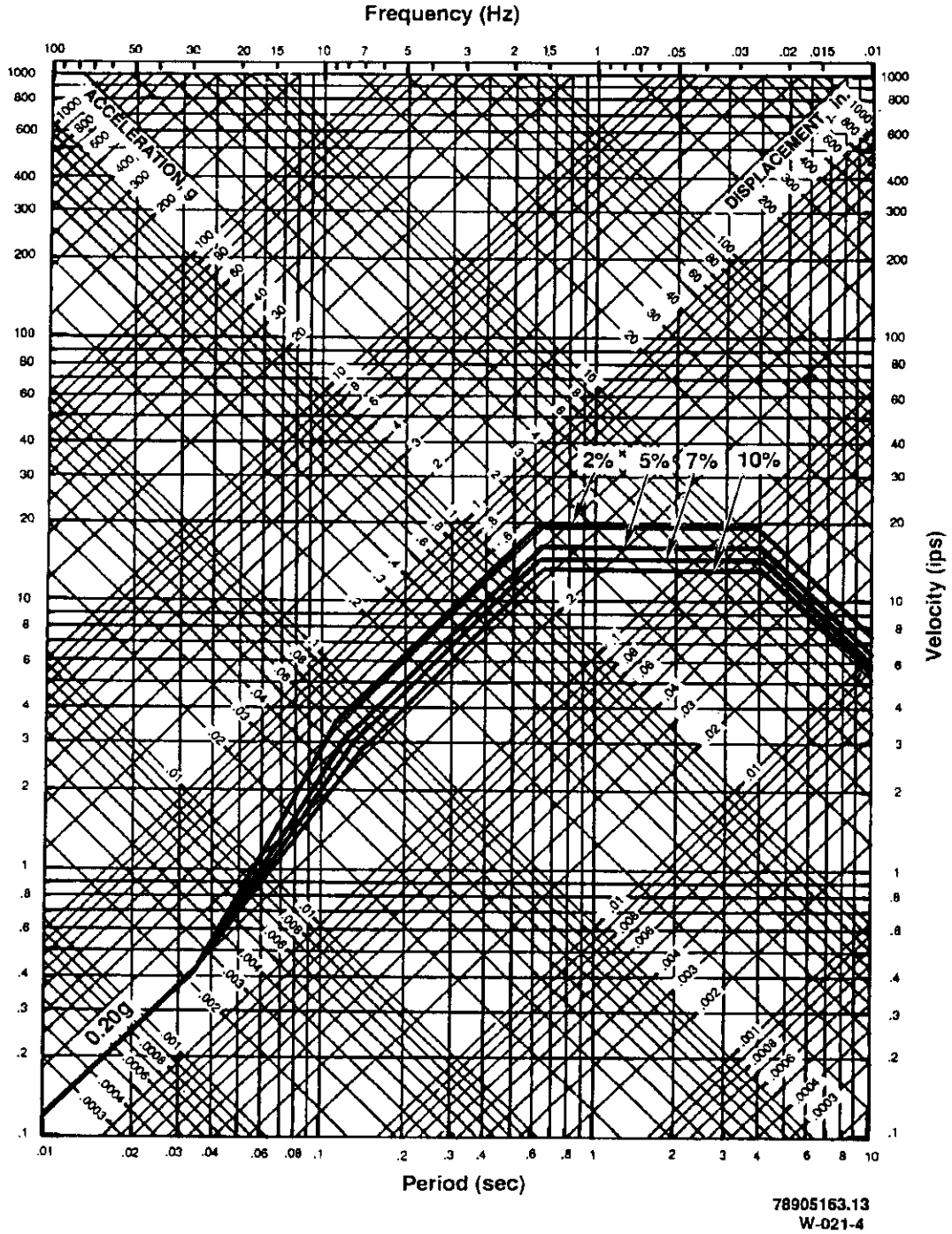


Figure 4-3. Response Spectra--Nonreactor Safety Significant with 2%, 5%, 7%, and 10% Critical Damping at 0.12 g.

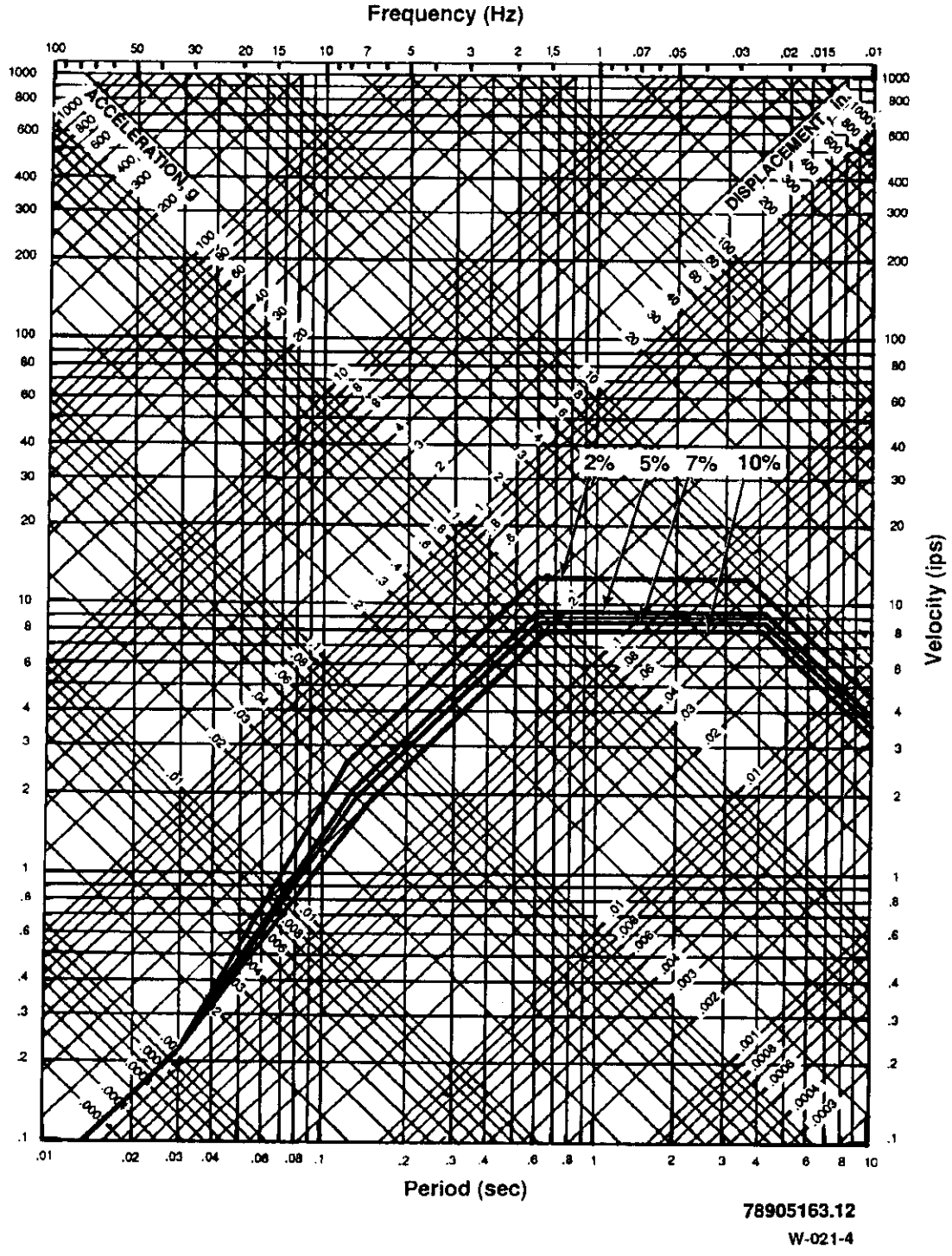


Figure 4-4. Response Spectra--Small-Magnitude, Near-Field Earthquake at 0.20 g.

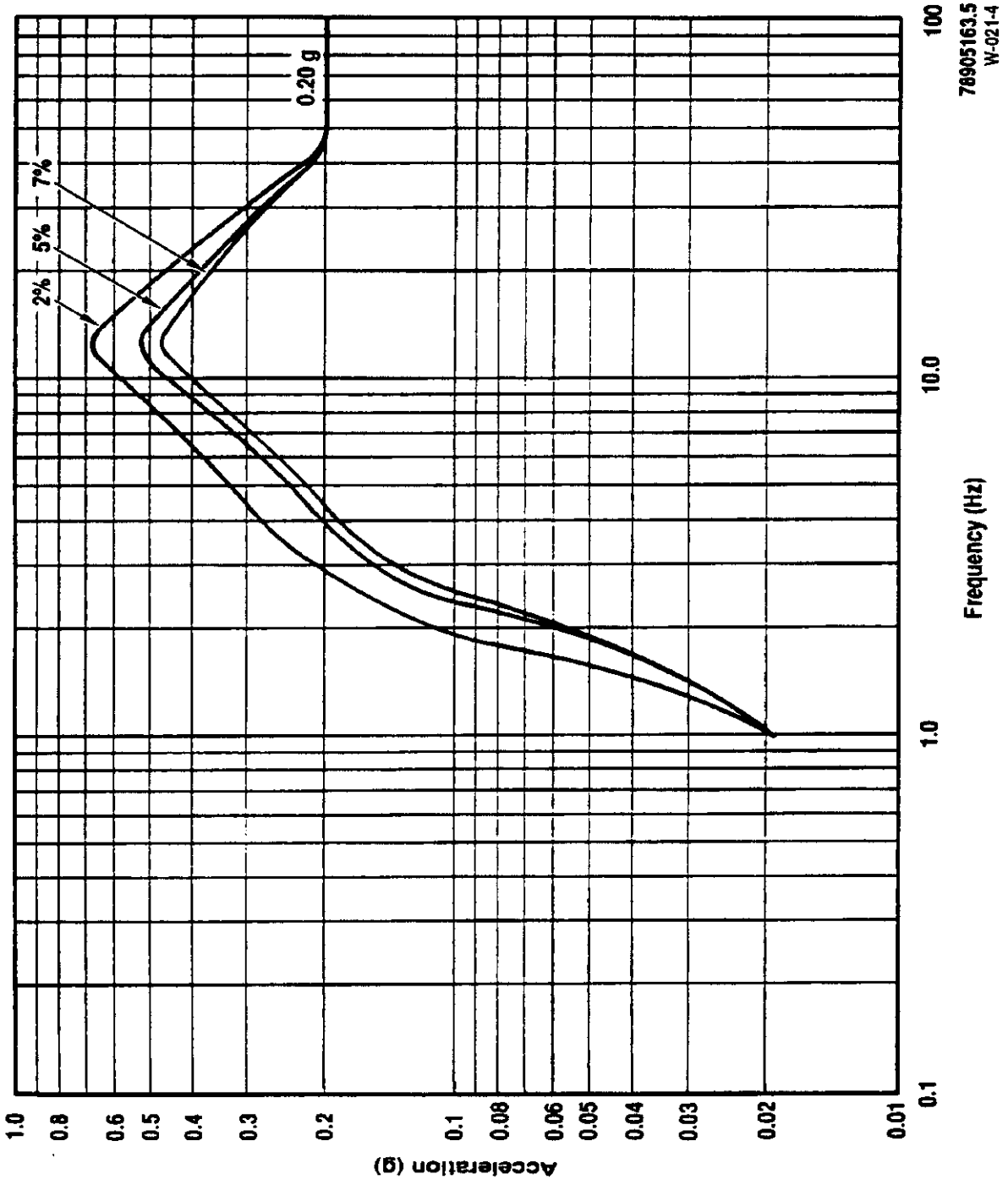
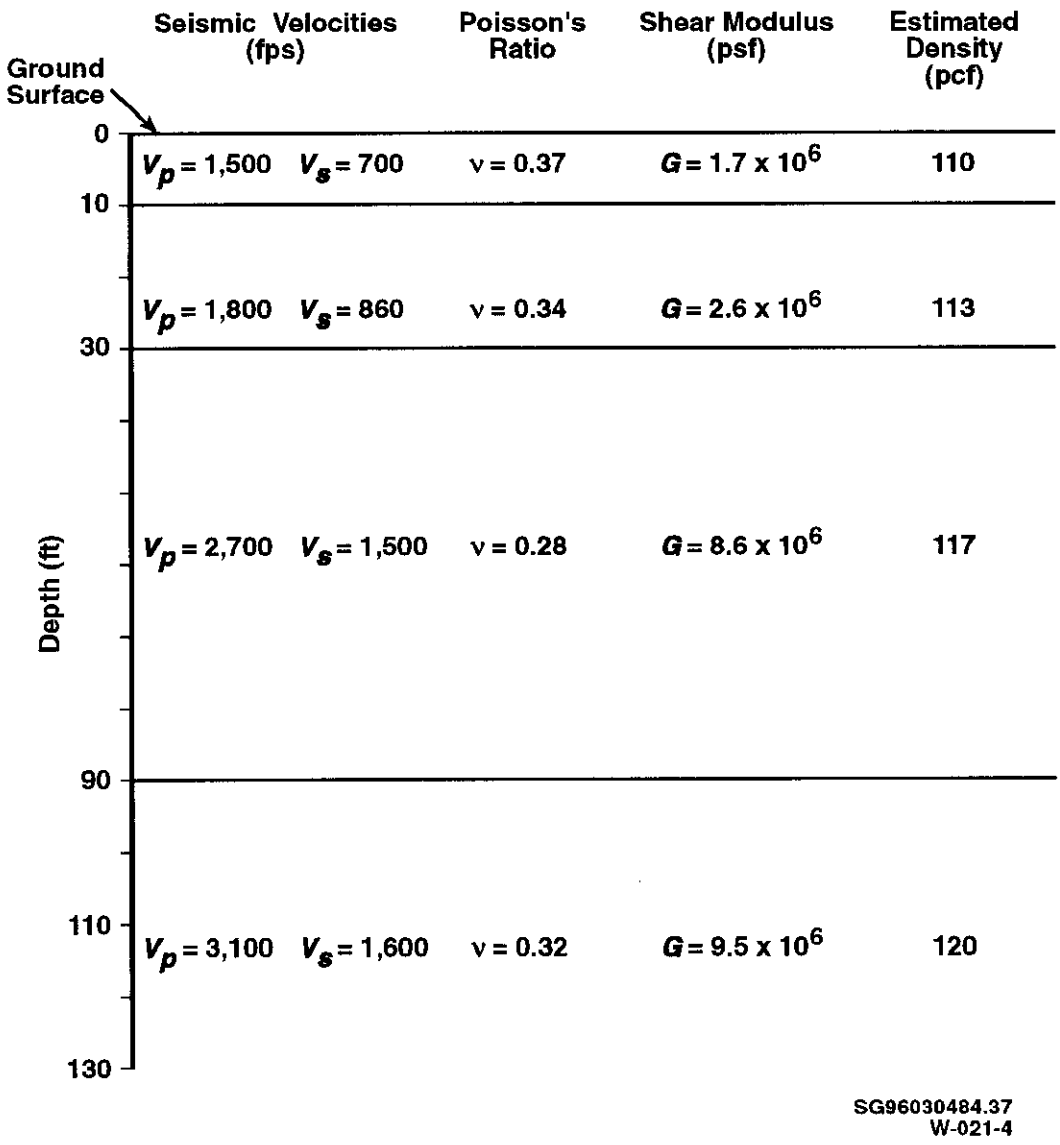


Figure 4-5. Profile Showing Dynamic Properties of Subsurface Materials at the Plutonium Finishing Plant Site.



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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 5.0

PLANT DESIGN

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 5.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) includes modifications for the following:

- Revisions to the description of the standby power and electrical systems
- Revisions to the description of glovebox HA-21I to include nuclear criticality safety features
- Clarification of the operation of the ventilation systems
- Clarification of the process/compressed air systems
- Incorporation of the Magnesium Hydroxide Precipitation Process
- Incorporation of the Bagless Transfer System

Other minor changes include editorial changes and additional clarifications.

The following summarizes the active and inactive processes performed at the PFP. Facility and systems descriptions are provided for both active and inactive processes. The active systems are currently or will be authorized for operation following approval of the FSAR, Revision 2, and controls implementation. The inactive descriptions are retained for historical purposes to support future material stabilization and D&D activities.

Active Processes.

- Plutonium material storage and support activities in the 2736-Z, 2736-ZA, and 2736-ZB Buildings, 2736-ZD vault, and the gloveboxes and vaults in the 234-5Z Building
- Reactive plutonium-bearing material stabilization in the 234-5Z Building using Gloveboxes HC-21C and HA-21I
- Waste packaging and reactive residue storage
- Transfer operations in gloveboxes HC-227S/T in the 234-5Z Building
- Low-level waste and waste water treatment in the 241-Z Complex and 243-Z Building, respectively
- The PFP Analytical Laboratory (PFP AL), Standards Laboratory, and Plutonium Process Support Laboratory (PPSL) in the 234-5Z Building
- Facility support systems [e.g., heating, ventilation, air conditioning (HVAC), radiation monitoring, steam, electricity, etc.].
- Bagless Transfer System operations in Glovebox HA-53BTS in the RMA Line in the 234-5Z Building

- Magnesium Hydroxide Precipitation Process operations in Gloveboxes HC-230C-3 and HC-230C-4 in the RMC Line in the 234-5Z Building.

Inactive Processes.

- Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner and Laboratory Prototype Calciner in the 234-5Z Building
- Plutonium recovery in the 236-Z Building
- Plutonium conversion in the 234-5Z Building
- Waste treatment in the 242-Z Building
- Laboratory waste concentrator.

It is noted that various sections of Chapter 5.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner located in the Plutonium Process Support Laboratories. Operation of either the production calciner or the laboratory calciner for solution stabilization is not authorized at this time and the related portions of Chapter 5.0 will be updated, if necessary, prior to initiation of operations.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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5.0 PLANT DESIGN

5.1 SUMMARY DESCRIPTION

5.1.1 Location and Plant Layout

The Plutonium Finishing Plant (PFP) Complex (see Figure 5-1), while in transition to the decontamination and decommissioning (D&D) phase of its life cycle, conducts the following operations:

- Plutonium material receiving, storing, and shipping
- Reactive plutonium-bearing material stabilization
- Plutonium-bearing solution stabilization
- Laboratory support
- Waste handling
- Shutdown facilities surveillance
- Limited cleanout
- Maintenance.

The buildings and structures that comprise the PFP Complex are listed in Table 5-1. The principal PFP structure, the 234-5Z Building, was completed in 1949 to purify plutonium nitrate solutions, reduce the nitrate to plutonium metal, and fabricate plutonium metal parts. The 234-5Z Building houses PFP transition operations, process support facilities and services, the Analytical Laboratory (PFP AL), the Plutonium Processing Support Laboratory (PPSL), and the Standards Laboratory. The 241-Z Liquid Waste Treatment Facility and the 291-Z Building, which house ventilation exhaust fans and mechanical service equipment, were built at the same time as the 234-5Z Building. An incinerator, housed in the 232-Z Building, was completed in 1961 and was used to recover plutonium from combustible scrap. Plutonium reclamation and waste treatment equipment is housed in the 236-Z and 242-Z Buildings, respectively, which were completed in 1964 (see Table 5-2 for construction dates).

In the original design of the PFP Complex process facilities, all of the planned operations and laboratories, except waste collection and disposal, were provided in the 234-5Z Building; however, with increases in production, storage, and scrap recovery requirements, the following major additions were made:

- The 236-Z Building [Plutonium Reclamation Facility (PRF)]
- The 241-Z Complex (Liquid Waste Treatment Facility)
- The 232-Z Waste Incinerator Facility

- The 2736-Z Support/Storage Complex (2736-Z, 2736-ZA, 2736-ZB, and 2721-Z Buildings, 2736-ZC enclosed shipping/receiving area, and 2736-ZD vault)
- The 243-Z Low-Level Waste Treatment Facility (LLWTF)
- An upgraded men's changeroom, 234-5ZA, attached to the 234-5Z Building.

The 234-5Z Building is no longer used to purify plutonium nitrate solutions, reduce the nitrate to plutonium metal, nor fabricate plutonium metal parts. The building is currently used for stabilization operations for reactive plutonium-bearing materials and plutonium-bearing solutions. Plutonium recovery operations are no longer conducted in the PRF, but the building is still available for interim storage of in-process material. The Waste Treatment Facility (the 242-Z Building) is no longer capable of restarting its original operations without upgrading and/or reestablishing services to process and facility equipment. The 232-Z incinerator is being prepared for decontamination and decommissioning.

5.1.2 Principal Features

5.1.2.1 Site Boundary. The federally owned Hanford Site is located in the southeastern part of Washington State about 45 mi north of the Oregon border (Figure 5-2). The Hanford Site occupies about 560 mi^2 of arid land.

In the middle of the Hanford Site, on an arid terrace about 7 mi from the Columbia River, are the 200 East and 200 West Areas (Figure 5-3), where fuel reprocessing, plutonium processing and storage, laboratory facilities, and waste processing and storage facilities are located. The locations of the 200 Areas were chosen to provide the most isolation from the Hanford Site boundaries and are the most remote from both surface and subsurface water. A more detailed description of the Hanford Site is provided in Chapter 3.0.

Public transportation facilities nearest the 200 Areas are State Routes 24 and 240. State Route 240 passes within 2.5 mi of the PFP (Figure 5-3). A four-strand barbed-wire fence separates the highway right-of-way and the Hanford Site.

5.1.2.2 200 West Area. The 200 West Area is located on an upland plateau near the center of the Hanford Site (see Figure 5-3). The locations of the PFP Complex and other major facilities in the 200 West Area are shown in Figure 5-4. The PFP emergency response envelope (see Figure 5-4, which identifies the emergency response envelope as a circle with the 291-Z-1 stack as its center point) encompasses all structures within approximately 1,800 ft of the 291-Z-1 stack, which is the approximate point of discharge for most releases. This area includes the 231-Z Building, the 232-Z Building and 216-Z-9 crib, temporary office structures to the east, portions of the Central Waste Complex to the northwest, and environmental remediation activities.

5.1.2.3 Protected Area. The PFP is separated from the 200 West Area by a double-fenced security enclosure (see Figures 5-1 and 5-4) which contains an electronic surveillance system. Only personnel who have duties and

responsibilities associated with the operation of the plant and auxiliary facilities have access authorization to the complex.

5.1.2.4 Site Utility Supplies and Systems. The Hanford Site utilities servicing the PFP are electricity and water. A brief description of each follows. Details are covered in Section 5.4.

5.1.2.4.1 Electrical Power Supply and Distribution System. The electrical power supply and distribution system includes the following and is detailed in Section 5.4.2.

- Normal power supply--Electrical power is supplied to the Hanford Site by the Bonneville Power Administration (BPA) substation at Midway through a 230-kV loop serving all outer areas of the site. The H. J. Ashe switchyard provides a redundant supply of 230-kV electrical power. This source is switched automatically into the 230-kV loop in the event of power loss from the Midway substation.

- Standby power--Standby power for the PFP Complex is available from three 325-kW diesel-generators housed in the 2721-Z Building.

- Uninterruptible power supply--Uninterruptible power (batteries) is provided to operate standby power supply diesel generators in Building 2721-Z, seismic shutdown systems, alarm systems, emergency lighting, and the MICON™ control system in the event of loss of normal and standby power.

5.1.2.4.2 Water Supply and Distribution System. All of the water supply needs for the PFP are provided by three sanitary water system lines. Water from the 283-W filter plant and clear wells is supplied to the PFP sanitary water service loop by a 10 in. diameter line that feeds into the loop at the southeast corner, an 8 in. diameter line that feeds into the loop on the north side, and a 12 in. diameter line that feeds into the loop at the northeast corner (see Sections 5.4.7 and 5.4.8 for details).

5.1.2.5 Storage Facilities. Compressed gas storage facilities are discussed in Section 5.4.4. Liquid chemical storage is discussed in Section 5.4.13.

5.1.2.6 Ventilation Exhaust Stacks. The PFP ventilation exhaust stacks are described below and locations are shown in Figure 5-1 [see Section 5.4.1 for details of the heating, ventilation, and air conditioning (HVAC) system].

- 291-Z-1 stack--The 291-Z-1 stack is 200 ft high with a 16-ft 6-in. ID at the bottom, and a 13 ft 6 in. ID at the top. The stack is constructed of reinforced concrete and effluents are sampled and monitored.

- 296-Z-3 stack--The 296-Z-3 stack is 25 ft high with a 14 in. diameter. The stack is constructed of stainless steel and effluents are sampled and monitored.

- 296-Z-5 stack--The 296-Z-5 stack is 27 ft 7 in. high with a 34 in. diameter. The stack is constructed of stainless steel and effluents are sampled and monitored.

- 296-Z-6 stack--The 296-Z-6 stack is 14 ft 8 in. high in a 36-in. by 22-in. rectangular configuration. The stack is constructed of carbon steel and effluents are sampled and monitored.

- 296-Z-14 stack--The 296-Z-14 stack is 21 ft high with a 12 in. diameter. The stack is constructed of stainless steel and effluents are sampled and monitored.

- 296-Z-15 stack--The 296-Z-15 stack is 42 ft high with a 12-in. diameter and is constructed of stainless steel. This stack is not routinely sampled and monitored because of the small likelihood of any plutonium entering the 243-Z Building and then escaping the piping and train drums. The sampling and monitoring that is done is to confirm the low radioactive emissions.

5.2 PROCESS AND SUPPORT BUILDINGS

This section describes the structural specifications, building layout, major process areas in the PFP Complex, and the design bases for major PFP process and support buildings.

The PFP is a complex of facilities and support buildings performing various functions to support past and present missions; facilities and buildings are both active and inactive. This chapter will describe those facilities and buildings containing processing equipment and having plutonium material and/or hazardous material inventories warranting consideration or providing one of the confinement systems at the complex. These facilities are identified as major facilities/buildings in this chapter. A list of buildings and structures of the PFP Complex are provided in Table 5-1.

The facilities that have been identified as major facilities/buildings are as follows:

- 234-5Z Building
- Plutonium Reclamation Facility (236-Z Building)
- Waste Storage and Treatment Facility (241-Z Building)
- Exhaust Air Stack Building (291-Z Building)
- Plutonium Storage Facility (2736-Z Building)
- Product Shipping and Receiving Facility (2736-ZB Building).

Some support buildings/facilities also contain inventories of plutonium material and/or hazardous materials warranting consideration, or are necessary to maintain the confinement features of the PFP (i.e., the 291-Z-1 stack). These include the following:

- 242-Z Building (inactive)
- LLWTF (243-Z/243-ZA Buildings)
- HVAC building (2736-ZA Building)
- Enclosed Off-loading dock (2736-ZC)
- Experimental breeder reactor II cask storage (2736-ZD)
- Standby diesel generator building (2721-Z Building)
- 231-Z Building (Under the cognizance of another Fluor Hanford Organization)

- Incinerator Facility (232-Z) (inactive facility)
- Waste Crib (216-Z-9)
- 291-Z-1 stack
- 296-Z-3 stack
- 296-Z-5 stack
- 296-Z-6 stack
- 296-Z-14 stack
- 296-Z-15 stack.

The 216-Z-9 crib is a plutonium-containing waste crib located outside of the double fences that encompass the PFP facility. The 216-Z-9 crib is not a major process facility nor support building of the PFP Complex. The 231-Z Building served as the predecessor to the Z-Plant (234-5Z Building and support facilities) in the 1940's. This facility was originally used to fabricate plutonium metal and was equipped with processing equipment (gloveboxes, fabrication machinery, chemical storage, etc.). A change in mission for the facility resulted in its being used for office space, training, and a rigging shop. This building contains PFP plutonium inventory and is the responsibility of a separate Fluor Hanford organization. Entry into the facility is restricted because of contamination in some sections of the building interior.

Original design specifications and procedures for PFP facilities were based on Uniform Building Code (UBC) requirements applicable at the time of construction or modification, together with Atomic Energy Commission, U.S. Energy Research and Development Administration, or U.S. Department of Energy (DOE) criteria. A list of the major PFP facilities, when they were designed, when they were constructed, and applicable design requirements are shown in Table 5-2. Additional requirements including *Minimum Design Loads for Buildings and Other Structures* (ANSI A58.1), *Building Code Requirements for Reinforced Concrete* (ACI 318), and the *Manual of Steel Construction* (AISC), were also used in the design of these buildings.

Since June 1961, facility additions and alterations have been made in accordance with the Hanford Plant Standards applicable at the time of modification. Current design criteria and procedures for analysis of the effects of natural phenomena on the PFP buildings are defined in *Standard Architectural-Civil Design Criteria, Design Loads for Facilities*, SDC 4.1, Rev. 12 (DOE-RL 1993), and DOE Order 6430.1A, *General Design Criteria* (DOE 1989).

The 234-5Z, 236-Z, 232-Z, 241-Z, 291-Z, 2736-Z, and 2736-ZB Buildings and 291-Z-1 stack and their service and utility systems have been reviewed for compliance with DOE Order 6430.1A (DOE 1989). The results of these reviews are presented in WHC-SD-CP-ES-128, *Preliminary Evaluation of PFP Conformance to DOE Order 6430.1A, Principle Design Criteria* (WHC 1990).

Structural specifications establish the bases and engineering designs required to maintain the confinement integrity of major buildings in the PFP Complex. The type of structure, materials of construction, and construction classification are summarized in Table 5-3. Significant natural phenomena hazards analyses/design information and conclusions specific to the major PFP buildings are summarized in Table 5-2. The natural phenomena hazards are earthquakes, extreme winds, wind-driven missiles, snowfall, and volcanic

ashfall. Evaluation of structures, systems, and components (SSCs) against the natural phenomena hazard design requirements of volcanic ashfall loading is required only for new safety class 1 (now safety class) SSCs and equipment and modifications or additions to existing high hazard facilities (DOE RL 1993); therefore, the design criteria for volcanic ashfall loading and combined snow and volcanic ashfall loads are not applied to those facilities built before 1993. In the structural evaluations of the PFP Complex buildings, analysis of the roof was performed to verify design adequacy with regard to live, dead, and snow loads, which are the normal roof loads. The 234-5Z Building was analyzed and found to acceptably resist combined volcanic ashfall and snowfall (Giller 1990) and the 243-Z Building was designed to meet the volcanic ashfall loading criteria of 24 lb/ft^2 for Safety Class 1 SSCs (DOE 1989).

The structural evaluation of the existing PFP facilities design bases differs from new facilities in that the in situ load configurations and conditions of the structures and components were assessed. This assessment included reviewing drawings and conducting field walkdowns to determine deviations from the drawings and any observed deterioration. In-place strengths of materials were used in the analyses when available. If noted during the walkdowns, corrosion and other aging processes that may have had adverse effects on the strength of the components were also considered in the analyses.

The evaluation of existing structures is similar to evaluations performed on new designs, except that a known configuration is evaluated instead of several possible options in an iterative manner, as required during the design process. Because the process is defined, configurations of the buildings and components are known, and the actual live and dead loads are used. The structural evaluation acceptance criteria of the PFP structures and components can be less conservative than that of a new facility where live and dead loads are not known, but are based on anticipated processes and occupancy. It also was required that the confinement capability of the facilities be maintained after a natural phenomena event. The acceptability of the structural evaluations is subject to the interpretation used in preparing the accident and risk analyses of Chapter 9.0.

Most of the seismic qualification analyses for the PFP discussed in this chapter were performed in accordance with SDC 4.1, Rev. 10 (DOE-RL 1987), which used a zero period acceleration of 0.25 g. Since the completion of these analyses, Rev. 11 and Rev. 12 (DOE-RL 1989 and DOE-RL 1993, respectively) have been implemented. In these later revisions, the zero period acceleration is 0.20 g for Safety Class 1 items in nonreactor facilities. DOE-RL (1987) response spectra are based on 84% amplification factors, whereas DOE-RL (1989) response spectra are based on median amplification factors. DOE-RL (1987; 1989) response spectra at 5% critical damping are shown in Figure 5-5. The DOE-RL (1987) spectra are generally more conservative than those in DOE-RL (1989) except for a very narrow frequency range (18 to 21 Hz) where DOE-RL (1989) has an equally conservative or slightly more conservative spectra than DOE-RL (1987). None of the buildings evaluated by dynamic analysis have a frequency with a significant mass participation that fall within the 18 to 21 Hz range; therefore, buildings previously qualified under DOE-RL (1987), satisfy DOE-RL (1989) requirements.

The seismic analyses for the 234-5Z Building assumed a critical damping ratio of 7% (URS 1987). The 7% damping ratio was used in accordance with the recommendations of U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.61 (NRC 1973). The east-west and north-south seismic lateral loads will be resisted by the reinforced-concrete shear walls and the bolted steel members. The structure was assigned a 7% damping ratio specific to design basis earthquake (DBE) load levels. The resulting maximum combined stresses were above one-half the yield stress; therefore, use of 7% damping was justified. The analyses were performed before DOE-RL (1989; 1993) were issued. DOE-RL (1989) recommends that damping values for nonreactor structures be in accordance with *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards*, UCRL 15910 (Kennedy et al. 1990). In Kennedy et al. (1990), the damping ratio for the above load-resisting structures is 10% for high hazard facilities; therefore, use of 7% damping is considered conservative.

The 291-Z Building is constructed with reinforced concrete for lateral load resistance; therefore, 7% damping was used again in the seismic analyses, which is in conformance with NRC (1973).

The 236-Z Building is also a reinforced concrete structure. In the preliminary seismic analysis, which used the 7% NRC (1973) damping ratio, resulting combined stresses were lower than one-half the yield stress; therefore, a lower damping ratio of 5%, specific to operating base stress levels, was used to avoid underestimating the amplitude of vibrations or dynamic stresses.

Table 5-4 provides a summary of the seismic analyses for the 234-5Z, 236-Z, 232-Z, 241-Z, 242-Z, 291-Z, 2736-Z, 2736-ZA, 2736-ZB, and 2721-Z Buildings and 291-Z-1 stack. This table shows the type of seismic analysis performed, the design response spectra of each building, the critical damping used, any consideration of soil structure, and the conclusions of each analysis.

The wind load analyses used the maximum velocity of 90 mi/h, based on the guidelines of DOE-RL (1989), and Kennedy et al. (1990). The wind load calculations are in accordance with the formulas and recommendations described in ANSI A58.1. The structures were all designed to withstand 20 lb/ft^2 of normal wind load. In addition to the normal wind load, the 2736-ZB and 2736-Z Buildings were designed to withstand tornado wind conditions with wind speeds of 175 mi/h and associated tornado-generated missiles identified in SDC 4.1, Rev. 7 (DOE-RL 1982).

The roof loading requirements of the major buildings were based on the UBC guidelines at the time of design. The roofs of all aboveground structures were designed for static vertical live and dead loads, including snow loads. Design requirements for combined snow and volcanic ashfall loading, and volcanic ashfall loading were not required until issuance of DOE-RL (1989). Analyses of roof designs to withstand natural phenomena hazards of combined snow and volcanic ashfall loads, if any, are discussed in individual building structural/design specifications in Sections 5.2.1 through 5.2.10. In many cases, specific analyses of roofs to resist combined snow and volcanic ashfall peculiar to the safety categorization of the building(s) were not performed,

though it may have been assumed that a roof would resist such natural phenomena due to dead, live, and snow design loadings.

Plan view drawings of the PFP buildings are shown in Figure 5-6. The principal structure is the 234-5Z Building, which contains plutonium processing facilities, laboratories, and an HVAC system. Offices, lunchroom, changerooms, maintenance shops, and Radiological Control provides for the tenants' requirements. Design of the 234-5Z Building provides a duct-level area to house service and utility distribution systems. The 234-5Z Building first-floor plan identifies the major processing areas in the building, for example, the Remote Mechanical A (RMA) and C (RMC) Lines, and locations of other process and support facilities. The duct level is a minimum-strength, metal deck between the first and second floors that contains most of the large ventilation plenums and ducts, and the piping loops for service throughout the building. The ventilation plenums and ducts and other services (e.g., telephone switchgear room, electrical room) are shown in the duct-level plan. Locations of support services (e.g., chemical preparation, ventilation supply fans, ventilation exhaust filter rooms) are shown in the second-floor plan.

Another major process building, the 236-Z Building (PRF), contains process equipment and services that were used for the recovery of plutonium from a variety of sources. The facility also has some maintenance shops and offices. Ventilation supply air and 26-in. mercury process vacuum services are provided from 234-5Z service systems. Process air, instrument air, and steam are supplied from the 291-Z Building. Services supplied by 236-Z installations include water from connections to the 8-in. PFP water supply loop, 17-in. mercury vacuum (air sample vacuum) system, and high efficiency particulate air (HEPA) filter banks for treating room exhaust air (E-3 system) and process exhaust air (E-4 system). Exhaust air is discharged to the atmosphere using the exhaust fans in the 291-Z Building and the 291-Z-1 stack.

A third major process facility is the 2736-Z Storage/Support Complex, which consists of the 2736-Z, 2736-ZA, 2736-ZB, 2736-ZC enclosed area, 2736-ZD vault, and 2721-Z Buildings. This is a stand-alone complex with its own HVAC systems, backup electrical power, changerooms, lunchroom, and offices.

Confinement Features. The exterior walls of 234-5Z, 236-Z, 242-Z, and 232-Z Buildings, and 241-Z Complex confinement features provide for physical barriers separating contaminated process hoods and vessels from the environment. The ventilation zone differential pressure (DP) is important to confinement by assuring that the airflow direction is from the clean zone 1 to the potentially contaminated zone 3 to the contaminated zone 4. Zone 1 is at a slightly positive pressure with respect to the outside building atmosphere, progressing negatively through zone 3 and then finally zone 4 to promote airflow toward the contaminated zone 4.

Zone 1 includes general office areas, lunchrooms, and some shop and service areas. It is not HEPA filtered and it is not discharged through the 291-Z Building. Zone 3 includes rooms that contain gloveboxes and hoods and/or rooms that have conditions that could result in contamination. Zone 4 includes the gloveboxes, hoods, and canyon cell, which are designated as contaminated areas.

Air from zones 3 and 4 exhausted through separate HEPA filters, and once cleaned the air joins to exhaust to the atmosphere through a stack. The stack is continuously sampled and monitored for radioactivity. The ventilation system for the majority of the PFP Complex is shown in Figure 5-7, which details the ventilation system for the 234-5Z, 236-Z, and 242-Z Buildings. For a more detailed description of the ventilation systems of the entire PFP Complex, see Section 5.4.1.

Processing rooms have strict controls for personnel and materials entry and exit for contamination control. Personnel access between zones 1 and 3 and between zones 3 and 4 is through airlocks. Additionally, gloveboxes use a seal-in/seal-out technique that does not cross tie the ventilation zones. Some equipment changes require a "greenhouse" access, which in effect, is a temporary airlock. Open-faced hood atmospheres are controlled by providing a specified air velocity from the room into the hood.

Radioactive materials are processed within enclosures such as gloveboxes, hoods, and cells that provide the primary confinement barrier to the release of radioactivity. Together with the ventilation system, these enclosures effectively reduce to acceptable levels the emissions of radioactive and other hazardous materials to the surrounding work spaces or to the environment. In addition, the enclosures are designed (e.g., rounded corners, smoothed welds, finished surfaces, and special surface coatings) to prevent material buildup and to enhance decontamination. Conveyor belts, enclosed in glovebox structures, move plutonium between gloveboxes. Encased piping (pipe-in-pipe) is used to transfer plutonium solutions between most gloveboxes and provides containment in case of a primary line leak; however, a few solution transfer lines are not encased and do not have leak detectors. These lines do not represent an unacceptable onsite/offsite risk because they are in the confinement structure in established radiation areas. Plutonium-containing solutions are transferred by vacuum wherever possible to reduce risks associated with transfers made under pressure.

To prevent the spread of contamination, radioactive materials within the enclosures are confined as close to the point of origin as practicable using nontestable HEPA filters installed on the supply and exhaust ducts of gloveboxes and on the exhaust ducts of hoods. Process gloveboxes typically are supplied with zone 3 room air through a HEPA filter. This filter protects the room from contaminated zone 4 glovebox air in case the airflow reverses. Both gloveboxes typically exhaust through a nontestable HEPA filter located in the top or upper portion of the enclosure, installed at the entrance to the exhaust duct. Exhaust air is then routed through two independently testable stages of HEPA filtration and discharged through an exhaust plenum (e.g., the 291-Z-1 stack). In the PRF (236-Z Building), the process cell and associated east access glovebox and west access glovebox are exhausted through four HEPA filter boxes (two boxes in corridor 10 and two in corridor 20), each containing two HEPA filters that are tested as one, and then through a single-stage testable HEPA filter bank before being discharged through the exhaust plenum and the 291-Z-1 stack (see Section 5.4.1.1.2 for additional details on the 236-Z HVAC system).

Some gloveboxes required a dry-air atmosphere to minimize metallic plutonium oxidation and/or plutonium powder moisture absorption during plutonium processing. On the RMA and RMC Lines, dry air from the dry air

generating system (see Section 5.4.3) was supplied to the conveyor gloveboxes (e.g., HC-1 and HC-2) (air is currently still supplied by the dry air system, however the desiccant equipment is not active). The conveyors serve as plenums that deliver air to the adjoining process gloveboxes. Air from the conveyors is drawn through each process glovebox to an exhaust duct opposite the conveyor junction. The air typically is exhausted through HEPA filters located at the exhaust duct entrance, routed to further HEPA filtration stages, and discharged through the exhaust plenum and the 291-Z-1 stack. Air from the dry air supply system (and, in some cases, exhaust) are regulated by a self-governing, diaphragm-operated supply valve. Exhausts are sized to accommodate the entire amount of air that the pressurized supply could deliver in case the supply valve fails in the fully open position. Separate diaphragm-operated valves regulate emergency exhaust on selected RMA and RMC Line gloveboxes to provide for added exhaust flow requirements in the event of a confinement breach (e.g., a glove or seal failure).

5.2.1 The 234-5Z Building

5.2.1.1 234-5Z Structural Specifications. The actual design of the 234-5Z Building was developed from the criteria that were in effect from 1943 to 1949. During this period, the Hanford Site above-ground structures, including the 234-5Z Building, were designed for static vertical live and dead loads. Seismic criteria were not added to the UBC until 1949 and were not included in the 234-5Z Building design criteria because the location of the Hanford Site was then regarded as a low-intensity, minimum-occurrence earthquake zone. Resistance to lateral wind forces, based on area wind data available at that time, was required.

The 234-5Z Building is approximately 500 ft long and 180 ft wide. The floor levels are the basement, first floor, duct level, and second floor. The frame is structural steel with an outer sheathing of aluminum panels over rock wool insulation and 16-gauge sheet metal. There are also 8 in. thick internal reinforced concrete walls, principally running in the east-west direction, and two box-type reinforced concrete stairwells. The stairwells extend to the roof; the reinforced concrete walls stop at the second floor.

The seismic evaluations of the 234-5Z Building have identified adequately those areas that are connected structurally and evaluated the effects of seismic interaction between adjacent structures. The conclusions are that the seismic interactions do not result in significant structural loads and do not affect the conclusions of the analyses of the individual structures.

5.2.1.1.1 Seismic Analysis. Historical seismic analyses indicated that 0.25-g DBE motions would produce nonlinear responses and possible structural collapse of the 234-5Z Building. Later, it was recognized that the building had considerably more capacity to resist DBE loads than previously believed. Therefore, comprehensive linear and nonlinear seismic analyses were performed. The objectives of these analyses were to consider all the building elements that realistically contribute to lateral (seismic) resistance and to determine whether the building could resist the DBE without collapse (URS 1987).

The expansion joint at column line 12 (identified in Figure 5-6, sheet 2) divides the 234-5Z Building into two sections similar in structural layout.

Both sections have concrete in-fill walls that, along with the second-floor slabs, represent the principal east-west lateral load-resisting system. Both sections depend on the frame action of the columns and steel beams as the principal north-south lateral load-resisting system. Because the two sections are similar, only the west section was analyzed in detail. The west section of the building is considered to be the more critical of the two because the east section contains lighter equipment, which decreases the mass of the structure, and the east section frames are wider than their counterparts in the west section. The wider frames in the east section will further reduce the north-south seismic stresses (URS 1987).

The seismic evaluation of the 234-5Z Building required a rigorous dynamic analysis using a detailed three-dimensional, nonlinear model. Element properties for the model were based on a detailed review and onsite measurements inside the building, as well as mockup cyclic testing of beam-column connections to determine moment rotation relationships. Equivalent static analyses were conducted to understand details of the structure's lateral-force-resisting system. Seismic demand on the structure was calculated using direct-integration time-history dynamic analyses for the three components of ground motion, including consideration of P-Delta (large displacement) effects (URS 1987).

The results show that the seismic response of the building is mainly linear elastic. Only four beam-to-column connections yield, and they remain comfortably below ultimate rotational capacities. The east-west displacements are small, 0.33 in. maximum at the roof. The maximum north-south displacement is over 7 in. at the roof. The north-south displacement at the second floor level is 3 in., maximum (URS 1987). The main conclusions of the 234-5Z Building seismic analyses were as follows.

- The building, as is, could resist DBE motions without collapse.
- Separation and some seismic pounding are expected between the second-floor slab and the stairwells. Shear cracks could develop in the stairwell walls. The integrity of the building and the use of the stairwells will not be threatened.
- North-south concrete walls along columns 4 and 8 would need to be isolated from the lateral load path so that the columns do not attract seismic shear forces that may exceed their capacity.

A further assumption is made that the building separates along column line 12 (the building joint) because of presumed differential motion between the east half and west half. In addition, the side panels are assumed to tear, buckle, or pull out of the girders at the attachments. This damage is slight on walls perpendicular to the earthquake direction and on walls nearer to the ground. The damage is more pronounced in walls parallel to the earthquake and at upper levels. A test was performed on panels in which a bounding condition of the seismic loads was applied (Giller 1989b). The panels suffered only minor damage around some of the fasteners; therefore, it is assumed in this analysis that the panels remain intact.

Seismic analyses and evaluations of all the gloveboxes (RMC and others), filterboxes, E-4 exhaust ducts, and seismic interactions were performed and

structural upgrades were identified (Ocoma 1988a, 1988b, 1990a, 1990b). The seismic qualification status and criticality prevention specifications of these gloveboxes and hoods are given in Table 5-5. During the analyses, the plutonium powder-containing gloveboxes and discrete segments of ventilation ducting that were not seismically qualified were assumed to fail and disperse plutonium within the facility. The building was also assumed to separate along column line 12 (the building joint), so it was expected that dispersible plutonium would exit the building through this separation and result in offsite (respirable) doses. Two cases were calculated for these seismic analyses.

- The ventilation systems are assumed to be either failed or shut down.
- Ventilation exhaust fan(s) continue to run as a result of continued supply of normal power following the earthquake or backup power from diesel generators.

In either case, it was found that the radiological consequences associated with these releases during the current transition phase of the PFP still met the risk acceptance guidelines for all except the "no ventilation" onsite dose case when the Laboratory Prototype Calciner releases are included (see Chapter 9.0, Section 9.2.4). However, it is noted that the laboratory calciner is not authorized for operation. The following list of seismic upgrades were implemented to prevent an increase in potential offsite doses.

- Seismic fan shutdown system was installed to shut down power to the supply fans.
- The FB-9A, 9B, 9A/B, and FB-8 filters have been removed to reduce plutonium inventory in the HVAC system.
- The FB-9A and FB-9B by-pass line has been removed to reduce plutonium inventory in the HVAC system.
- Filterboxes FB-14, -20, -21, and -22 were seismically upgraded.
- Glovebox HC-4 was seismically upgraded.
- Booster panel cabinet for gloveboxes HC-13 and HC-15 were seismically upgraded.

In addition to the above seismic upgrades to limit the consequences of a seismic event, see the Laboratory Prototype Calciner addendum to this FSAR for additional features to limit seismic event consequences. Note that the laboratory calciner is not authorized for operation.

5.2.1.1.2 Wind Analysis. The 234-5Z Building structure was evaluated for its response to wind-generated wall pressures and missiles. The design wind condition is specified in DOE-RL (1989), as an extreme wind of 90 mi/h and the wind-driven missile is defined as a 2 in. by 4 in. wood plank weighing 15 lb and traveling at 50 mi/h.

Loads from the wind analyses were compared to those from existing seismic analyses to qualify the structures for extreme wind loads. The extreme wind analyses and strength evaluations are included in *Extreme Wind Analysis PFP Structures 236-Z, 291-Z, and 234-5Z Buildings* (Giller 1989a).

Analyses of the 234-5Z Building show that the main load-bearing structure is not overstressed by the extreme wind or adversely impacted by the missile loads. The external skin panels were tested and found acceptable for missile resistance. Additionally, the roof deck was evaluated and found acceptable (Giller 1989a). The building was deemed to meet DOE-RL (1993) criteria.

5.2.1.1.3 Snowfall Analysis. The 234-5Z Building roof was analyzed for normal roof loading of a minimum 20 lb/ft^2 in accordance with ANSI A58.1 and DOE-RL (1989), guidelines. The effects of live and dead loads and snowfall were found acceptable (Giller 1990). The building was deemed to meet DOE-RL (1993) criteria.

5.2.1.1.4 Ashfall Analysis. The 234-5Z Building roof was analyzed for natural phenomena hazard combined snow and volcanic ashfall loading and was found to meet DOE-RL (1989), design criteria (Giller 1990) (24 lb/ft^2). The building was deemed to meet design criteria in DOE-RL (1993).

5.2.1.2 234-5Z Description.

5.2.1.2.1 Function. The radiological operations performed in the 234-5Z Building are as follows:

- Reactive plutonium-bearing material stabilization (by thermal stabilization) in RMA and RMC Line gloveboxes HC-21C and HA-21I, with gloveboxes HC-21A, HC-18BS, HA-23S, HC-13MD, HC-18M, HC-1, HC-2, HC-3, HC-4, HA-22B and HA-28 supporting this process (see Chapter 6.0, Section 6.4.1, for a description of RMA/RMC Line reactive material stabilization).

- Plutonium-bearing solution stabilization (by the Production Vertical Denitration Calciner [VDC] process) in RMC Line glovebox HC-230C-2 with gloveboxes HC-18BS, HC-18M, HC-1, HC-2 and HC-3 supporting this process (see Chapter 6.0, Section 6.4.1, for a description of solution stabilization).

- Non-organic-residue-containing-plutonium-bearing-solution treatment using the Magnesium Hydroxide Precipitation Process gloveboxes, HC-230C-3 and HC-230C-4, in the RMC Line area. Equipment and operations involved in the process are described in the Magnesium Hydroxide Precipitation Process addendum to this FSAR (Carson 2000). The addendum contains the required page changes. No further discussion is provided in this chapter.

- Packaging plutonium materials in the Bagless Transfer System (BTS) glovebox, HA-53BTS. Equipment used in the process is described in the calculation notes for the BTS (FH 2000). No further discussion is provided in this chapter.

- Load-in/load-out (LI/LO) operations using glovebox HC-227S and hood HC-227T and interim storage.

- Laboratory functions (see Section 5.4.14 for details of the three supporting laboratories). Operations involving the Laboratory Prototype Calciner in the Plutonium Process Support Laboratory (PPSL) are discussed in the Laboratory Prototype Calciner addendum to this FSAR.

- Other production gloveboxes are used for storage and handling operations.

A cutaway of the 234-5Z Building (with aerial view of other PFP buildings) showing locations of the RMA and RMC Lines and LI/LO operation is given in Figure 5-8.

5.2.1.2.2 Components.

Remote Mechanical A and Remote Mechanical C Lines. Operations in the RMA and RMC (or "Button") Lines of the 234-5Z Building consist of reactive plutonium-bearing material (thermal) stabilization, plutonium-bearing solution stabilization, LI/LO operations using glovebox HC-227S and hood HC-227T, and interim storage of plutonium materials in active gloveboxes. The reactive material stabilization process uses gloveboxes HC-21C and HA-21I, with gloveboxes HC-21A, HC-18BS, HA-23S, HC-18M, HC-13MD, HC-1, HC-2, HC-3, HC-4, HA-22B and HA-28 supporting the process. Plutonium-bearing solution stabilization (by the Production VDC process) uses RMC Line glovebox HC-230C-2 with gloveboxes HC-18BS, HC-18M, HC-1, HC-2 and HC-3 supporting this process. Chapter 6.0, Section 6.4.1, provides descriptions of RMA/RMC Line reactive material stabilization and RMC Line solution stabilization processes. In addition to solution stabilization operations in the RMC Line, solutions are also stabilized during operations performed using the Laboratory Prototype Calciner in the Plutonium Process Support Laboratory (PPSL). The equipment and process descriptions for the laboratory calciner are provided in the Laboratory Prototype Calciner addendum to this FSAR. See Figure 5-9 for the general location of the RMA and RMC Line gloveboxes and control areas in the 234-5Z Building although some of the details shown for the RMA/RMC Lines are not current. Locations of the gloveboxes and control station that are used in the reactive material stabilization (thermal stabilization) and solution stabilization (Production VDC) processes are shown in Figure 5-10.

The RMA and RMC Lines are used to reduce the inventory of unstable plutonium-bearing materials and solutions that do not meet criteria for secure, long-term storage. These materials and solutions are currently being stored in various gloveboxes and vaults at PFP. Following stabilization in gloveboxes in the RMA and RMC Lines, the stabilized materials in the form of PuO_2 are packaged for long-term storage in one of the vaults at the PFP.

The RMA Button Line portion of the RMA Line was used to produce plutonium oxide powders and buttons but is not currently authorized for production operations. The line is located to the north of the RMC Line and occupies rooms 235A-1, -2, and -3, and 232-A with the now inactive control room in room 233 (see Figure 5-9).

The RMC Line (or C Button Line) occupies rooms 227, 228A, 228B, 228C, 230A, 230B, 232, and 166 with the now inactive control room in room 229 (see Figure 5-9). Plutonium conversion operations, i.e., the conversion of plutonium oxide to plutonium metal buttons, were formerly conducted using the RMC Line but these operations are not currently authorized (see Chapter 6.0, Section 6.4.3).

Reactive Plutonium-bearing Material Stabilization Summary. There are five categories of reactive plutonium-bearing material containing less than 10 g of organic per charge that are thermally stabilized in the muffle furnaces in Glovebox HC-21C. The furnaces in Glovebox HC-21C are used to stabilize PRF sludges from the last PRF campaign, mixed uranium and plutonium oxides (MOX), floor sweepings, plutonium oxalates, and plutonium oxide to meet long term storage requirements. The furnaces in Glovebox HA-21I are used to thermally stabilize all of the categories of reactive plutonium-bearing material that are stabilized in Glovebox HC-21C except PRF sludges. Plutonium oxides consist of both "clean" and non-product quality plutonium oxides. "Clean" plutonium oxide is defined as materials containing no organic contaminants, plastic, debris or pyrophoric material whereas non-product quality plutonium oxides may contain some of these contaminants.

Processing operations are initiated with the selection of containers from storage. Only containers meeting the type A or B definitions shown in Figure 5-69 may be selected for processing to minimize the amount of hydrogen potentially available for reaction when opening the container. The containers of plutonium-bearing materials are sealed-in using either glovebox HC-21A, HC-13MD or conveyor glovebox HA-28, removed from the package, weighed, placed into a container called a boat which is then covered and transferred via the conveyer system to glovebox HC-21C or HA-21I. The boat cover is removed and the boat is placed into a muffle furnace and the appropriate temperature controller program is started. The controller (or control program) is pre-programmed to ramp and hold the furnace temperature at rates and temperature soaks specific to the material being processed. The material is cooled, ground, sampled, and analyzed to verify that the material meets vault storage criteria. A loss-on-ignition (LOI) analysis is used to verify volatiles have been removed. The processed material is then packaged for long term storage (see Chapter 6.0, Section 6.4.1, for a complete description of the reactive material stabilization process).

Plutonium-bearing Solution Stabilization Summary for the Production VDC Process. The PFP currently contains significant quantities of plutonium-bearing solutions that are in a form considered unsuitable for long-term storage. These solutions primarily consist of the following:

- Plutonium nitrate solutions
- Concentrated filtrate solutions
- Flush solutions.

As part of the PFP cleanout operations, these solutions are stabilized by conversion to plutonium oxide which is suitable for long term storage. The Production VDC process (not authorized for operation) is used to stabilize the solutions by heating the material to a temperature of 1000 °C. Only the plutonium nitrate solutions are suitable for direct stabilization using the Production VDC process. The other two solutions require pretreatment prior to

processing in the VDC. Only processing of the plutonium nitrate solutions in the VDC are covered in this revision of the PFP FSAR. The pretreatment and processing of the other two solutions will be added in a future revision of the FSAR.

Processing using the Production VDC begins by loading in the plutonium nitrate solutions using the LI/LO gloveboxes, HC-227S/HC-227T. The solutions are sampled and blended, as needed, and pumped to the VDC glovebox, HC-230C-2, where they are processed through the VDC. The finished product is transferred to glovebox HC-18M where a sample is removed. The sample is transferred to the PFP Analytical Laboratory where the LOI is determined. If the LOI results are acceptable, the finished product in glovebox HC-18M is appropriately packaged and transferred to the storage vaults. Items not passing the LOI are reprocessed through the muffle furnaces in Glovebox HC-21C or HA-21I as described for reactive material stabilization.

See Chapter 6.0, Section 6.4.1, for details of the solution stabilization operations using the Production VDC process and subsequent paragraphs of this section for descriptions of the components used in the solution stabilization operations.

In addition to solution stabilization using the Production VDC, solutions are also stabilized during operation of the Laboratory Prototype Calciner (not authorized for operation) in the PPSL. The laboratory calciner operations are discussed in the Laboratory Prototype Calciner addendum to this FSAR.

Reactive Material Stabilization Process Control Station (Room 230A). Room 230A (Figure 5-9) contains the HC-21C glovebox, a control console/annunciator panel for the HC-21C glovebox, a Computer Display Screen for the HA-21I gloveboxe (see Figure 5-10 for console locations), and a CO_2 cabinet. Control of the current RMA and RMC Line thermal stabilization process is maintained in this room. At least one operator is stationed here when the process line is in operation. Cameras provide remote viewing of the HA-21I glovebox. The 5-in. mercury vacuum system is operated from the control consoles and the 26-in. mercury process vacuum system is controlled from the MICON™ control station (see Section 5.4.5 for details of the vacuum systems).

- The HC-21C Control Panel. The furnace temperatures in glovebox HC-21C are controlled by digital temperature controllers with setpoint programming. Each furnace in HC-21C has a separate control system. The controllers are preprogrammed and the program is protected from unauthorized changes. The operator selects the program desired and activates startup of HC-21C from the control panel. The controller sends output to a silicon controlled rectifier (SCR), which regulates the power to the furnace. A temperature limit switch provides an independent control for furnace overheat. Lights on the control console indicate when power is supplied to the furnaces. The controllers are equipped with a temperature deviation alarm that removes power from the furnace when the furnace setpoint deviation reaches the alarm setpoint. A temperature monitor compares the input from three thermocouples set to measure glovebox temperature and removes power when the temperature exceeds the setpoint. The console also has a manual switch to remove power from the furnace elements.

- The HA-21I Control Computer. The furnace temperatures in glovebox HA-21I is controlled by a programmable logic controller (PLC). The setpoints and alarms are programmed on the PLC. Each furnace in HA-21I is controlled by the PLC. A personal computer (PC) interfaces with the PLC. The PLC is preprogrammed and the program is protected from unauthorized changes. The operator selects the desired program on the PC and activates start up. The PLC controller sends output to an SCR, which regulates the power to the furnace. A separate program on the PLC provides a temperature limit switch as an independent control for furnace overheat. Displays on the PC indicate when power is supplied to the furnaces. The PLC controllers are equipped with a temperature deviation alarm that removes power from the furnace when the furnace to setpoint deviation reaches the alarm setpoint. Glovebox temperatures are also monitored by the PLC. The PLC compares the input from three thermocouples and removes power from the furnaces when glovebox temperature exceeds the setpoint. The PC contains an icon for emergency shutdown of the furnaces in glovebox HA-21I. The 5-in. mercury vacuum system is operated by this control console.

Plutonium-bearing Solution Stabilization Process Control Station for the Production VDC Process. A Modular Automation System (MAS) located on the mezzanine in room 235B controls the Production VDC and instruments in the VDC glovebox, HC-230C-2. The controls and alarms for the MAS associated with glovebox HC-230C-2 are available on an operator display screen located near the local control panel at the control station in room 230C. The control station allows access to the MAS to control the operations in glovebox HC-230C-2. Due to the potential for high radiation exposure, the control station is separated from the glovebox by sufficient space or shielding to protect the operator from excessive exposures.

The Production VDC is automatically controlled from the programmable logic controller located in room 235B (refer to Figure 5-10). The local control panel in room 230C houses the furnace power supply computer console and emergency shutdown features. This panel is also used as a termination cabinet for control and power wiring between the program logic controller and the relay cabinet (MAS) located on the mezzanine in room 235B. The relay cabinet located in room 235B houses the bulk of the control components used to operate the calciner glovebox.

Details of the instrumentation and control for the production calciner process are provided in the following sections of the FSAR:

Chapter 5.0, Section 5.2.1.2.3, "Design Bases and Safety Assurance"
Chapter 6.0, Section 6.4.1.4, "Chemical Process Systems"
Chapter 6.0, Section 6.4.1.5, "Instrumentation and Control Systems"
Chapter 6.0, Section 6.4.1.9, "Identification of Items for Safety Analysis."

In addition to solution stabilization using the Production VDC in the RMC Line, the Laboratory Prototype Calciner in the PPSL also stabilizes solutions during operation. The laboratory calciner is discussed in the Laboratory Prototype Calciner addendum to this FSAR.

Remote Mechanical A Line Control Room (Room 233) Oxide Line Control Room. The control room (now unused) for the RMA Line is shielded by concrete, steel water walls, and water-filled viewing windows. The large, transparent panels provide good visibility from the control room of personnel working at the gloveboxes and of the level and color of solutions. It is a long, narrow room with control positions along a bench below the viewing windows. The original control room allowed operators to visually observe activities in the RMA Oxide Line. Spotlights and closed-circuit television were provided to aid in viewing. See Figure 5-9 for the location of the RMA Line control room.

Remote Mechanical C Line Control Room (Room 229) Button Line Control Room. This room (now unused) is a shielded facility from which the operation of most of the liquid handling and mechanical equipment is controlled. A series of control desks face the gloveboxes, and visibility of the various pieces of equipment is made possible by a line of water-filled windows along the south and west walls of room 229 and by the presence of windows on the north side of glovebox HC-1. Operators at control desks opposite the individual gloveboxes could operate the sweep arms, conveyor, hydraulic lifts, and much of the other equipment in the gloveboxes. See Figure 5-9 for the location of the RMC Line control room.

Remote Mechanical A and C Line Glovebox General Features. The RMA and RMC Line gloveboxes are constructed of stainless steel frames and floors and clear, self-extinguishing or nonself-extinguishing polycarbonate safety sheets, or glass and wire-mesh panels on the sides and top. The panels are penetrated by gloveports, bag-in/bag-out ports, sphincter ports, solution transfer lines, and instrument and electrical connectors. Thick polycarbonate panels, water walls, leaded safety glass, and lead-filled gloves provide neutron and gamma-ray shielding.

Remote Mechanical A and C Line Glovebox Equipment for Reactive Plutonium-bearing Material Stabilization (Thermal Stabilization). The following provides a detailed description of the support systems and equipment found in the RMA/RMC Line process gloveboxes used in the thermal stabilization process.

- The 4,000 W muffle furnaces have an operating temperature range of 150 °C to 1093 °C. A door safety switch removes power to the heating elements when the door is opened. Factory drilled holes have been located in the back plate of the furnace for the CO_2 supply line, the exhaust line, and two thermocouples. The holes for the CO_2 line in the furnaces located in gloveboxes HA-21I and HA-20MB are plugged.

- The boats (referred to as "cake pans") have a volume of 2.2 L. They are made of 1/8-in. Hastelloy X™.

- The exhaust line from each furnace in glovebox HC-21C ties into the plant 26-in. mercury vacuum system. The exhaust air first passes through a ceramic filter and then a needle valve that is used to adjust flow rates. An orifice and differential pressure gauge is used to maintain flow within limits. A rotameter is used to establish a differential pressure across an orifice to set-up flow. The rotameter is then bypassed and the offgas flow monitored using differential pressure across an orifice to detect variation in flow

during the processing cycle. Heat resistant tubing is used between the furnace and filter housing.

- The exhaust line from each furnace in glovebox HA-21I ties into a 5-in. mercury vacuum system. Similar to the HC-21C system, the exhaust first flows through a ceramic filter and then through an orifice and DP gauge to maintain flow within limits. The DP gauges are located on a rack located on the mezzanine in room 235. The flow is controlled by a needle valve to maintain an exhaust flow rate of at least 2 to 3 f^3/m.

- A baffle is installed in each of the furnaces to reduce the amount of material being sucked into the offgas line and depositing on the ceramic filter. From there the air passes through two stages of HEPA filtration before entering one of two 2.5 hp blowers located in the duct level (room 264). The blowers can be started remotely at the control station or directly at the pumps.

- A stainless steel housing with ceramic filter media is installed in the exhaust line to filter out suspended particles in the offgas. The filters remove particulates greater than 2 μm. The ceramic filters have a DP gauge to indicate if the filter becomes plugged. The DP is checked before starting the heating cycle. When the filter becomes plugged, it is cleaned and reused. The housing provides capability of cleaning.

- The CO_2 is supplied to glovebox HC-21C by a CO_2 station in room 230A. The station consists of a cabinet that houses two liquid CO_2 cylinders. A manifold automatically switches to another cylinder when one empties. The cylinders are equipped with a sight glass to determine liquid level. The station is equipped with a visual alarm mounted on the outside of the cabinet that alarms when the manifold switches. Each bottle is equipped with a vent that vents roughly 2 lb of CO_2 per day to reduce the bottle pressure.

- An electric Mettler balance in room 228C is used to weigh the product material once it has been canned (in addition to the scales located in gloveboxes HC-18M and HC-21A).

- Two canners are located in room 228C. One canner is used to seal a slip lid into a secondary can. The second canner is set up to seal the PUREX secondary can into a 7-in. can.

Remote Mechanical A Line Thermal Stabilization Process Gloveboxes. The RMA Line gloveboxes used for thermal stabilization processes are as follows: HA-22B, HA-23S, HA-28, and HA-21I. The criticality prevention specification and seismic qualifications of these gloveboxes are given in Table 5-5.

- Glovebox HA-22B. This glovebox is located in room 235-B. It is approximately 3 ft long, 2 ft 6 in. deep and 4 ft 6 in. high. It is used to seal-in containers of plutonium material for transfer by conveyor Glovebox HA-28 to Glovebox HA-23S for storage of the containers and for staging items into and from glovebox HA-21I.

- Glovebox HA-23S. This glovebox is located in room 235-B. It is 12 ft 3 in. long, 3 ft deep, and 8 ft 10 in. high (Figure 5-12). It is used for feed lag storage for the thermal stabilization process.

- Conveyor Glovebox HA-28. This glovebox is located in room 235-B/C, with the very end of the conveyor in room 235-A1. Conveyor Glovebox HA-28 houses a conveyor that is used to move items between gloveboxes HA-19, HA-20MB, HA-21I, HA-22B and HA-23S and for moving items to and from the RMC Line. HA-28 also serves as the ventilation supply plenum for Gloveboxes HA-23S, HA-21I, HA-19, HA-20MB and HA-22B in the RMA Line and Glovebox HC-230C-2 in the RMC Line.

- Glovebox HA-21I. This glovebox is used to thermally stabilize reactive plutonium-bearing material. It is about 13 ft long, with the inside of the glovebox floor being about 43 in. wide (Figure 5-13) with a criticality drain. The glovebox is supported by a stand so that the floor of the glovebox is 36 in. above the room floor. Barriers are installed between the legs of the support frame to prevent a fissile material transport wagon from being placed under the glovebox. Conveyor HA-28 runs along the south end of the glovebox and fits closely to the working floor. There are three muffle furnaces in HA-21I that are operated by a PLC. Offgas is removed via a dedicated 5-in. mercury vacuum system that empties into the E-4 exhaust system.

Remote Mechanical A Line Miscellaneous Gloveboxes. The remainder of the RMA Line gloveboxes (those not used in the thermal stabilization process) are inactive. Gloveboxes which are inactive comply with criteria given in Criticality Prevention Specification, CPS-Z-165-80010 (FH 2000) and PFP Operational Safety Requirements, WHC-SD-CP-OSR-010, which state that introduction of containers of plutonium material is prohibited. No new process equipment will be installed in these gloveboxes, and any changes made to these gloveboxes (following USQs) should be related to cleanup activities of the gloveboxes. Inactive gloveboxes of the RMA Line consist of the following: formerly wet process gloveboxes (HC-6, H-7A, HA-9A, H-14P) and dry process gloveboxes (H-8A, H-9B, H-9C, H-9D, H-9E, HC-10, H-11, H-12S, H-13MD, H-13G, H-13ABC, H-14CC, H-14DC, H-14S, H-15B, H-15, H-16CS, H-16BS, H-16L, and HA-19). See Figure 5-9 for RMA Line glovebox locations. A list of inactive RMA Line gloveboxes and their process functions is given in Table 5-6.

Remote Mechanical C Line Thermal Stabilization Process Gloveboxes. The RMC Line gloveboxes used for thermal stabilization processes are HC-1 (supply plenum only and to pass items between glovebox HC-18BS and glovebox HC-18M), HC-2, HC-3, HC-4, HC-21A, HC-21C, HC-18BS, HC-13MD, and HC-18M. The criticality prevention specifications and seismic qualifications of these gloveboxes are given in Table 5-5.

- Conveyor Gloveboxes HC-1 and HC-2. Gloveboxes HC-1 and HC-2 are conveyor gloveboxes. Glovebox HC-1 connects the middle section of HC-9B (through the cross conveyor) to all the other processing gloveboxes in room 228, except HC-7 and HC-17P. Glovebox HC-2 extends from glovebox HC-18BS to an airlock in room 230-B. Gloveboxes HC-21A and HC-21C are also connected to the HC-2

conveyor. The conveyors are in use to provide ventilation to the existing gloveboxes and to support the reactive material stabilization activity as described in Section 6.4.1.4.2. See Figures 5-9 and 5-10 for the locations of the glovebox conveyors.

The gloveboxes are equipped with 4 1/2 in. wide, electrically powered, slat conveyors that travel between 5/8 in. high guide rails separated by a distance of 7-5/8 in. Powder pans were used to transport PuF_4 powders, scrap materials, and other miscellaneous materials along the conveyors. The HC-1 conveyor glovebox also carried pressure vessels and the round pallets used to transport and store buttons. Electrically driven sweep arms at the various gloveboxes sweep the containers off and onto the conveyor.

The conveyor gloveboxes serve as plenums that deliver air to all the adjoining gloveboxes except the top and bottom sections of HC-9B and HC-17P (Figure 5-14). Air is normally exhausted through high-efficiency particulate air (HEPA) filters located in the gloveboxes and out the E-4 gas system. At least -0.5 in. w.g. pressure is maintained in the gloveboxes by the exhaust system.

HVAC supply air from the dry air system (also known as zone-4 supply air) enters at the top of glovebox HC-2 (conveyor) adjacent to glovebox HC-18BS, through a 4-in. self-governing regulating valve rated at 250 std ft^3/min. Flow is regulated between 25 to 250 std ft^3/min. The sensing pressure is applied directly to the diaphragm chamber to control pressure between -0.5 to -1.2 in. w.g. and is able to operate from full-open to full-closed within 3 s. As pressure increases to greater than -0.5 in. w.g. the valve closes, thus avoiding loss of negative pressure, overpressurization, or discharge of air through an open port (see Section 5.4.1 for more details of the HVAC system; see Section 5.4.3.1.3 for details of the dry air system).

A differential pressure switch connected to an annunciator in the power control room monitors the pressure in the dry-air gloveboxes and alarms if it exceeds -0.3 in. w.g. The operator can shut down the line if necessary.

Two similar valves regulate exhaust on an emergency basis. Each parallel 4-in., 200 std ft^3/min valve connects to a common, locally unfiltered 8 in. diameter duct to exhaust a total of 400 std ft^3/min. The valves are normally closed tight for any upstream pressures less than -0.5 in. w.g. They are set to start opening at -0.45 in. w.g. and to be opened fully before upstream pressure becomes positive. The resulting flow of unfiltered air goes to the 12 in. diameter E-4 header in room 263 above the RMC Line and to four primary filterboxes connected in parallel.

An electrically controlled valve located on the 8 in. diameter emergency exhaust duct is interlocked with the glovebox heat detectors. If a fire with sufficient heat to activate the heat detectors occurs, the emergency duct valve would close to prevent air flow removal of the Halon fire suppression gas. This would also

reduce the heat load on the first-stage filters and reduce the flow of air aiding the fire.

A 12 in. diameter unfiltered duct, equipped with a manual valve, is located on the west end of glovebox HC-2. This valve is used to regulate airflow during glovebox panel changes.

Large windows on the north side of conveyor glovebox HC-1 enable the control room operators to see from the control room into individual gloveboxes. Equipment controls are located on a console in line with each glovebox. In addition, this glovebox is equipped with a criticality drain serving the gloveboxes that it connects. It also has a fire detector.

- Conveyor Glovebox HC-3. Glovebox HC-3 is located in room 230C. The glovebox houses a conveyor that is used to move items between conveyor gloveboxes HC-2 and HC-4 and glovebox HC-230C-2.

- Conveyor Glovebox HC-4. Material is transferred from and to the HA-28 conveyor to and from HC-3. The criticality prevention specification limit and seismic qualification of this glovebox is given in Table 5-5.

- Glovebox HC-13MD. Glovebox HC-13MD is located in Room 228-B and is connected to the HC-1 conveyor glovebox. This glovebox has a radiological containment tent attached when needed to facilitate seal-in and bag-out of plutonium bearing materials.

- Gloveboxes HC-21A and HC-21C. These gloveboxes are stainless steel framed with the following dimensions: 10 ft 8 in. long (not including an airlock on the south end), 3 ft tall, and 3 ft 6 in. deep (Figure 5-15). Gloveboxes HC-21A and HC-21C are in rooms 230B and 230A, respectively. Glovebox HC-21A is used for product handling. Glovebox HC-21C is used for thermal stabilization of reactive plutonium-bearing materials. The inside of the working floor of each glovebox is 42 in. wide, with a sloping face along its entire length on the east side. Each glovebox has a lower section that is isolated from the upper section and will not be used for stabilization activities. Each glovebox is supported by a stand, and the glovebox floor is 54 in. above the room floor. The HC-2 conveyor runs along the north end of each glovebox and fits closely to the respective working floor. A filter assembly leads from the tops of the gloveboxes into the E-4 ventilation exhaust system of the 234-5Z Building.

  For Glovebox HC-21A operation, reactive Pu-bearing materials from Building 2736-Z and Building 234-5Z storage vaults are sealed into the gloveboxes. Batches for stabilization are made up by loading measured quantities into boats which are transferred to HA-21I or HC-21C. In-process materials from any other active glovebox can be transferred into HC-21A via the HC-2 conveyor glovebox. Emptied boats are returned to HC-21A. Glovebox HC-21A may contain electric scales, a storage rack, a mortar and pestle, and a Mettler balance to provide an alternate location for performing the operations

normally done in Glovebox HC-18M. In this case, approximately 10-g samples of powder are taken from product cans and placed into vials for LOI testing. PUREX slip-lid cans of thermally treated material that successfully meets the LOI testing requirements are sealed out of HC-21A in a polyethylene plastic bag, placed into a PUREX secondary can, and hand carried to the canners in room 228C.

Glovebox HC-21C contains a deactivated sweep assembly located next to the HC-2 conveyor system which was formerly used for transferring items from the conveyor across slide plates to the glovebox. Items are now hand transferred from the conveyor glovebox to Glovebox HC-21C. Glovebox HC-21C contains two muffle furnaces equipped with CO_2 purge systems and may contain two stainless steel desiccators. The CO_2 flow rate is indicated on rotameters and controlled by using built-in manual valves. Offgas is removed via the 26-in. mercury vacuum system. Carbon dioxide purge is used during the thermal stabilization of PRF sludge material. A rotameter is adjusted to provide the desired flow rate of CO_2 purge into each furnace. Purge by CO_2 gas is not required for stabilization of "clean" plutonium oxide. Two thermocouples are installed in the furnace to measure furnace temperature.

- Glovebox HC-18BS. This glovebox is 8 ft 1.8 in. long, 6 ft 10 in. deep, and 2 ft 6.1 in. high. It is used as product lag storage. A serpentine conveyor belt provides lag storage and carries product from HC-2 to the glovebox interior and also to the exit point for transfer from HC-18BS to HC-18M.

- Glovebox HC-18M. This glovebox is used for product sieving, grinding, sampling, weighing and load-out. It contains scales, mortar & pestle, sieve shaker, tools, and equipment for performing these operations.

Remote Mechanical C Line Glovebox for Solution Stabilization Using the Production VDC. RMC Line glovebox HC-230C-2 is used for solution stabilization operations using the Production VDC process. Figure 5-65 is an isometric view of glovebox HC-230C-2. The description of the Production VDC process in the glovebox is provided in Chapter 6.0, Section 6.4.1. In addition to solution stabilization using the Production VDC, solutions are also stabilized during operation of the Laboratory Prototype Calciner. The process and equipment for the laboratory calciner are discussed in the Laboratory Prototype Calciner addendum to this FSAR.

As shown in Table 5-5, the glovebox structure is seismically qualified for the design basis earthquake (DBE) of 0.2 g horizontal ground acceleration. However, the viewing windows have not been specifically designed to withstand the earthquake. The glovebox criticality prevention specification limits are also shown in Table 5-5 and are based on the Criticality Prevention Specification (CPS) (CPS 1997). The principal criticality limits are a plutonium nitrate feed concentration <450 g-Pu/l, and a maximum Pu product density of 5.5 g-Pu/ml.

Supporting the solution stabilization operations using the Production VDC are conveyor gloveboxes HC-3 and HC-2 and gloveboxes HC-21A, HC-18BS, HC-1 and

HC-18M which provide for material transfer, product sampling and packaging and product testing. These supporting gloveboxes are described in this section under the heading "Remote Mechanical C Line Thermal Stabilization Process Gloveboxes."

- Glovebox HC-230C-2. This glovebox is of lead-lined, stainless steel construction with either wire-reinforced glass or Lexan viewing windows and glove ports to permit access to internal components. The Lexan windows are used because the material does not warp under heat stress and requires an external heat source to initiate and sustain a fire (self extinguishing). The glovebox is provided with a criticality drain to prevent spilled solutions from reaching a depth that could result in a criticality.

  The glovebox provides confinement for the Production VDC process equipment which consists of various pumps, tanks, the calciner, an offgas scrubber and related piping, valves and instrumentation. Figure 5-66 shows the flow diagram for the Production VDC process system and Figure 5-67 presents the process flow sheet. The major components for the Production VDC process are described in this section of the FSAR under the heading "Remote Mechanical C Line Solution Stabilization Glovebox Equipment."

  Support services for the glovebox required for Production VDC process operations include ventilation supply and exhaust, 26-in. Hg process vacuum, bottled compressed dry air, plant process air, fire suppression, electrical power, Pu nitrate solution transfer line, caustic and acid supplies, and chilled water.

  Ventilation supply and exhaust systems are used to maintain negative pressure within the glovebox relative to room 230C. The ventilation systems also provide for removal of excess heat from the glovebox resulting from production calciner operation to prevent excessive internal glovebox temperatures.

  Ventilation supply for the glovebox is provided through the connection to the HC-3 conveyor glovebox. The transition section connecting the HC-230C-2 glovebox to the HC-3 glovebox is designed so that seismic forces will not be transmitted between the two gloveboxes. The transition section and glovebox HC-3 are not seismically qualified.

  Ventilation exhaust for the glovebox is through a testable HEPA filter at the E-4 exhaust system connection to the glovebox. The connection to the E-4 system contains a bellows, downstream of the filter, which is designed to fail in a seismic event such that seismic forces are not transmitted between the E-4 system and the glovebox. In addition, the HEPA filter media has not been specifically designed to withstand seismic forces.

  Offgases generated in the calciner during Production VDC process operations are removed by the 26-in. Hg process vacuum system. These gases are processed through a scrubber system prior to entering the vacuum system for discharge to the atmosphere.

Bottled compressed dry air is supplied from an external 4-bottle rack located in the hall outside room 230C. The dry air is required for atomizing the production calciner feed stream and to provide pulse-air to periodically backflush the calciner offgas filters to prevent plugging.

Plant process air is provided to run some of the process pumps in the glovebox and for operation of various process valves associated with Production VDC operations.

Because of the high temperature operations and potential for fire, the glovebox is provided with a fire detection system and a dry chemical fire suppression system. To minimize fire potential, combustible materials in the glovebox are kept to a minimum and gloves are pulled out of the glovebox when not in use.

Electrical power requirements are supplied from an electrical box on the end of the glovebox to components within the glovebox. Power is from a 480V panel in room 235B. The bulk of the power is required to operate the high temperature furnaces providing heat for the production calciner.

A solution transfer line connects glovebox HC-230C-2 in room 230C to glovebox HC-227S in room 227. The line enables transfers of Pu nitrate solutions to glovebox HC-230C-2 for processing. It also enables transfer of solutions from glovebox HC-230C-2 to glovebox HC-227S. The transfer line consists of an outer stainless steel encasement enclosing three stainless steel tubes. One tube is for transfer into glovebox HC-230C-2 and the other is for transfers out of the glovebox. The third tube is a spare. The outer encasement includes a leak detection system which is resistant to acids, bases, and solvents. The transfer line is not designed for the DBE but does meet *Uniform Building Code* (UBC) seismic requirements.

Nitric acid flush solution is provided by a connection between the glovebox and an external tank in room 230C. The acid is used to flush the feed pump and line and the production calciner.

A caustic solution (NaOH) is used in the scrubber in the offgas scrubber system. The NaOH is pumped from 55-gal drums from the solution drum station in room 230C.

Chilled water supply and return lines are provided for operation of the scrubber in the glovebox. The chiller unit is in room 263 external to glovebox HC-230C-2.

Remote Mechanical C Line Glovebox Equipment for Solution Stabilization using the Production VDC. The following provides a description of the equipment provided in glovebox HC-230C-2 which is used for solution stabilization operations using the Production VDC process. Equipment used in solution stabilization operations using the Laboratory Prototype Calciner is described in the Laboratory Prototype Calciner addendum to this FSAR.

- Calciner. The Production VDC is an annular-shaped chemical reactor with a 4-in. 310S stainless steel pipe on the inside and a 6-in. 310S stainless steel pipe on the outside. The 4-in. section is dome shaped and welded to the base plate and the outer 6-in. pipe is bolted to the base plate. The outer pipe is connected by a flange at the top to another 6-in. pipe above it. This second 6-in. pipe is flanged to plates that hold and cover the ceramic filter elements used to remove solid particles from the offgas. The vertical calciner is approximately 40 in. high. Figure 5-19 is a schematic of the Laboratory Prototype Calciner used in laboratory testing in the PPSL. The Production VDC for solution stabilization operations is similar in design and construction. The production calciner supports are seismically qualified for the UBC earthquake but the calciner has not been specifically designed to withstand seismic forces.

  The Production VDC operates by injecting liquid feed solution upward through the base into a bed of hot (1000 °C) oxide powder. The oxide powder is kept in motion through the action of an agitator driven from above. As the feed solution contacts the hot oxide, it flashes off the liquid as steam. The solid residue left behind quickly oxidizes as it works its way upward through the material bed. When the level builds up above a set amount, the top surface overflows into a collection vessel located below the calciner. The vapors and decomposition gases pass upward through a set of three one-micron ceramic offgas particle filters within the calciner vessel prior to treatment in the offgas scrubber.

  The production calciner is heated through a dual furnace system. A small cartridge heater operating at about 1400 °C heats the surface of the overflow dome to 1000 °C. A high power vertical tube furnace surrounds the lower section of the calciner. This "jacket heater" operates at up to 1650 °C providing radiant heat to the calciner vessel adjacent to the bed of oxide material.

- Process Tanks. The various process tanks consist of the feed receipt tank (FRT), feed pump tank (FPT), flush tank (FT), chemical addition tank, phase separator tank (PST), vacuum trap (VT), vent catch tank (VCT), and spent scrubber solution receiver tanks (SSSRT). The process tank functions, level monitoring instrumentation, materials of construction and sizes are described in the following subparagraphs. The supports for the various process tanks have been designed to meet UBC seismic requirements but the actual tanks have not been specifically designed to withstand seismic forces.

  - Feed Receipt Tank. The FRT basically provides surge capacity for Pu nitrate solutions transferred between the HC-227S LI/LO glovebox and the Production VDC feed pump tank in glovebox HC-230C-2. The tank is of glass construction with stainless steel end flanges. The tank is approximately 6 in. in diameter and 24 in. long with a nominal operating volume of 10 L. Tank level is monitored using a conductivity probe.

- Feed Pump Tank. The FPT provides storage capacity of Pu nitrate solutions for transfer by the feed pump to the production calciner. The tank is of glass construction with stainless steel end flanges. It measures approximately 6 in. in diameter by 24 in. long with a nominal operating volume of 10 L. Tank level is monitored by weight factor instrumentation.

- Flush Tank. The FT receives nitric acid from the external chemical addition tank in room 230C to provide flush solution for the feed pump, feed line and the production calciner. The tank is of glass construction with stainless steel end flanges. It measures approximately 6 in. in diameter by 12 in. long with a nominal operating volume of 4 L. Tank level is not monitored except by visual observation.

- Chemical Addition Tank. The chemical addition tank is located outside glovebox HC-230C-2 in room 230C. The tank contains the nitric acid solution for makeup to the flush tank. It is of stainless steel construction and measures approximately 8 in. in diameter by 16 in. long with a nominal operating volume of 10 L.

- Phase Separator Tank. The PST accumulates the overflow solution from the scrubber for periodic transfer to the SSSRTs. The PST also provides a second removal stage to separate the gases from the liquids. The gases flow to the VT and are discharged to the plant 26-in. Hg process vacuum system. The liquids are either returned to the scrubber or transferred to the SSSRTs.

  The phase separator tank is a 6 in. by 36 in. glass tank with stainless steel end flanges. The tank contains stainless steel demister material 6 to 7 in. from the top. Tank level is monitored by conductivity probes inserted through the top of the tank to give both high- and low-level indication.

- Vacuum Trap. The VT provides the vacuum interconnection between the Production VDC process equipment and the plant 26-in. Hg process vacuum system. Offgases from the calciner flow to the vacuum trap after passing through the scrubber and are released to the atmosphere via the plant vacuum system. The VT allows for vapor and liquid to be captured so as not to enter the vacuum system where they could present a criticality hazard. The liquids are then drained to the VCT.

  The VT is of glass construction with stainless steel end flanges. It measures approximately 6 in. in diameter and 18 in. long with a nominal operating volume of 7 L. Tank level is monitored by conductivity probes.

- Vent Catch Tank. The VCT provides for collection of vapors and liquids which may overflow from the FRT, FPT and FT. It also receives liquids drained from the VT.

The VCT is of glass construction with stainless steel end flanges. It measures approximately 6 in. in diameter and 12 in. long with a nominal operating volume of 4 L. Tank level is monitored by visual inspection.

- Spent Scrub Solution Receiver Tanks. The two SSSRTs receive spent scrubber solution from the PST. These solutions are then gravity drained to waste tank TK-D8 in Building 241-Z for eventual transfer to the tank farms. Each SSSRT consists of two parallel tanks. Each tank is of glass construction with stainless steel end flanges. They measure 6 in. in diameter and 48 in. long with a nominal operating volume of 20 L (40 L per bank). Tank level is monitored by weight factor instrumentation.

- Scrubber. The offgas scrubber processes the production calciner offgases by bubbling the heated gases through a chilled caustic solution. It cools and condenses out excess water vapor, while at the same time removing NO_x and corrosives from the offgases. A cooling loop is suspended down through the center of the scrubber. The cooling loop is positioned to allow circulation within the scrubber on the outside and inside of the cooling loop. A 1-in. pipe extends from the top of the scrubber to the base of the cylinder for offgas flow into the scrubber through a box constructed of stainless steel sintered plate.

  The scrubber is made of 6-in. tempered glass pipe with stainless steel end caps. It stands about 48 in. tall and contains about 15 L of NaOH solution. The gases pass downward under vacuum through a stainless steel inlet tube and dispersing filter. Small bubbles provide pumping action to circulate the scrub solution around the cooling coils and suspends precipitated solids. Condensate, caustic make-up solution and suspended solids overflow through an internal stand pipe and are transported under vacuum to the phase separator tank.

  - Chiller. The chiller pumps water through the scrubber cooling coils, providing cooling to maintain the scrub liquid at about 10 °C. The chiller operates from a 480 V power supply to provide 10,650 W of cooling capacity.

- Process Pumps. Two identical metering (positive displacement) pumps are provided, one (P-230-A) for the Pu nitrate feed solution, and one (P-230-B) for the scrubber caustic (NaOH) makeup. The pumps are electrically driven and are capable of accurately metering solutions from 0 L to at least 4 L, but no more than 10 L per hour. They are compatible with corrosive and caustic solutions and are capable of limiting output pressure to 50 psi or less.

  Three other pumps support Production VDC process operations, each of which are compressed air operated, double diaphragm pumps. Air is provided by the plant process air system. One of the pumps, P-230-C, provides recirculation of scrubber solution from the phase separator tank to the scrubber or transfers spent scrub solution

from the phase separator tank to the spent scrub solution receiver tanks. Pump P-230-D provides recirculation of spent scrub solution through the receiver tanks. The P-230-E pump is used for transfers of various solutions from the Production VDC process tanks to the HC-227S glovebox. Temporary connections may be made when there is a need for solution transfer.

All pumps are constructed of materials resistant to the corrosive affects of acids, bases, and solvents.

Remote Mechanical C Line Miscellaneous Gloveboxes. The following RMC Line gloveboxes are only used for interim storage and handling of plutonium material: HC-4, HC-7, HC-9B, HC-11, and HC-5. See Figure 5-9 for glovebox locations. Previous production process functions, equipment, and design bases of these RMC Line gloveboxes are given in Table 5-7. Schematics of various RMC Line gloveboxes are provided in Figure 5-16, sheets 1 through 11 (individual gloveboxes are called out in Table 5-7 where appropriate).

Room 227 Load-in/Load-out Operations. Room 227 in the 234-5Z Building houses hood HC-227T and glovebox HC-227S (see Figure 5-9 for layout and Table 5-5 for the criticality prevention specifications and seismic qualifications of the hood and glovebox). The hood and glovebox are used in the LI/LO operations for plutonium-bearing nitrate solutions and for blending processes in the glovebox. The glovebox is also used to transfer Pu nitrate solutions to glovebox HC-230C-2 in room 230C for stabilization operations using the Production VDC. Solutions are loaded into the glovebox using the hood which accommodates either product receiver (PR) cans or 10-L polyethylene bottles transported in their outer containers, though other containers also may be used. The glovebox may also be used to load-out solutions to suitable containers located in the hood or to smaller containers which are removed directly from the glovebox through bag-out ports. Chemical solutions required for LI/LO operations in glovebox HC-227S and hood HC-227T are supplied via piping from room 336.

Glovebox HC-227S is the source of solutions for transfer to the Laboratory Prototype Calciner for stabilization operations. The process description for operation of the laboratory calciner is provided in the Laboratory Prototype Calciner addendum to this FSAR.

Room 227. This room is located on the first floor of the 234-5Z Building. A chemical addition tank, used to receive solutions of concentrated or diluted HNO_3, is on the north wall of room 227 next to glovebox HC-227S. A vent line leads from the tank to the E-4 exhaust system. Solutions in the chemical addition tank can be vacuum transferred directly into batch tanks 1 and 2 in glovebox HC-227S, into all three receiver tanks in the glovebox, to the load-in head situated in hood HC-227T, or into polybottles placed in hood HC-227T.

Hood HC-227T. This hood is 8 ft 6 in. high, 11 ft 6 in. long, and 2 ft 10 in. deep. It is mounted on a frame 6 ft 6 in. tall (Figure 5-17). The hood contains PR can LI/LO heads (with necessary piping to glovebox HC-227S) for vacuum transferring solutions to and from liquid containers resting on a balance, container vent lines and a sampling point for an NO_x gas monitor. Two exhaust vents lead from the glovebox into the E-4 exhaust system of the

234-5Z Building. A row of four windows overlooks the hoist assembly. Another row of sliding panels overlooks the LI/LO heads and coverplates leading to the storage cabinets.

Glovebox HC-227S. This glovebox is 11 ft 8 in. high, 12 ft long, and 2 ft deep (see Figure 5-17). One electrical pump and one air-driven pump circulate solutions through the available piping that interconnects nine tanks. The air-driven pump also transfers Pu nitrate solutions to glovebox HC-230C-2 in room 230C for solution stabilization operations using the Production VDC process. Chapter 6.0, Section 6.4.1, describes the solution stabilization process using the Production VDC.

For solution stabilization operations using the Production VDC, the HC-227S glovebox receives Pu nitrate solutions from PR cans in the HC-227T hood and transfers the solutions to glovebox HC-230C-2 for stabilization operations. Figure 5-68 is a schematic diagram of hood HC-227T and glovebox HC-227S. Solutions are transferred from the PR cans to the glovebox using the load-in head in the hood. The solutions are blended and sampled and, if acceptable, pumped to glovebox HC-230C-2. The equipment used and processes are essentially the same as used for other solution LI/LO operations in glovebox HC-227S prior to installation of the Production VDC process in the facility. However, the VDC process required the installation of a new double encased transfer line to connect the HC-227S glovebox piping to the HC-230C-2 glovebox VDC equipment. A second line, in the same encasement, allows solution transfers from glovebox HC-230C-2 to glovebox HC-227S and a third line in the encasement serves as a spare.

A single pipe connects the glovebox to the 26-in. mercury vacuum system through a vacuum trap. The glovebox is connected to the E-4 exhaust ventilation system of the 234-5Z Building by a single ventilation duct. Process air is supplied by the process air supply system.

Glovebox HC-227S contains nine tanks that are used in the process of transferring solutions from glovebox HC-227S to polyjugs and for blending/sampling (see Chapter 6.0, Section 6.3.1, for details of the solution LI/LO process):

- Batch tanks 1, 2, and 3
- Receiver tanks 1, 2, and 3
- Load-out tank
- Vacuum trap
- Vacuum catch tank.

Each of the batch tanks is a glass cylinder assembly that is approximately 96 in. long, 6 in. in diameter, and 0.5 in. thick. The operating volume of a batch tank is 9.5 gal. Each tank has the following typical functions: solution-in (from the chemical addition tank in room 227), recirculation-in, vacuum-venting (for solution transfer to the vacuum trap tank), a spare, and solution-out. Polyjugs are filled with solutions transferred from batch tank 3 through the load-in head in HC-227T.

Retention tanks 1, 2, and 3 are glass cylinder assemblies approximately 30 in. long, 6 in. in diameter, and 0.5 in. thick. The operating volume of a retention tank is 3 gal. Each retention tank has the following typical

functions: solution-in (from the chemical addition tank in room 227), vacuum venting (for solution transfer to the vacuum-trap tank), air sparge, solution-out, and dip-leg transfer of solution out of the tank.

The load-out tank is a glass cylinder assembly approximately 24 in. long, 6 in. in diameter, and 0.5 in. thick, with an operating volume of 2.5 gal. It has following typical functions: vacuum venting (for solution transfer to the vent trap tank), solution-in (from the chemical addition tank in room 227), a spare, and drain. The load-out tank is used in conjunction with the load-out head in HC-227T.

The vacuum trap is a glass cylinder assembly that is approximately 18 in. long, 6 in. in diameter, and 0.5 in. thick with a 1-gal operating volume. It has the following typical functions: one for the 234-5Z Building 26-in. mercury vacuum supply system, a glovebox vacuum header, a drain, and a conductivity probe that annunciates an alarm upon detection of liquid.

The vacuum catch tank is a glass cylinder assembly that is approximately 12 in. long, 6 in. in diameter, and 0.5 in. thick, with an operating volume of 1 gal. It has five nozzles for the following typical functions: accepting drainage from the vacuum trap tank, venting (allowing the tank to vent exhaust into the glovebox, which is then exhausted by pipe into the E-4 exhaust system of the 234-5Z Building), a spare, a vent air sparge, and drain.

Laboratory Prototype Calciner Glovebox 188-1. A prototype vertical calciner and associated ancillary equipment (located in glovebox 188-1 in room 188 of the PPSL) is used to demonstrate direct denitration processing of various plutonium solutions to stable, storable solids. The equipment and processes associated with operation of the Laboratory Prototype Calciner are described in the Laboratory Prototype Calciner addendum to this FSAR. See Section 5.4.14 for a description of room 188. A detailed description of the development of the vertical direct denitration calciner process is provided in *Technical Assessment of the PFP Vertical Direct Denitration Calciner* (Merrick and Rickords 1996).

Recoverable Material Dissolution and Stabilization Gloveboxes. Additional capacity and capabilities for recovering plutonium were provided by four gloveboxes located in the 234-5Z Building (in addition to the PRF process capabilities). Glovebox HC-60, located in room 230, was used for hydrolysis of scrap containing greater than 20% organic. Glovebox HA-40F, located in room 169, is equipped with two furnaces that were used to calcine miscellaneous solids, primarily ash from the incinerator at the Rocky Flats Plant (RFP), Colorado. Glovebox HC-46F, located in room 170, contains dissolver pots and support equipment that were used for dissolving plutonium-bearing solids. See Table 5-8 for details of the equipment used by these gloveboxes in the miscellaneous treatment process.

Process Chemical Storage, Staging, and Preparation Rooms.

Room 165. Room 165 (shown in Figure 5-9) served as a storage location for calcium metal, iodine, and argon used during RMC Line plutonium metal production (the calcium and iodine have been removed). The room is 9 ft 6 in. by 12 ft 3 in. and serves as an entrance to vault room 166. The walls and ceiling are made of 0.75 in. thick plaster on metal lath with lighting

fixtures recessed in the ceiling. The room is equipped with wet-pipe sprinklers and rate-of-rise heat detectors. A ceiling diffuser delivers the S-3 room air, which can exit the room through a 0.38-in. space under the 40-in.-wide door. The room is used as a local supply room. The argon supply has not been capped and is available to provide 15 lb/in^2 (gauge) pressure of argon. The argon piping is equipped with a pressure regulator set at 15 lb/in^2 and a pressure relief valve (PRV) set at 18 lb/in^2. It is assumed that the pressure of flow from the S-3 ventilation air diffusers would push argon out of the room via under the door. See Section 5.4.13 for details of argon handling in this room.

Chemical Make-Up, Rooms 336 and 337. Facilities in rooms 336 and 337 (shown in Figure 5-20) were used to prepare and supply chemicals to the RMC Line. The rooms are currently used to provide acid to HC-227S (in room 227) for solution handling and associated blending operations and base for neutralizing acidic solutions. Tanks are arranged along the south wall of the rooms in a low-walled sump (see Figure 5-20). The tank area is hooded (except for tanks G-2, E-1, and HF1-1) and ventilates through roof exhausters. The room is equipped with safety showers, sump drains, and fire sprinklers. The walls and ceiling are constructed of 0.75 in. thick plaster on metal lath. Motor controls for outside chemical supply pumps are located in room 337. See Section 5.4.13 for details of the chemical contents of the chemical makeup rooms.

The 234-5Z Building and its services/utilities have been reviewed for compliance with current requirements of DOE Order 6430.1A (DOE 1989). The results of this review are presented in Tables 1 through 9 of WHC (1990).

5.2.1.2.3 Design Bases and Safety Assurance. The 234-5Z Building ventilation system is designed to maintain DPs between areas of differing contamination potential (see Section 5.4.1 for more details of the ventilation system).

Seismic evaluation studies have been made of the 234-5Z Building gloveboxes (presented in Table 5-5) and their exhaust ventilation ducts through the first testable stage of HEPA filtration, located on the duct level (Ocoma 1988a).

Each room, glovebox or hood has been analyzed by the methods outlined in Section 6.4.2.9.1 to ensure compliance with the criticality safety criteria presented in Chapter 4.0, Section 4.4.4, and Chapter 8.0, Section 8.3.4. Criticality safety features incorporated into the design of the RMC Line include the following.

- Process equipment is designed to be geometrically favorable even if filled with plutonium at the maximum credible concentration and optimum moderation.
- Process containers such as powder pans and pressure vessels are designed to be subcritical even if overbatched and moderated.
- Physical spacers are provided in storage gloveboxes to minimize interaction between plutonium batches.

- Criticality safety drains are provided to ensure that a critical depth cannot be achieved even if material is spilled and the glovebox is flooded.

- The stainless steel discs, filler blocks or plates have been placed in the sumps to prevent the accumulation of large amounts of solution.

- Raschig rings (neutron absorbers) have been placed in the sump in room 166 for criticality safety in the event of a large spill of solution.

- Vacuum traps are instrumented to detect liquid. Interlocks shut off the vacuum supply to prevent plutonium solutions from being syphoned to geometrically unfavorable equipment.

Shielding is provided at most of the gloveboxes. Lead glass, of appropriate thickness, is provided at those gloveboxes where operators or maintenance personnel are normally located. Additional lead glass is installed on some external gloveboxes as necessary to reduce dose rates to personnel working in those gloveboxes. A 3 in. thick Lexan™ and a 3 in. thick water wall are provided around the middle section of HC-9B to reduce the neutron exposure from the PuF_4 in the fluorinator section. An 8 in. thick water wall is provided around HC-11 where PuF_4 powder pans were stored. Water walls and concrete are provided around the control room to reduce neutron exposure.

All plutonium processing operations were confined within gloveboxes in the entire process until plutonium metal buttons were loaded out in triple-contained cans. Conveyer belts, enclosed in glovebox structures, moved the solid plutonium between gloveboxes. Encased piping (pipe-in-pipe) moved plutonium solutions between most gloveboxes. The lines between HC-4, HC-6, and HC-7 are not encased but have plastic sleeving. The line that transferred pickling solution between HC-17B and HC-7 also is not encased. Processes that used the unencased lines are now inactive.

All gloveboxes are maintained at negative pressure (-0.3 to -1.5 in. w.g. relative to the room) to confine plutonium to the gloveboxes should a small break in the confinement barrier occur. Differential pressure gauges, located in all gloveboxes, measure the negative pressure in the gloveboxes relative to the room. Two stages of filtration are provided before E-4 ventilation exhaust is discharged to the atmosphere via the 200 ft high stack.

Installations throughout the facility provide continuous air monitors (CAM) with alarms, criticality detectors with alarms, smoke and heat detectors, fire alarms, evacuation alarms, and intercommunication systems.

Fire protection is provided by several means. An automatic wet-pipe sprinkler system with standard spray upright and pendent sprinkler heads provides fire suppression equipment throughout most the building. These sprinklers provide coverage in conformance with applicable National Fire Protection Association (NFPA) codes and standards (NFPA 1979a). Details on design standards are found in Chapter 4.0. Compartmentalization and fire barriers are used to restrict the spread of fires. Minimal use of combustible

construction materials is required to limit fuel sources. Detection systems (e.g., heat, smoke), alarm systems, fire-fighting equipment (fire extinguishers), and facility worker fire-safety awareness and fire-prevention training are in place. Noncombustible materials were used whenever possible in the construction of this building. Where combustible materials were essential, every effort was made to minimize the quantity and provide backup protection. The roof is a Factory Mutual Approval Guide (FM) fire class I roof installed over a previously existing metal deck in a 1983 facility upgrade. The exterior walls are constructed of corrugated 16-gauge aluminum, over 1.5 in. of rock wool insulation that is supported by structural steel. The interior walls are metal partitions, plaster on metal lath, gypsum board on metal studding, and, in the case of vaults and process areas, 8 in. thick reinforced, poured concrete. The floors generally are poured concrete finished with tile in some areas. The exception is the floor in the duct level, which is metal deck. All interior finish is of noncombustible material. Stairwells 1 and 2 are isolated with fire barriers. See Section 5.4.11 for more details of fire protection equipment in the 234-5Z Building.

Nuclear criticality safety is ensured by using geometrically favorable equipment design; engineered barriers; and/or administrative controls that limit quantities of plutonium in the gloveboxes, vessels, filter boxes and rooms, and 26-in. mercury vacuum system.

Criticality, fire, NO_x, and evacuation alarms; the CAM alarms; intercommunication systems; and the commercial telephone system alert personnel to emergencies. Safety communications systems are discussed in Section 5.4.10. Fire alarms are discussed in Section 5.4.11.

Design Bases and Safety Assurance for Remote Mechanical A/Remote Mechanical C Line Gloveboxes/Hoods. The original RMA Line installation was completed in the early 1950's, and the RMC Line installation was completed in 1960. The original design specifications for the lines have been destroyed but specifications for other facilities (e.g., PRF and 242-Z) built about the same time are available and assumed to be applicable to the RMA and RMC Lines.

The process equipment for the most part complies with DOE Order 6430.1A (WHC 1990). Specific nonconformance items not identified earlier in this section include the following:

- Lack of redundancy in equipment and instrumentation
- A few solution transfer lines between gloveboxes are not doubly encased and do not have leak detection capability
- Ventilation exhaust from the middle of HC-9B, which potentially contained hydrogen fluoride gas, was not scrubbed to remove the hydrogen fluoride gas content
- Water walls are not equipped with leak detectors and alarms
- Area radiation monitors are not installed.

These factors are also considered in the Chapter 9.0 accident analysis and do not represent undue safety risks.

Most of the process equipment for the RMA and RMC Lines was fabricated onsite in the 200 Area shops. The exceptions were commercially available 300 Series stainless steel and carbon steel pipes, valves, pumps, and glass tanks. Process piping was generally 304-L stainless steel although some 316-L was used. Carbon steel piping was used for dry air supply, cooling water supply, and caustic supply. Valves, pumps, and other similar equipment were specified as equivalent to a specific commercial product but specifying the materials of construction such as 300 Series stainless steel, and carbon steel.

The process equipment, such as tanks, calciners, pressure vessels, etc., was designed and fabricated according to the Hanford Site standards applicable at that time. The 1960 standards applicable to piping used in the installation of the RMC Line are shown in Table 5-9.

These standards called for fabrication and installation in accordance with American Standard Code for Pressure Piping ASA B31.1, Section 6, Chapter 4.0 (1955) with welding according to Division VII. Piping hangers and supports were according to ASA B31.1, Section 6, Chapter 1.0. The ASTM codes used for stainless steel pipe are shown in Table 5-10.

In addition, American Standard Code ASA B 16.5 (1957) was used for flanges and fittings. In 1988 for RMC Line equipment upgrades, the corresponding specification used for seamless and welded austenitic stainless steel was ASTM Code A 312-86b. Also, the equipment in 1988 complied with DOE Order 6430.1, which included all other codes and standards applicable to the design, with DOE Order 5480.1B, and with DOE-RL Order 5700.1A. It is noted that the design and installation specifications applied the best available standards and codes at the time of construction.

The major pieces of equipment in the RMC Line gloveboxes and the material of construction, design pressure, and design temperature are listed in Table 5-7. Glass vessels (5-in.-ID) were tested at 20 lb/in^2 (gauge) and 4 in. diameter glass vessels were tested at 40 lb/in^2 (gauge).

The gloveboxes are fabricated of stainless steel frames with top and side panels of clear polycarbonate. The large windows provide reasonable visibility from the control room to the glovebox internals as well as improved visibility for the floor worker. The window panels are penetrated by glove ports, glovebox load-in/seal-out ports and sphincter seals. Most of the gloveboxes are provided with an equivalent of 1 in. thick lead glass shielding and lead filled gloves for gamma ray shielding. Glovebox HC-9B also has 3 in. thick Lexan™ panel or water wall for neutron shielding of the center section due to the presence of PuF_4 powder pan storage.

Steel, 12 in. thick water walls with viewing windows are provided around the control room to reduce neutron exposure to control room occupants. Control room windows are constructed of double plastic sheeting with water between them. A water wall and 3 in. thick Lexan™ panel are located around the outside of glovebox HC-11C which stored PuF_4 powder cans (a high neutron source).

Air supply to gloveboxes are regulated by self-governing, diaphragm-operated supply valves. Glovebox exhausts are sized to accommodate the entire amount of air supplied in case the supply valve fails in the fully open position. Separate diaphragm-operated valves regulate emergency exhaust on selected RMA and RMC Line gloveboxes to provide for added exhaust flow requirements in the event of a confinement breach (e.g., a glove or seal failure). The conveyors serve as plenums that deliver air to all adjoining gloveboxes except the top and bottom sections of HC-9B and HC-17P.

Air is normally exhausted through nontestable HEPA filters located at the gloveboxes and through the E-4 exhaust system. Glovebox design calls for a general operating differential pressure range of -0.5 in. w.g. to -0.7 in. w.g. This negative pressure is maintained in the gloveboxes by the exhaust system in accordance with the DP zoning of the building. A DP switch connected to an annunciator in the power control room monitors the pressure in the dry-air gloveboxes and alarms if the pressure exceeds -0.3 in. w.g. Two valves regulate exhaust on an emergency basis to a common, locally unfiltered duct. The valves are normally closed for any upstream pressures less than -0.5 in. w.g. Any flow of air under positive pressure opens the valve to redirect the airflow to a 12 in. diameter E-4 header in room 263 above the RMC Line area (and then airflow passes into the E-4 ventilation exhaust system of the 234-5Z Building). A valve located on the 8 in. diameter emergency exhaust duct is interlocked with the glovebox heat detectors. If a fire with sufficient heat to activate the heat detectors occurs, the emergency duct will close to reduce the heat load on the first-stage filters and reduce the flow of air aiding the fire. A 12 in. dia, unfiltered duct equipped with a manual valve is located on the west end of glovebox HC-2. This valve is used to regulate airflow during glovebox panel changes. Each glovebox has a DP gauge to monitor its interior pressure relative to the room. A condensation dew point hygrometer system, with a sample tube in glovebox HC-21C, is located in room 235B (it is currently inactive).

Wet process gloveboxes (those gloveboxes that were designed to handle solutions such as plutonium nitrate) or those containing significant quantities of fissile material that may be flooded in an accident condition, are equipped with criticality drains. A criticality drain is a 3 in. diameter bag port attached to the side of the glovebox at a height such that the port opening is below the maximum allowed glovebox floor liquid accumulation depth. An open ended plastic bag is attached to the port. The open end is closed for radiological confinement purposes by a precision-finished steel roller balanced on a polished steel plate inside a protective cage, or by a weighted knife-edged clamp. The weight of the liquid entering the port bag moves the steel roller off the bag or pulls the bag out from under the knife-edge clamp, thus freeing a path for drainage to the room floor. Accompanying contamination is a less severe hazard than a criticality incident. Gloveboxes HC-1 and HC-5 each have a criticality safety drain provided to ensure that a critical depth cannot be achieved in the event that material is spilled and the gloveboxes are flooded. The sumps and criticality drains for criticality prevention are geometrically favorable. The sumps have liquid level alarms. "Dry" gloveboxes have no active sumps since liquids are not present. "Dry" gloveboxes are connected to glovebox HC-1 with matching floor levels. In the unlikely event that liquid should enter a dry glovebox, it would drain to glovebox HC-1 which has a criticality drain. Accumulation of solids on the

floor of "dry" hoods is administratively limited to less than 240 g/ft^2 of plutonium.

Design Bases and Safety Assurance for Thermal Stabilization Gloveboxes, HA-21I and HC-21C. Each furnace in the thermal stabilization gloveboxes is equipped with a temperature indicating controller (the furnaces in glovebox HA-21I have a temperature controller on the PLC with indication on the PC) with an associated thermocouple to monitor for furnace temperature deviation. Programmed into the controller is a deviation band alarm that is set at ±20 °C. When the furnace temperature deviates from the program setpoint by ≥20 °C, power is removed from the furnace. If the thermocouple or controller fails, or is removed from the system, the furnace power control circuit fails open and power is removed from the furnace.

Each furnace in gloveboxes HC-21C and HA-21I is equipped with a high temperature alarm switch and associated thermocouple to monitor furnace temperature. The alarm switch is part of the PLC programming for glovebox HA-21I. The alarm switch will remove power from the furnace upon exceeding the established setpoint of 1050 °C. The purpose of removing power is to prevent damage to the heating coils in the furnaces. If thermocouple or alarm switch fails, or is removed from the system, the furnace power control circuit fails open and power is removed from the furnace.

A heat detector in glovebox HC-21C is set to activate the Halon Fire Suppression System when the glovebox temperature reaches the setpoint of 93 °C. The glovebox temperature monitor alarms at a temperature of 70 °C. This provides enough cushion to avert a Halon release into the glovebox. The glovebox temperature setpoint in glovebox HC-21C could be exceeded, and the Halon system activated by either a fire of combustible material in the glovebox, or possibly total failure of both furnace temperature control systems and interlocks. A strobe light will actuate and the fire alarm gongs sound once the Halon system setpoint is exceeded. The release of the Halon is delayed for 30 s. A Halon release hold button is available to delay the release of Halon for 30 s, and the button can be repeatedly pushed or held down, as needed, to further delay Halon release. A heat detector in glovebox HA-21I is set to activate the dry chemical fire system when glovebox temperatures reach the setpoint of 93 °C. The glovebox "High Select" temperature monitor alarms at a temperature of 70 °C. This provides enough cushion to avert a dry chemical release into the glovebox. When glovebox temperature reaches 70 °C, an interlock in the glovebox temperature monitor removes the power to the muffle furnaces. The glovebox temperature setpoint in glovebox HA-21I could be exceeded, and the dry chemical system activated by either a fire of combustible material in the glovebox, or possibly total failure of both furnace temperature control systems and interlocks.

Each furnace in glovebox HC-21C has a separate control system. The controllers are preprogrammed and the program is protected from unauthorized changes. Lights on the control consoles indicate when power is supplied to the furnaces. Each furnace in glovebox HA-21I is controlled by the PLC. The PLC is preprogrammed and the program is protected from unauthorized changes. A PC interfaces with the PLC, and serves as the focal point for control of the gloveboxes. Displays on the PC indicate when power is supplied to the furnaces.

The windows of the HA-21I, HC-21C, and HC-21A gloveboxes are made of Lexan or some other equivalent, equally heat-resistant material.

The HA-21I glovebox is provided with a criticality drain to prevent liquid accumulation from reaching a depth that could result in a criticality. The HA-21I glovebox is provided with a 5-in mercury vacuum system.

The 26-in. mercury vacuum system for furnaces in glovebox HC-21C must be operable to remove butene or other gases which can potentially be generated during processing of organic containing material.

A manual switch for the HC-21C glovebox is located on the control console and is used to remove power from the furnace elements. The manual button must be pulled out to power furnace heating elements. Power to the control system is not affected by the emergency shutdown switch, only furnace power. A manual switch is located on the exterior of glovebox HA-21I, which removes power from all furnace elements in this glovebox when the button is depressed. Also an emergency stop button is located in Room 230A to shutdown the HA-21I furnaces. The PC computer station contains an icon for emergency shutdown of the furnaces in glovebox HA-21I.

Material foam over into a furnace can occur but has not been identified as a problem. A scraper and paint brush can be used to sweep up material from the bottom of the furnace once it has cooled. This material would then be mixed with the charge material.

For space and criticality safety considerations, a maximum of one boat may be in each furnace in gloveboxes HC-21C and HA-21I during use. Total quantity of material is restricted by the inventory limits of the glovebox.

Design Bases and Safety Assurance for Solution Stabilization Glovebox HC-230C-2 for the Production VDC. The design bases and safety assurance items for this glovebox and the enclosed Production VDC process equipment primarily involve features to provide radiological, chemical, criticality, and fire safety. In addition, process safety is generally provided by instrumentation, controls, interlocks and alarms which indicate and/or mitigate undesirable process situations.

Some design bases and safety assurance features for solution stabilization components are provided in Section 5.2.1.2.2 of this chapter. More in depth information is provided in Chapter 6.0, Section 6.4.1, Reactive Pu-Bearing Material Stabilization and Pu-Bearing Solution Stabilization.

Design Bases and Safety Assurance for the HC-227S Glovebox and HC-227T Hood. A NO_x gas monitor is provided in room 227. The sampling point for the monitor is located below hood HC-227T.

The liquid level in the chemical addition tank located in room 227 is monitored visually and alarmed by a level detection element that sounds at a panel below the feed valve wall in room 227.

A conductivity element in the top of the vacuum trap of glovebox HC-227S monitors for liquid in the trap. Detection of liquid closes an electric valve to isolate the 26-in. mercury vacuum system from the vacuum trap.

The HC-227S glovebox floor contains a criticality drain with a sump probe alarm set to activate if liquid exceeds a depth of 0.5 in.

Nonsparking bronze tools, ground straps, and the use of noncombustible tools and materials are used during this process to minimize the chances of combustion of any radiolytically produced hydrogen released from the polyethylene containers or LI/LO processes.

Vacuum supplied by the 26-in. mercury vacuum system (see Section 5.4.5) is used to transfer solutions during the LI/LO process. Vacuum is used to avoid the pressurization of transfer lines during piping of solutions.

Design Bases and Safety Assurance for Laboratory Prototype Calciner Glovebox 188-1. The design bases and safety assurance provisions for the Laboratory Prototype Calciner and related equipment and operations are provided in the Laboratory Prototype Calciner addendum to this FSAR.

Design Bases and Safety Assurance for Process Chemical Storage Rooms. The design bases and safety assurances of the process chemical storage rooms is discussed in Section 5.4.13.

5.2.2 The 236-Z Building

5.2.2.1 236-Z Structural Specifications. The 236-Z Building is located south of the southeastern corner of the 234-5Z Building and is connected to it by the 242-Z Building. The building is essentially a four-story structure, 79 ft by 71 ft by about 47.5 ft high, surmounted at the southwest corner by a two-story penthouse, which is 22.5 ft high.

The 236-Z Building was designed in accordance with the 1961 UBC (UBC 1961), which included a seismic criterion (0.10 g) that is significantly lower than the present-day criterion (0.20 g) used for design of high hazard nonreactor facilities at the Hanford Site (DOE-RL 1993). Seismic analysis showed that the 236-Z Building could withstand a 0.25 g ground acceleration, which exceeds the 0.20 g DBE for high-hazard nonreactor nuclear facilities (see Tables 5-2 and 5-4).

With the exception of the roof, the south end of the process cell, and the fourth-floor ceiling, the building is constructed of reinforced concrete. The roof is constructed of an open-web steel joist frame, a steel deck with rigid insulation that consists of light-weight concrete fill, and gravel-covered built-up roofing. A portion of the south wall is also the 1 ft thick wall of the process cell and includes an opening in the reinforced concrete wall. This opening is filled by a pair of large steel double doors that are surrounded by a concrete block wall. A HEPA filter is installed in the west door. The south wall has a bridge-shaped cross section of concrete blocks with welded steel plates added to preclude leakage during a seismic event. An equipment transfer facility, added after initial construction of the 236-Z Building, is located against the large door. This facility consists of a 35 ft by 13 ft airlock (room 72) and two anterooms (rooms 70 and 71) (see Figure 5-6, sheet 1 for location of rooms and doors). The room 72 airlock outer double doors each have an inlet HEPA filter (see Section 5.4.1 for additional details of the 236-Z Building ventilation system). The tanks and

columns used in the solvent extraction process are located in the process cell, a three-story room in the center of the 236-Z Building. The process cell is 52 ft long by 32 ft wide by 26 ft high and has 2 ft thick concrete walls (except on the south side, which is an exterior wall). The equipment in the process cell includes many long, narrow, upright metal tanks or columns that vary in length from 2.5 ft to about 50 ft and are 4 to 6 in. in diameter. Because of their height, the extraction column (CA) and stripping column (CC) extend into the column penthouse.

5.2.2.1.1 Seismic Analysis. Seismic analyses and evaluations were performed for the 236-Z Building to determine whether it can resist the 0.25-g DBE (URS 1988a). Three-dimensional, lumped-mass beam models of the building were developed. Seismic forces and moments for these models were computed using the modal superposition response spectrum method of dynamic seismic analysis. The overall seismic forces and moments were distributed to the individual walls and diaphragms and evaluated against their calculated code-allowable capacities. The evaluation indicated that the 236-Z Building will meet the code requirement to resist the DBE motions postulated for the Hanford Site. Specific conclusions for the key structural members are as follows.

- Roof--The metal roof deck has a maximum demand/capacity ratio of 0.94, indicating that it meets the code requirement.

- Concrete floor slabs--All slabs meet code acceptance criteria.

- North-south walls--All reinforced concrete walls oriented in the north-south direction have demand/capacity ratios of less than 0.62 for shear and overturning moments. All north-south walls meet the code requirement.

- East-west walls--All east-west walls, except one, have acceptable demand/capacity ratios of less than 1.0 for shear and overturning moment. East-west wall 4 has a ratio of 1.23 for overturning; however, this is a minor wall, and the loads from this wall can be carried by the adjacent east-west wall 3, which has more than adequate capacity to carry the additional overturning force.

- Concrete block wall--The concrete block wall (4 in. and 8 in. thick) at the south cell wall does not meet the acceptance criteria because it has a demand/capacity ratio greater than 1.0. This ratio is not based on inspection since inspection results were not available. It is to be emphasized that this is not a load-carrying wall and its performance will not affect the structural behavior of the building. The entire area of the concrete block wall has been covered with welded steel plates that overlap into the poured concrete wall. The plates were installed on the exterior side with anchor bolts and sealed all around to preclude a leak path.

In addition to the conclusions enumerated above for the building, seismic analyses and evaluations of all the PFP gloveboxes (presented in Table 5-5) and filter boxes were performed (Ocoma 1990a), and recommended structural upgrades were identified.

5.2.2.1.2 Wind Analysis. The wind analysis for the 236-Z Building consisted of calculating wind-generated moments, shears, and torsions at specific elevations of the building. The results of the 236-Z Building extreme wind analysis are shown in Giller (1989a). A comparison of the wind and seismic values shows that the wind moments, shears, and torsions are less than the seismic values, which were shown to be within acceptable limits. By association, the wind condition is acceptable for the main structure of the building. The evaluation of the roof deck showed an acceptable safety margin of 1.24. Evaluation of wall axial loads and bending moments shows values within the acceptable limits; therefore, the 236-Z Building meets the code requirements to withstand extreme wind loading. The analysis also evaluated the effects of wind-generated missiles and determined that the building can withstand the impact loads.

5.2.2.1.3 Snowfall Analysis. The 236-Z Building roof was analyzed for normal roof loading of a minimum 20 lb/ft^2 in accordance with ANSI A58.1 and DOE-RL 1989 guidelines. The analysis indicates that the roof can withstand the effects of live and dead loads and of snowfall (Giller 1990).

5.2.2.1.4 Ashfall Analysis. The 236-Z Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.2.2 236-Z Description.

5.2.2.2.1 Function. The 236-Z Building (PRF) houses the majority of the plutonium recovery process equipment used to convert various plutonium-bearing materials and aqueous feeds to a purified plutonium nitrate product suitable for conversion to plutonium metal or PuO_2. The process included the following:

- Recoverable material dissolution and scrap stabilization [miscellaneous treatment (MT)]; hydrolysis, clarification, and calcination
- Plutonium purification; feed preparation, solvent extraction (SX) and stripping, and organic cleanup
- Concentration and clarification of the aqueous product and waste streams.

Most of these process steps were located in the PRF in the 236-Z Building. Some of the miscellaneous processing took place within the 234-5Z Building of the Plutonium Finishing Plant (PFP). A cutaway view of the 236-Z Building is given in Figure 5-21.

The Plutonium Reclamation Facility (PRF) process systems are inactive and are not authorized to operate. Active electrical power to the PRF is limited to the 17 in. mercury vacuum system, criticality alarm system, normal lighting/receptacle panels, elevator, security systems, building support systems (e.g., HVAC), and emergency lighting/receptacle panels. A total restoration of PRF electrical power is not planned. Power to PRF process systems and equipment will remain deactivated except when required for PRF facility clean-out and deactivation.

This section identifies the associated major components that remain in place. Note that reactivation of these process systems, either in part or in total, would require the performance, documentation, review, and approval of new hazard and accident analyses with associated modifications (as required) to this final safety analysis report (FSAR).

5.2.2.2.2 Components. The process cell contains the major processing equipment formerly used for plutonium recovery operations. Building floor plans that indicate the location of the process cell for the 236-Z Building are shown in Figure 5-6 (sheets 1 through 4).

Recoverable Material Dissolution and Stabilization (Miscellaneous Treatment) Process Equipment. A variety of components were used to stabilize (hydrolyze, decarbonize) and dissolve recoverable plutonium from various solid and liquid materials. A cluster of five gloveboxes in room 41 (see Figure 5-6, sheet 4 for the location of the room) contains MT processes. The MT was a multipurpose facility capable of small-scale processes for plutonium recovery from scrap. Primary equipment in room 41 included dissolver pots, hot plates, centrifuges, condensers, and furnaces. Capabilities of MT processes included receiving, inspecting, screening, sorting, and weighing plutonium-bearing materials (glovebox MT-1; see Figure 5-22), dissolving of bulk metallic plutonium in nitric acid using electrolytic dissolvers (glovebox MT-3), residue stabilization and recovery of plutonium oxide powder by distillation of polystyrene cubes and burning of residual carbon (glovebox MT-4), acid dissolution and leaching of plutonium from solids (glovebox MT-5; see Figure 5-23), clarification of plutonium-bearing nitrate solutions from MT-5 for transfer to the PRF canyon and cementing of solid residuals for waste disposal (glovebox MT-6; see Figure 5-24).

Two receiver tanks (TK-25 and TK-26) are located in positions EM and EN (see Figure 5-25). These tanks receive clarified dissolver solution from the MT gloveboxes.

Additional capacity and capabilities were provided by four gloveboxes located in the 234-5Z Building. Glovebox HC-60, located in room 230C, was used for hydrolysis of scrap containing greater than 20% organic. Glovebox HA-40F, located in room 169, is equipped with two furnaces that were used to calcine miscellaneous solids, primarily ash from the incinerator at the Rocky Flats Plant (RFP), Colorado. Glovebox HC-46F, located in room 170, contains dissolver pots and support equipment that were used for dissolving plutonium-bearing solids. Two continuous refluxing dissolver/condensers installed in the 236-Z Building process canyon were used for dissolving crushed sand and S&C from the Remote Mechanical C (RMC) Line in the 234-5Z Building.

Two nearly identical dissolvers, located in the 236-Z process cell, were used to dissolve crushed sand and S&C from the RMC Line. The dissolvers were supported by three systems: acid feed, product treatment, and offgas treatment. Three interconnected gloveboxes in room 43 of the 236-Z building also supported dissolver operations.

Cans of feed material were dropped into the dissolvers from the charging glovebox. The dissolvers contained hot nitric acid provided by the acid feed system. Gases evolved during dissolution passed through a reflux condenser and scrubber before being vented into the 236-Z process cell. The product

solution flowed to a settling tank where large entrained solids were removed. The product then flowed to a centrifuge where remaining solids were removed. The product solution was used as feed to the SX system.

The major components of the S&C dissolver system include the following:

- Two reflux dissolvers, TK-08 and TK-124
- Two condensers, TK-09 and TK-125
- Acid feed system tankage
  - TK-A-101
  - TK-A-112
  - TK-A-102
  - TK-EC-01
  - TK-ED-02
- Product treatment system
  - solids settling tank, TK-53
  - centrifuge "A"
- Offgas treatment system
  - two deentrainers, TK-10A and TK-12A
  - two offgas scrubbers, TK-10 and TK-12
- Sorting glovebox
  - canning machine
- Loading glovebox
  - gauge ring
  - loader
- Dissolver charging glovebox.

Purification. Plutonium purification was accomplished by feed preparation, solvent extraction, and organic cleanup. The positions of the associated major components within the canyon are shown in Figure 5-25. The tank locations, function, working volume, and overflow capacity are described in Table 5-11. The tanks are interconnected with vents and drain lines to maintain mass, volume, and geometric criticality limits, and to provide primary containment. All process tanks associated with plutonium purification have been drained. The process cell and the gloveboxes that provide access for manual operation are the primary confinement barrier. The following sections identify and describe the major components associated with feed preparation, solvent extraction and organic cleanup, chemical makeup, and associated support equipment (i.e., pumps, filters, and centrifuges).

Feed Preparation. In the feed preparation system, chemicals (e.g., an anti-emulsifying agent, ANN, and HNO_3) were added to an aqueous solution to produce a feed solution suitable for plutonium separation by solvent extraction. The feed preparation tanks (15, 16, 17, and 18) are located in the process cell (canyon) and are made of banks of welded stainless steel cylindrical vessels connected together at the top and bottom. This arrangement provides fixed volume, mass, and geometry for criticality safety.

Typical tank configurations are shown in Figure 5-27. The bank is mounted on a supporting dunnage with tapered plugs. The plugs fit into the 2-ft-thick concrete wall of the canyon. The concrete wall serves as support for the vessels and radiation protection for personnel. All piping goes through the plugs to the access glovebox. The gloveboxes contain the piping, valves, pumps, instrumentation, filters, and small vessels that service the equipment in the process cell.

Solvent Extraction and Organic Cleanup. Solvent extraction was used to generate a purified plutonium nitrate solution suitable for feed to the RMC Line. Organic cleanup was used to clean organic solvent for reuse in the solvent extraction process. A schematic diagram of the solvent extraction and organic treatment systems is shown in Figure 5-26. As shown in this figure, a number of abbreviations are used to designate process streams. The first two letters identify the column (e.g., CA, CC, OA) and the last one or two letters identify the type of stream. For example, CAIS designates the CA column intermediate scrub. These codes are as follows:

F	Feed	CA	Plutonium extraction
I	Intermediate	CC	Plutonium stripping
P	Product	CO	Organic recovery
R	Recycle	CU	Uranium scrub
S	Scrub	CX	Degraded organic removal
W	Waste	OA	Acid scrub
X	Extractant		

There are six solvent extraction and organic treatment columns (tanks 32, 33, 34, 48, 69, and 123). These tanks are 4, 5, or 6 in. diameter columns 4 to 51 ft high as shown in Figure 5-28. The columns are made from stainless steel, Pyrex™ glass, and/or Kynar™ pipe. The CA column contains stainless steel perforated plates spaced at 4-in. intervals. The CC column contains stainless steel perforated plates spaced at 2-in. intervals. The remaining columns contain plastic Raschig ring or Intalox™ saddle packing. The SX, CC, and CU columns have air pulsers for improving mixing and movement of the aqueous and organic phases through the column. The pulsing action is imparted by means of a pulse generator that connects to the bottom of the column via a hydraulic pulse leg. The pulse height is dependent on the frequency of the pulse and the air pressure of the supply air. The pulse frequency is varied between 30 and 100 cycles/min at air pressures of 20 to 50 lb/in^2 (gauge) to produce the desired pulse height and maintain efficient aqueous-organic emulsion type operation.

Chemical Makeup and Metering Equipment. The chemical makeup vessels are located in room 40 of the 236-Z Building. The vessels are fabricated from stainless steel, except for tanks A-107 and A-110.

Tank A-103--The vessel has a 280-L capacity, 1,200-lb scale, and agitator. It is used as a pump tank for 1 M NaOH.

Tank A-105--The vessel has a 1,700-L capacity and is used as a head tank for 12.4 M HNO_3. The tank is equipped with a digital readout and is refilled from a 32,000-L storage tank located outside the building.

Tanks TK-A-101 and TK-A-102 (Dissolver Acid Preparation)--These 1,570-L cylindrical tanks, located in chemical preparation room 40, are constructed of 304-L stainless steel. Each is equipped with an agitator and gauge for volume determination.

Tank A-106--The vessel is similar to tank A-105 and is used as a head tank for 1.8 M $Al(NO_3)_3 \cdot 9\ H_2O$.

Tank A-112--The vessel has a 280-L capacity, 1,200-lb scale and agitator. It is used for the makeup of 5,000-ppm Mistron™ - 0.5 M HNO_3. A timed metering pump is used to add about 3 L of solution to each SX feed batch.

Tank A-107--The PVC plastic vessel has a 300-L capacity, volume calibration scale, and an agitator. It is used for the makeup of 0.4 M Na_2CO_3 (CXX) solution.

Tank A-108--The vessel is similar to tank A-103. It is used for the makeup of 1.5 M HNO_3 (CAS).

Tank A-109A--This tank has been removed from the facility.

Tank A-110--The vessel is similar to A-107 and has weight factor instrumentation. It is used for the makeup of 2.0 M HNO_3 - 0.2 M HF (COX) or 3 M HNO_3 - 1 M ANN (flush) solution.

Tank A-114--The vessel is similar to tank A-103. It is used for the makeup of 20% TBP in CCl_4 (CAX).

Tank A-115--The vessel is similar to tank A-114 and is used as a head tank for CCl_4.

Support Equipment.

Pumps--Some of the columns and most of the tanks used pumps. The majority of these pumps are located in either the east or west gloveboxes, depending on the location of their respective columns or tanks. The pumps were required to pump fluid of approximately 1.5 specific gravity at flow rates of ~15 gal/min at a discharge head of 85 ft.

Three types of pumps were used in the solvent extraction system (given below):

- Centrifugal--Corcoran, Deanline, Eastern
- Nutating--Saturn
- Air Operated--Magnum 600.

Motor-operated centrifugal pumps used the solution flow for cooling. The electric motors used on these pumps are Underwriter's Laboratories listed and equipped with thermal overload shutoff devices.

The Saturn pump is a motor-operated, nutating, diaphragm-type pump. This pump can be operated with no solution flow without damaging the pump. There are two of these pumps in the system. Saturn pumps were used only in the organic cleanup function.

The Magnum 600 is an air-operated, diaphragm pump. Normally, the air pressure used was less than 50 lb/in^2 (gauge).

Filters--Two filter systems (the 16.1 and 16.2 filters and the 51 filters) were used in the solvent extraction system. These filters removed large solids (greater than 100 mm) from various solution streams in the system.

Centrifuges--Centrifuges were used for clarifying four different process streams in the PRF. They were as follows:

- S&C product (A)
- Solvent CAW (B-1 and B-2)
- Batch dissolver product
- Product clarification (D).

The B-1, B-2, and C centrifuges are installed in glovebox MT-6. The A centrifuge is installed at location EF on the east wall glovebox of the second floor. The D centrifuge is installed at the WV location of the west wall glovebox on the second floor.

The centrifuge contains an internal bowl, which is rotated at a high speed. The spinning action of the bowl forces solids to the side of the bowl. The solution, now free of solids, overflows from the bowl. Periodically the cover is removed, and the bowl is scraped and cleaned of solids.

Aqueous Solution Concentration.

Product Concentration. The product concentrator was used to concentrate the plutonium product from solvent extraction before use as feed to the RMC Line (Figure 5-29). Before being fed to the product concentrator, the CCP stream was routed to TK-58, a 4-in. pipe partially filled with clean CCl_4, to remove organic material that may have been present in the aqueous product from the CC column.

The product concentrator is a jacketed, falling film type, steam-heated evaporator. It is made of welded titanium and contains titanium Raschig ring packing. The 30-lb/in^2 (gauge) steam, introduced to the 6 in. diameter by 7-1/2 ft outer pipe, was used to heat the inner 4 in. diameter pipe and 1 in. by 1/16 in. packing. Plutonium nitrate flowed down through the heated pipe and over the packing. The concentrate then flowed by gravity into a stainless steel receiver tank. Live steam was introduced at the bottom to strip soluble organic from the solution. The vapor exited the concentrator via a deentrainment section and entered the condenser (TK-44). Two 6 in. long tantalum mist eliminators deentrained mist from the vapor that was condensed by a shell and tube condenser (tank 44). The vapor entered the shell side of the stainless steel horizontal condenser and was cooled and condensed by water flowing through the coiled tubes.

The concentrated product was clarified using a centrifuge and stored in tanks 45, 46, and 128. The product was pumped to tanks BT-1, -2, or -3 in glovebox HC-227S, 234-5Z Building, then loaded out into product receiver cans or sent to the RMC Line for conversion to metal.

Filtrate Evaporation. The filtrate evaporator was used to concentrate dilute aqueous solutions for use as feed to the solvent extraction process. The filtrate evaporator (tank 21) is a 304-L stainless steel thermosyphon evaporator with tube and shell heat exchanger. An overhead vapor deentrainment section, containing tantalum mist eliminators, connects the evaporator to a shell and tube condenser (tank 22). The condenser was sized for a 20,000 Btu/h design duty. It has one tube bundle 6 in. in diameter by 6 ft high. Vapor entered the shell side of the stainless steel horizontal condenser and was cooled and condensed by water flowing through the coiled tubes. The condensate was normally routed to the D-8 tank.

Aqueous Waste Treatment. When the PRF was in operation, aqueous wastes containing plutonium were received from a number of sources (Figure 5-30). The bulk of the solvent extraction liquid waste was collected in receiver tanks, sampled and then analyzed. If below about 0.05 g/L plutonium, the solutions were transferred to tank TK-D8 of the 241-Z Complex. Liquid waste containing high plutonium concentrations were sent to aqueous waste treatment prior to discharge to the 241-Z Complex.

General. Maintenance shop facilities are located on the service (east) side of the building (room 16) on the ground floor. The PR can unloading facility in room 19 (see Figure 5-6, sheet 1), has been removed from service and partially dismantled. Nondestructive analysis (NDA) equipment has been installed in this room and is used to measure the plutonium content of miscellaneous packaged solid wastes. The second floor of the service side has a maintenance glovebox and ventilation exhaust filters. Building service equipment and electrical switchgear are on the third floor of the facility. On the fourth floor are chemical preparation, MT, the operating control room, slag and crucible dissolver charging equipment, and offices for building personnel. Sections of two extraction columns (CA and CC) penetrate the cell ceiling and are housed in gloveboxes on the fourth, fifth, and sixth floors. Most of the major control activities carried out by operating personnel are located on the fourth floor.

A remotely operated overhead crane in the process cell can be used to remove or replace process equipment. Equipment can be moved by the crane to a special maintenance station at the north end of the process cell. The CA and CC columns, located in the penthouse, do require partial disassembly before being moved into this maintenance cell by the overhead crane. The cell crane is remotely operated from the third floor. The work area is viewed through water-filled-shielding viewing windows. This maintenance area is shielded partially from the rest of the cell by a 10-in. concrete wall. The maintenance station is equipped with a lead-covered stainless steel hood panel and leaded safety glass windows.

5.2.2.2.3 Design Bases and Safety Assurance. Plutonium is a highly radioactive fissile pyroforic material that requires criticality prevention standards and radiation safety practices be carefully followed throughout the processes. Both engineered and administrative controls are employed to prevent accidents and to minimize consequences. Engineered controls include the use of long, narrow columns and tanks that provide criticality safe geometry; remotely controlled operations; the confinement of pumps, valves, and piping connections inside of gloveboxes; the use of equipment that is engineered for reliability; and the use of radiation detection instrumentation

to alert personnel if an accident occurs. Though the PRF is currently not authorized for operation, plutonium-bearing solutions may still exist in the piping of the process cell and plutonium residues may remain in columns. Therefore, the design bases for process cell equipment (i.e., piping, columns, and tanks) will be retained until the PRF is cleanout.

The PRF was designed to confine plutonium and meet commercial and industrial safety criteria. The design of operating area compartments and critical safety (nuclear and chemical) structures has been reanalyzed and upgraded a number of times since the facility was built. This section describes the designs of the individual process vessels and their enclosures.

The 236-Z process cell is constructed of noncombustible materials (concrete walls, floors and ceiling, with a stainless steel floor liner capable of holding spills from leaking piping or vessels). The process cell uses limited or controlled air in-leakage to prevent loss of containment. The cell walls and the ceiling are 2 ft thick, providing limited radiation protection in the event of a criticality. The process equipment was designed to be geometrically favorable for criticality safety. Personnel exposures were limited by minimizing "hands on" operation through extensive use of mechanical equipment. Valving and pumps are located outside of the process cell but inside gloveboxes. Major components can be replaced and repaired in the hot maintenance shop, which is located just outside of the process cell. Stainless steel-paneled gloveboxes containing safety glass viewing windows and hood gloves provide access to the process cell. The gloveboxes are located on both sides of the cell on the first two floors. Process piping is carried in process tank dunnage that is secured in the port that penetrates the shielding wall to equipment in the cell, and to pumps, valves, flowmeters, and other equipment in the gloveboxes that most frequently require maintenance.

The south wall of the process cell contains double doors, serviced by a large airlock structure outside the south wall. This arrangement permits controlled movement of equipment into the cell.

Cell entry by personnel is infrequent but is done when the cell crane cannot accomplish what is needed (e.g., cell floor cleaning, installation of new tanks, failed equipment removal). Entries into the cell is key locked, and special work authorizations are required for maintenance of equipment, including the crane.

The process vessels and piping were designed to contain contaminated (plutonium-bearing) solutions. Generally, these streams were operated at atmospheric pressure and relatively low temperatures. Specific equipment items, listed on Table 5-11, were designed to meet the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* and the ASTM Code for pressure piping (*Standard Specification for Austenitic Stainless Steel Tubing*, *Standard Specification for Austenitic Stainless Steel Pipe*, *Standard Specification for Chrome-Nickel High Temperature Steel*, *Boiling Nitric Acid Test*, *Welded and Seamless Steel Pipe*, *Alloy Steel Bolting*, and *Alloy Steel Nuts*, *External and Internal Threaded Fasteners*). Standard practice is to provide welded tube sheets for primary loop (i.e., those that contain plutonium-bearing solutions on either the tube or shell side) process heat exchangers. Secondary loop heat exchangers usually rely on rolled, rather than welded, tube sheet. The tanks are connected to ventilation systems,

overflow drain lines, and overflow collection tanks. Contaminated effluent lines are of all welded construction with bolted, flanged joints where required.

The process vessel design drawings specify standard Schedule-40 piping and flanges, which is in accordance with the provisions of *ASME Boiler and Pressure Vessel Code*, Section VIII. The specifications for fabrication, testing, and inspection were as follows:

- Fabrication Standard--American Welding Society (AWS) D1.1/D1.3/B3.0 or HS-BS-0013 (Hanford Standard) Kynar™ per Fluoroflex-K, Cat SK-7
- Performance Specification--ASME Section IX and AWS D1.1/B3.0
- Filler Material--ASME Sect. II/AWS A5
- Inspection--Visual (VT) (Non Rated Service), Welding Std. IN (1), SSP 2.5.0 (Hanford Standard), Penetrant (PT) Welds with Liquid Service, Welding Std. IN (1), SSP 2.1.0 (Hanford Standard), Radiograph accessible welds, and Severity Level 3.

Most of the vessels and piping were operated at ambient temperatures and pressures. The S&C dissolver was the only vessel operated at pressure and was subject to erosion by recirculating solids. Consequently, it was designed for severe operating conditions. Laboratory corrosion data do not provide a satisfactory basis for predicting vessel design life because local corrosion/erosion conditions cannot be duplicated. Consequently, the facility design included a fully installed and instrumented unit and a spare vessel that could be installed remotely. All equipment and service lines were pressure tested with water at 20 lb/in^2 (gauge) after installation to verify that the connections, piping, and vessels were leak tight. The vessel design did not include an estimated design life or corrosion rate; the materials of construction (glass, 304-L stainless steel, polyester plastic, and Kynar™) were chosen to give maximum expected life of the equipment based on analysis of laboratory and plant operating experience. The pressure vessel design conditions are summarized in Table 5-12.

All pressurized process piping was designed and fabricated in accordance with the American Standard Code for Pressure Piping (Table 5-13). Piping was either welded in accordance with American Standards Association (ASA) B31.1 or, if it fell out of this scope, was fabricated using 304-L stainless steel in accordance with Hanford Specification HW-4924-S for stainless steels, and HW-4926-S for carbon steels. Valves, strainers, and gaskets were made of 300-L series stainless steel in accordance with the manufacturer's design specifications for the intended application. The backflow preventors are rated for 100 lb/in^2 (gauge). Safety relief valves and pressure reduction valves (PRVs) were ASME rated and sized by the manufacturer. The diaphragm control valves are rated for 600 lb/in^2 (gauge) at 800 °F.

Most of the columns and tanks for the solvent extraction process are located in the process cell. If any of these columns or tanks should leak, the solution would be safely contained on the floor of the process cell until it can be cleaned up. For the volumes of material available in the tanks, the cell floor is considered an infinite slab for criticality purposes. Equipment

that handles radioactive solutions is located in gloveboxes on the first, second, fourth, fifth, and sixth floors. Each glovebox is maintained at a lower negative air pressure than the room air surrounding the glovebox. This difference in pressure enhances the barrier between the operator and radioactive materials by directing air flow into the contaminated glovebox. HEPA filters at the air supply inlet of gloveboxes are a barrier to contamination spread into the room if air flow becomes reversed. Seismic qualifications of these gloveboxes are presented in Table 5-5.

All of the solvent extraction columns are single-barrel vessels. The diameter of these vessels is designed to be geometrically favorable for criticality safety. With the exception of the small, single-barrel tanks in the gloveboxes, the tanks in the process cell are four-barrel tanks (Figure 5-27). The small diameter of each vessel in a tank coupled with the spacing between vessels is designed to make each four-barrel tank geometrically favorable. The four-barrel tanks also have sloping bottom lines which facilitate drainage.

Process piping throughout the PRF typically is stainless steel. Fluorocarbon pipe is used for solutions that contain free fluoride ions that are corrosive to stainless steel. The slag and crucible dissolvers are made of stainless steel pipe lined with fluorocarbon.

The Magnehelic™ pressure gauges and instruments are designed to withstand 4 lb/in^2 over or under pressurization without loss of function or accuracy. The piping materials specifications were:

- American Society for Testing Materials (ASTM) 262-55T--Boiling HNO_3 test for dissolver castings
- ASTM A53-59T--Welded and seamless steel pipe
- ASTM A193-59T--Alloy-steel bolting for high temperature service
- ASTM A194-59T--Alloy-steel nuts for bolts for high-pressure and high-temperature service
- ASTM A307-58T--External and internal threaded fasteners
- ASA B16.5-1957--Steel pipe flanges and flanged fittings
- HWS-8067-S--Stainless steel welding electrodes and filler.

The MT gloveboxes were designed to confine plutonium and provide for inlet and outlet air ventilation through HEPA filter systems. The process equipment was designed to provide confinement during normal feed preparation and stabilization. The spacing and size of the equipment is used in conjunction with administrative mass and concentration limits to provide criticality control. The glovebox, ventilation system, and process equipment were designed to minimize the amount of contamination, should a fire or explosion occur, by maintaining airflows and pressure drops.

The roof is tar and gravel over a concrete slab on a metal deck. An Underwriters Laboratory (UL) listed class A polyurethane foam has been applied over this assembly. The exterior walls and floors are poured concrete and concrete block. The interior walls consist of plaster on metal lath, poured concrete, and concrete block. Fire detection and suppression systems are detailed in Section 5.4.11.

Criticality safety features incorporated into the design of the plutonium recovery operations include the following.

- The process equipment is designed to be geometrically favorable even if operated with plutonium at the maximum credible concentration (if the plutonium precipitates during a process upset) and optimum moderation.

- Spacing between major pieces of process equipment is fixed to reduce neutron interaction.

- Process cell tanks are spaced from the walls, floor, and ceiling to reduce neutron reflection from the concrete.

- Process containers such as cans or polybottles are designed to be subcritical even if overbatched and moderated.

- Liquid level in the east and west glovebox floors is physically controlled by weirs, with each floor weir discharging to a lower level and the lowest discharging to the process cell floor bays.

- The depth of liquid in the process cell floor bays is physically controlled by weirs that direct flow of solutions from bay sections near the east and west walls to the center of the cell. The process floor bays can hold all the tankage of the cell without exceeding the maximum safe depth.

- Process waste is collected in geometrically favorable tanks that are physically isolated from sources of concentrated plutonium. These tanks are connected to waste storage systems through lines operated by supervisor-controlled valves. Transfers are made only after sampling verifies acceptable plutonium content in the waste.

- Cooling water systems are designed to ensure that any leakage would flow into the process system and not discharge into the waste storage system.

Operating procedures incorporate administrative criticality safety requirements. These requirements include plutonium mass limits, limits on the number and size of containers, spacing limits between containers, concentration limits, and the depth of solution spills.

The PFP is equipped with an integrated criticality detector system. Detector coverage includes all areas where the occurrence of a criticality is considered possible. Periodic operability checks of both detectors and alarms are made and personnel response to criticality alarms is checked by drill exercises.

Although plutonium conversion is no longer being performed, the associated gloveboxes and process cells contain residual radioactive material and may be used for the storage of in-process material. The gloveboxes and cells provide the primary confinement barrier to release of radioactivity. Gloveboxes are maintained at negative pressure (-0.3 to -1.5 in. w.g.) to ensure plutonium is confined should a small break in the confinement barrier should occur. Airflow is through a nontestable high-efficiency particulate air (HEPA) filter at the glovebox exit and at least two testable HEPA filter stages in series in the E-4 offgas treatment system. Pressure drop across filters is indicated by Magnahelic gauges and is periodically monitored to detect filter plugging.

The process cell tanks are shielded by a 24-in. concrete wall. Individual gloveboxes, such as at the maintenance cell, have provisions to add lead glass shielding as needed. Leaded gloves are used in most positions to reduce gamma ray exposure to the hands and arms. Surveys are taken frequently to assess radiation levels at workstations.

The CAMs are provided to monitor workplace breathing air in rooms where there is a probability of airborne radioactivity. Portable CAMs are used when performing nonroutine maintenance activities. Filtered and fresh-air-supplied respirators are available, if needed.

Criticality, fire, and evacuation alarms, CAM alarms, intercommunication systems, and the commercial telephone system provide for alerting personnel to emergencies. Each system is detailed in Section 5.4.10, and additional detail of the fire protection system is given in Section 5.4.11.

The 236-Z Building and its service and utility systems have been reviewed for compliance with the requirements of DOE Order 6430.1A (DOE 1989). The results of these reviews are presented in Tables 1 through 9 of WHC (1990).

5.2.3 The 232-Z Building

5.2.3.1 232-Z Structural Specifications. The 232-Z Building is approximately 37 ft wide by 57 ft long. The building is a single story over the process and storage areas and two stories over the service areas at the north end. The respective roofs are about 15 ft and 19 ft above grade and consist of concrete over metal decking, with an insulation and built-up asphalt gravel covering. The facility structure is constructed of concrete blocks. It has its own ventilation air supply and exhaust air filtration system, with exhaust air being routed to the atmosphere through the 296-Z-14 stack. The incineration equipment in this building is no longer used and has been cleaned out of plutonium material.

5.2.3.1.1 Seismic Analysis. Seismic analysis for the 232-Z Building has not been formally documented. By inspection, the 232-Z Building was deemed incapable of resisting DBE motions (Ballinger 1993). In the event this facility fails as a result of seismic and/or other natural forces, a portion of the residual plutonium inventory could be released to the environment from the E-4 ventilation exhaust system duct upstream of the HEPA filters. The

acceptability of the failure and consequences is discussed in Chapter 9.0, Section 9.2.4A.

5.2.3.1.2 Wind Analysis. The wind analysis for this building is not documented.

5.2.3.1.3 Snowfall Analysis. The snowfall analyses for the 232-Z Building is not documented.

5.2.3.1.4 Ashfall Analysis. The 232-Z Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.3.2 232-Z Building Description.

5.2.3.2.1 Function. The 232-Z Building housed an enclosed system of gloveboxes and hoods used for sorting solid plutonium contaminated wastes, leaching noncombustibles, chopping wastes for size reduction, and incinerating the combustible wastes. Solutions and ash from this process facility were processed for plutonium recovery in the 236-Z Building. A cutaway view of the 232-Z Building is given in Figure 5-31.

This building has its own air supply ventilation system; exhaust ventilation is provided by two fans that discharge to the atmosphere through the 296-Z-14 stack.

5.2.3.2.2 Components. The plutonium recovery processes in this building were shut down years ago and the facility is not in use. The process equipment, which includes the incinerator hood and the glovebox housing the offgas scrubber, is inactive and has been isolated. The building ventilation supply and exhaust systems, including the HEPA filtration systems, are in operation, though sections of the exhaust ventilation system piping connecting hoods and gloveboxes to the E-4 system have been isolated and removed (see Section 5.4.1 for more details). Installed safety systems, such as the fire detection and alarm system, the automatic wet-pipe sprinkler system (temporarily deactivated), CAMs on HEPA filtered exhaust (with local audible and visible alarms), and instruments for DP measurements between ventilation zones are operable. Building surveillance is provided on a shiftly (at least once every 12 hours) frequency for detection of abnormalities. The building is heated with ceiling heaters.

The 232-Z Building has undergone bulk plutonium removal from the gloveboxes and hoods and associated ventilation exhaust piping and decontamination and decommissioning activities have been completed. All ventilation ducting, whether still in place or removed, and the main pieces of process equipment (e.g., the incinerator glovebox and scrubber cell) have undergone NDA.

5.2.4 The 241-Z Complex

5.2.4.1 241-Z Structural Specifications. The 241-Z Complex (or Liquid Waste Treatment Facility) consists of five structures: the 241-Z Building, the 241-ZA sampling building, the 241-ZB caustic tank (inactive and scheduled for removal), the 241-Z-RB retention basin (scheduled for removal) and the 241-ZG changeroom. The 241-Z Building consists of two parts: a corrugated metal

enclosure located above a belowgrade structure consisting of five separate cells with sumps, each containing a tank that is used to accumulate the potentially radioactive liquid wastes generated in the PFP for chemical adjustment before transfer to 244-TX. (Tank TK-D6 has been emptied, isolated and is unavailable for liquid storage.) The belowgrade structure is constructed of reinforced concrete, and the approximate dimensions are 20 ft wide, 92 ft long, and 22 ft deep, with cell walls of the sumps being 1 ft thick (each cell is 17 ft wide, 17 ft long, and 22 ft deep-see Figure 5-32). The roof (consisting of 6 in. thick, reinforced concrete coverblocks allowing access to the waste tanks) is at approximately grade level. Atop the coverblocks is the pre-engineered corrugated metal enclosure that serves as a weather cover to house the ventilation filter enclosures, 1,500-lb capacity monorail crane for lifting coverblocks and tools, steam jet piping for sampling equipment, tanks TK-D10 (inactive) and TK-D11 (chemical addition tank), and instrument racks.

The 241-ZA sampling building is a corrugated metal square structure 12 ft on a side. The 241-ZB caustic tank and 241-Z-RB retention basin are scheduled for removal. The 241-ZG Changeroom is a corrugated metal structure.

5.2.4.1.1 Seismic Analysis. Seismic analysis of the 241-Z Building belowgrade reinforced concrete vault is not documented; however, seismic analysis of the reinforced concrete vault cover blocks shows that the blocks will withstand DBE motions (Ocoma 1988a). Although the in-cell tanks can fail during a seismic event, cover blocks will not fall into the cells and cause further tank damage (see Chapter 9.0, Section 9.2.4A). It is assumed that the corrugated metal enclosure above the waste tanks of the 241-Z Building will not withstand the DBE. The 241-ZA sampling building, 241-ZB caustic tank, 241-Z-RB retention basin, and 241-ZG changeroom have not been analyzed for the DBE.

5.2.4.1.2 Wind Analysis. Wind and missile design analyses for the corrugated metal structure of the 241-Z Building are formally documented in Giller (1990). The analysis was performed by comparing the 241-Z Building specification for wind forces with the Hanford Site criteria, which determined the specification forces were less than the DOE-RL (1989), criteria for extreme wind forces. It is assumed that the corrugated metal enclosure of the 241-Z Building will not withstand extreme wind forces and associated missiles. The 241-ZA sampling building, 241-ZB caustic tank, 241-Z-RB retention basin, and 241-ZG changeroom have not been analyzed for extreme wind forces and associated missiles.

5.2.4.1.3 Snowfall Analysis. The 241-Z Building corrugated metal roof was evaluated (Giller 1990) by comparing the normal load roof design capacity with the DOE-RL (1989) normal roof load criteria. The corrugated metal structure of the 241-Z Building was found to be adequately designed for live and dead loads (Giller 1990). The 241-Z corrugated metal structure has not been analyzed for snowfall. The 241-ZA sampling building, 241-ZB caustic tank, 241-Z-RB retention basin, and 241-ZG changeroom have not been analyzed for snowfall.

5.2.4.1.4 Ashfall Analysis. The 241-Z, 241-ZA, 241-ZB, 241-Z-RB, and 241-ZG facilities have not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.4.2 241-Z Complex Description.

5.2.4.2.1 Function. The 241-Z Complex (or Liquid Waste Treatment Facility) consists of five structures: the 241-Z Building, 241-ZA sampling building, 241-ZB caustic tank (now inactive and scheduled for removal), 241-Z-RB retention building (scheduled for removal) and 241-ZG changeroom. This complex serves to adjust and temporarily store PFP radioactive liquid waste (RLW) before transfer to the 244-TX receiving facility.

5.2.4.2.2 Components.

241-Z Building. The five below-grade storage tanks (tanks TK-D4, TK-D5, TK-D6, TK-D7, and TK-D8) are made of stainless steel, and each has a capacity of 4,300 gal. Nuclear criticality safety for these tanks is provided administratively by limiting plutonium concentrations and quantities. A list of the tanks and their associated equipment in the 241-Z Building is shown in Table 5-14. See Figure 5-33 for the layout of a typical Building 241-Z storage tank.

Tank TK-D8 receives PFP aqueous wastes. The wastes originate from the PPSL, PFP AL, and periodic flushes from the 26-in. mercury vacuum seal water. During plutonium solution stabilization operations with the Production VDC or Laboratory Prototype Calciner, wastes transferred to TK-D8 include caustic scrubber liquor from the spent scrub solution tanks. The waste collected in TK-D8 is batch transferred via steam jet to TK-D5 after sampling. Chapter 7.0 details the waste management processes of the PFP.

The pH of the stored waste is adjusted using NaOH or KOH before transfer to the 244-TX receiving facility. Chemicals, such as $Fe[NO_3]_3$ from TK-D11 in the 241-Z Building, are needed as required to meet Waste Acceptance Criteria (see OSD-184-Z-00010).

Tank TK-D5 is equipped with a pump and a steam jet. The pump is a 3-hp, 4-stage with 51 to 58 ft of head at the discharge nozzle. It has a high temperature interlock set for 200 °F. Pump operation is interlocked with controls located at the 244-TX vault so that waste transfers cannot be made without personnel in attendance at the 244-TX receiving facility. The steam jet receives 50 psig inlet steam, has 100 gal/min discharge, an operating temperature of 100 °F, and has a maximum operating temperature interlock set for 200 °F, 14.5 ft suction lift, and a discharge head of 22 ft of water. The maximum operating temperature for TK-D5 tank transfers is 200 °F. The steam jet is used when TK-D5 requires an NDA. The steam jet is configured to remove all solution in TK-D5.

Leak detection is provided for the transfer line (2 in.-LSW/HSW-M9) to tank TK-D8 by a leak detection element (to relay panel LDE-D84A). A second leak detection element (to panel LDE-D84B) is provided for a 2-in.-spare-M9 transfer line (currently capped with a plug). Both leak detector relay panels send to panelboard L located in the corrugated metal aboveground structure. Signals from the leak detection elements are sent to the leak detector junction box number 1, which in turn is directed to LDI-84A and LDI-84B in the 234-5ZA Building. The leak detectors are powered by a 15 A circuit breaker in panelboard L.

There are approximately 25 drains from the multiple-branched pipe system that are open to the zone 3 air space. Each of these drains has a water P-trap as a design feature to mitigate possible suck back because of air pressure differences; however, these P-traps dry out over time. These drain lines are routed to the pipe drain header to which the Building 241-Z transfer pipe is connected.

Tank TK-D6, which is a confirmed leaker, has been isolated and abandoned in place. Tanks TK-D4, TK-D7, and TK-D7 overflow tank are used to catch overflow from the TK-D8 and TK-D5 tanks.

Waste tank data are periodically recorded on instrument readout charts in 241-ZA Sampling Building. The Building 236-Z control room for the 241-Z Complex is not continuously manned.

Various penetrations (pipes, electrical) allow in-leakage of building air through the floor (cell ceiling) to the cells and into the tanks. Exhaust air is drawn from the cells and tanks by two separate headers connected to a common header and is then heated, filtered through a two-stage testable HEPA filter, sampled and monitored continuously for radioactivity, and discharged to the atmosphere through a 25-ft stainless steel stack (296-Z-3).

241-ZA Sampling Building. The 241-ZA sampling building houses the sampler glovebox (GB-2-241-ZA) used to take samples from the below-grade waste tanks via dip leg, dip legs to each tank using only one steam jet that ejects the liquid into TK-D5. It also houses the annunciator panel and an inactive and disconnected sampling glovebox (GB-1-241-ZA).

241-ZB Caustic Tank. The 241-ZB caustic tank once housed caustic tank TK-D9, which was used in buffering transuranic (TRU) waste in the 241-Z below-grade storage tanks. The tank is scheduled for removal. The 55-gal drums of caustic will be brought in by truck as required for buffering of the 241-Z tank waste.

241-Z-RB Retention Basin. The 241-Z-RB retention basin is a concrete retention basin previously used to hold waste from 241-Z Complex prior to discharge into the PFP crib system (which is now isolated from PFP discharges). The basin is scheduled for removal.

241-ZG Changeroom. The 241-ZG Building houses the changeroom for workers who are to enter the 241-Z sump metal shack and the 241-ZA Sampling Building. It is a corrugated metal structure.

Transfer Line to 244-TX receiving facility. The transfer line has no documented operating pressure, though it is believed that the lowest maximum operating pressure is 230 psig. There is no rupture disk/PRV in the line to limit pressures. The control panel at 244-TX has a TK-D5 pump enable switch that must be turned on in order for any pumping from TK-D5 to 244-TX to take place.

Transfer Lines to 241-Z Building. There are four pipe lines that direct liquid waste to the 241-Z below-grade tanks: two 2 in. diameter spare pipes, a 2 in. diameter spare LSW/HSW pipe, and a 2 in. diameter LSW/HSW pipe. Each pipe line is enclosed in a 4 in. enclosure pipe, which is in turn enclosed by

a 10 in. diameter sheet metal duct. The pipe lines are secured at various locations by 16 gauge galvanized steel ducting attached to concrete anchor blocks. The underground conduit

Cathodic Protection System. The transfer piping is protected from corrosion by a cathodic protection system which consists of anodes, anode junction boxes, vertical prepackaged anodes, test stations, and a rectifier. Anode headers and loop cables are routed in the same trench, directly over the pipe lines. Anode junction boxes are enclosed in a concrete junction box enclosure with a steel cover, buried at grade level. The anode headers and anode loop cables test stations consist of a test station conductor with two pipe test conductors exothermically welded to the 2 in. LSW pipe line, and a reference electrode connected to a reference electrode lead wire. The test conductors are enclosed in a concrete test station enclosure with a steel cover, buried at grade level.

Detailed discussions of the 241-Z Complex processes and the wastes handled by it are found in Chapter 7.0, Section 7.2.2.

5.2.4.2.3 Design Bases and Safety Assurance. Exhaust air from the 241-Z Complex (which has a potential for radioactive contamination) is continuously monitored and sampled any time forced ventilation is occurring through the stack.

The 241-Z Complex is constructed of noncombustible materials. It houses belowgrade tanks that contain liquid waste and has essentially no combustible contents. The roof, exterior walls, and interior walls are corrugated metal. The floor is poured concrete. All finish materials are noncombustible.

The 241-Z Building belowgrade tanks and sumps are not a geometrically favorable design. Therefore, the fissile content is controlled by the engineered barriers, evaluation of analytical results, and/or administrative controls.

5.2.5 The 242-Z Building

5.2.5.1 242-Z Structural Specifications. The 242-Z Building (previously the Waste Treatment Facility) is not in use. The approximate dimensions of the building are 40 ft wide, 26 ft long, and 23 ft high. The tank room occupies about 10 ft by 40 ft of the south portion of the building. The tank room extends the full inside height of the building. The north portion of the building, which was the control room, has a mezzanine over its west half that was used for chemical addition tanks. The south wall of the 242-Z Building is reinforced concrete. The remainder of the building has a structural steel frame covered with metal lath and plaster internally and insulating material wall panels externally. The roof is constructed of metal decking covered by insulation and built-up asphalt and gravel. The 242-Z structure is between the southeastern corner of the 234-5Z Building and the 236-Z Building (see Figures 5-6, sheets 1 and 2). A corridor runs along its east side, connecting the 234-5Z, 242-Z, and 236-Z Buildings (though the entrance connecting the 242-Z Building and the corridor has been sealed shut by welded steel plates). An entrance enclosure at the west end of the control room was used for outside entry into the 242-Z Building and the analytical laboratories in the 234-5Z

Building, however this entry has been sealed shut by welded steel plates. Both the east side corridor and the west side entrance enclosure are considered to be part of the 234-5Z Building, not the 242-Z Building. A cutaway view of the 242-Z Building is given in Figure 5-34.

5.2.5.1.1 Seismic Analysis. The 242-Z Waste Treatment Facility was analyzed (Giller 1991a) using the ANSYS PC/linear computer program to determine whether the facility could withstand DBE loads. The structural geometry, member section properties, and building masses were modeled, and a dynamic modal analysis was performed to determine the building frequencies. The analysis showed stresses of some members are not within the code allowables. The structure can be qualified with minor modifications to two column baseplates and by replacing two rod braces with larger diameter rods. During the DBE, structural failure is assumed for these members, though the facility would survive. The acceptability of the failure and the consequences are discussed in Chapter 9.0, Section 9.2.4A.

5.2.5.1.2 Wind Analysis. The results of the extreme wind and missile design/analyses for the 242-Z Building are stated in Giller (1990). The results show that the main load-bearing structure can withstand extreme wind forces, and wind-generated missiles will not penetrate the wall panels.

5.2.5.1.3 Snowfall Analysis. The 242-Z Building roof was analyzed for normal roof loading of a minimum 20 lb/ft^2 in accordance with ANSI A58.1 and DOE-RL (1989) guidelines. The analysis indicates that the roof can withstand the effects of live and dead loads and of snowfall (Giller 1990).

5.2.5.1.4 Ashfall Analysis. The 242-Z Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.5.2 242-Z Description.

5.2.5.2.1 Function. The 242-Z Building houses equipment that was used to treat PRF wastes and extract americium from the wastes. Following the exothermic reaction rupture of an ion exchange column used for extracting americium, high levels of contamination where deposited in the rooms, necessitating the isolation of the facility. Entry to this building is nonroutine and strictly controlled. The main effort is to confine the contamination to the building rooms. In 1977, a testable HEPA filter was added to the building E-3 exhaust system. In 1981, glovebox ports were sealed, nonessential services were disconnected, and contaminated surfaces were treated with Butvar™, a strippable coating.

5.2.5.2.2 Components. The tank room in the 242-Z Building houses large process vessels, which are piped to the process gloveboxes of the control room.

5.2.6 The 291-Z Building

5.2.6.1 291-Z Structural Specifications. The 291-Z Building, known as the exhaust fan house, exhaust air stack building, and compressor and fan house, is a reinforced concrete structure located south of the central part of the 234-5Z Building. Of irregular shape, its approximate dimensions are 74 ft

wide by 143 ft long. Its overall height is approximately 23 ft, with only 4 ft above grade. This building houses the exhaust fans, the mechanical service equipment, and the substation.

5.2.6.1.1 Seismic Analysis. The 291-Z Building was evaluated for DBE loads (URS 1980). Preliminary analysis and evaluation indicated that the building is structurally adequate to resist lateral forces from a DBE. Subsequently, confirmatory detailed seismic analyses were carried out (URS 1980). The analyses verified that the 291-Z Building can survive a DBE.

5.2.6.1.2 Wind Analysis. The integrity of the 291-Z Building walls was checked for resistance to missile penetration from a 15 lb wood plank and to forces from a 90 mi/h extreme wind. The analysis shows that the 291-Z Building can withstand the wind forces and missile (Giller 1990).

5.2.6.1.3 Snowfall Analysis. The 291-Z Building roof was analyzed for normal roof loading of a minimum of 20 lb/ft^2 in accordance with the guidelines of ANSI A58.1 and DOE-RL (1989). The analysis indicates that the roof can withstand the effect of live and dead loads and snowfall.

5.2.6.1.4 Ashfall Analysis. The 291-Z Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.6.2 The 291-Z Building Description.

5.2.6.2.1 Function/Components. Ventilation exhaust for the 234-5Z, 242-Z, 236-Z, and 291-Z Buildings is provided by seven electric motor-driven fans in the 291-Z Building (see Figure 5-6, sheet 1 for the floor plan of the 291-Z Building). These fans and the inlet and exhaust plenums are the primary contents of the 291-Z Building. Two steam-driven fans that provide emergency exhaust in the event of loss of electrical power are also located in Building 291-Z. The 291-Z Building ventilation supply and exhaust systems are used only to remove the heat generated by the motors and other equipment. Evaporative coolers supply air cooling in the summer. Exhaust is provided by exhaust outlets. A cutaway view of the 291-Z Building is given in Figure 5-35.

The 291-Z Building consists of an electrical room (room 500, also designated as the 252-Z-2 substation), a compressor and pumps room (room 501), two fan rooms (rooms 502 and 509), two exhaust plenums (rooms 503 and 510), two cross passageways (rooms 504 and 506), an inlet plenum (room 505), an air supply room (room 507), and a discharge plenum extending to the stack (room 508).

The inlet plenum (room 505), which divides the facility, enters at an angle and then makes a horizontal run. On each side of the inlet plenum is a fan room with a discharge plenum below. The inlet plenum is 136 ft long, 15 ft wide, and varies in depth but is about 20 ft deep.

Each fan room (140 ft long, 13 ft wide, and 13 ft 6 in. deep) has positions for four electric exhaust fans and one steam-turbine exhaust fan. There are four electric-powered fans and one steam-turbine-driven fan (deactivated) in the west fan room (room 509), but only three electric fans and one steam-turbine-driven fan (scheduled for deactivation) in the east fan

room (room 502). The east exhaust plenum (room 503) and west exhaust plenum (room 510) are combined in a common plenum (room 508) that discharges to the 291-Z-1 stack. Below the inlet plenum (room 505), where it enters at an angle, is a cross-passageway (room 504) connecting the two fan rooms. There is also a cross-passageway (room 506) on the south side of the inlet plenum. Room 507, formerly the stack sample room, is now equipped with air supply units that, along with others that are individually installed throughout the 291-Z Building, provide conditioned air. See Figure 5-6, sheet 1, for the room locations.

On the east side of the 291-Z facility is a switchgear room (room 500), also designated as the 252-Z-2 facility, which contains the 13.8 kV/440 V transformers for the 291-Z, 236-Z, and 232-Z facilities. This room is 35 ft long and 18 ft wide. South of the switchgear room is a mechanical room (room 501) in which two 90-lb air compressors, emergency compressed nitrogen gas supply, two instrument air compressors (not in use), and two 17-in. mercury air sample vacuum (ASV) pumps are located. A hygrometer located in room 501 is used to measure the moisture content of the air that services the room. This hygrometer is connected to an indicator in room 321A of the 234-5Z Building. There is a sump (4 ft wide, 13 ft 6 in. long, and 7 ft 2 in. deep) located in the northeast corner of the mechanical equipment room. There are three electrical pumps, and one backup steam jet installed in the sump, which discharge to a header going to the 234-Z Building. See Figure 5-6, sheet 1 for room locations.

5.2.6.2.2 Design Bases and Safety Assurance. The 291-Z Building is capable of functioning during design basis accidents, as discussed in Section 5.2.6.1.

5.2.7 The 291-Z-1 Stack

5.2.7.1 291-Z-1 Stack Structural Specifications. The 291-Z-1 reinforced concrete stack is located adjacent to the 291-Z Building. The stack and the 291-Z Building are separated by an expansion joint. Because the stack is separated structurally from the 291-Z Building, it is possible to evaluate the stack independently of the building (URS 1988b). The stack is constructed of reinforced concrete and is 200 ft tall. The stack has an interior diameter varying from 13 ft 6 in. at the top to 16 ft 6 in. at the base. The thickness of its walls also varies, though not uniformly, from 6 in. at the top to 9 in. at the base. The stack foundation is a massive concrete footing block that is approximately octagonal in shape and has a dimension of 32 ft across its flat sides. The foundation block is 27 ft, 2 in. thick, and its top is about 3 ft 5 in. above the finished grade. A 16 ft dia, 90° elbow opening in the footing connects the bottom of the stack to the duct of the 291-Z Building.

5.2.7.1.1 Seismic Analysis. A preliminary and conservative seismic evaluation of the 291-Z Building and stack indicated that the building was structurally adequate to resist lateral forces resulting from postulated DBE loading, but the stack showed overstress (URS 1980). The seismic demand of the stack was calculated by the linear elastic response spectrum procedure, assuming a fixed base.

In a more recent study, the demand on the stack was calculated using an equivalent stick model (URS 1988b). The soil half space surrounding the structure was modeled by frequency-independent springs to account for soil-structure interaction effects. The stack responses were calculated using the time history model superposition procedure with the free-field time histories conservatively applied at the embedded base level. The calculated demand was then compared with the capacity of the stack. The capacity of the stack to resist horizontal and vertical DBE loading was rigorously calculated on the basis of nonlinear behavior of concrete and reinforcement bars. The nonlinearities considered were concrete cracking, parabolic compression behavior of concrete with crushing and ultimate strain specification, and elastic-plastic behavior of reinforcing bars. The capacity for reinforcement bar yielding initiation and the ultimate capacity were calculated for each section of the stack. The results of this study show that the stack has enough ultimate capacity to resist the postulated DBE loading with ductile behavior.

The URS (1988b) study rigorously and conservatively evaluated the capacity of the 291-Z-1 stack to resist a postulated DBE with a zero period acceleration of 0.25 g. Alternative calculations were also performed to show the conservatism of the present evaluation. The conclusions of this study may be summarized as follows.

- The dynamic analysis and evaluation of the 291-Z-1 stack demonstrates that the stack reinforcing has enough ductile capacity to resist the DBE loading without collapse.
- The maximum horizontal and vertical displacements at the top of the stack have been shown to be less than 8 in. and 0.2 in., respectively.
- The maximum horizontal acceleration at the top of the stack has been calculated to be less than 0.8 g.

5.2.7.1.2 Wind Analysis. The wind loading analysis for the 291-Z-1 stack consisted of calculating moments and shears at specific elevations along the stack (Giller 1989a). These moments and shears are compared to demand/capacity curves developed in the 291-Z-1 stack seismic analysis.

The results from the extreme wind analysis of the 291-Z-1 stack demonstrate that the extreme wind demand is significantly less than the stack capacity and the seismic demand at all elevations (Giller 1989a). Therefore, the stack is qualified for the extreme wind condition.

5.2.7.1.3 Snowfall Analysis. The normal roof loading analysis is not applicable to the 291-Z-1 stack because there is very little horizontal surface area compared to the vertical stiffness. The stack can withstand snow loads (Giller 1990).

5.2.7.1.4 Ashfall Analysis. The 291-Z-1 stack has not been analyzed for natural phenomena volcanic ashfall loadings, though it is assumed that ash fall would have little effect on the structure due to the low horizontal surface area of the stack.

5.2.7.2 291-Z-1 Stack Description.

5.2.7.2.1 Function. The purpose of the 291-Z-1 stack is to provide an outlet for the E-3 and E-4 exhaust gases of the 234-5Z, 242-Z, 236-Z, and 291-Z Buildings.

5.2.7.2.2 Components. See Section 5.4.1.1.6 for details of the equipment in the 291-Z-1 stack.

5.2.7.2.3 Design Bases and Safety Assurance. The 291-Z-1 stack is constructed of reinforced concrete. This stack is capable of functioning during design basis accidents, as discussed in Sections 5.2.7.1.

5.2.8 2736-Z Support/Storage Complex

The 2736-Z Support/Storage Complex consists of the 2736-Z, 2736-ZA, 2736-ZB, 2736-ZC enclosed area, 2736-ZD vault, and 2721-Z Buildings. The 2736-Z Building is designated the primary plutonium storage facility. The 2736-ZA Building contains the equipment that provides exhaust ventilation for 2736-Z. The 2736-ZB Building is used for shipping, receiving, repackaging, and NDA of nonliquid plutonium material. The 2736-ZC is an enclosed off-loading dock and a building corridor. The 2736-ZD is an aboveground vault used for storage of experimental breeder reactor II (EBR-II) casks. The 2721-Z Building provides backup electrical power. The layout of the complex is shown in Figure 5-6, sheet 1. (See Chapter 6.0, Sections 6.2.1, 6.3.1, and 6.5.4) for a more detailed description of 2736-Z Support/Storage Complex operations).

This complex houses all operations required to make the facility capable of performing all of its functions and procedures during normal conditions. The MICON™ automation system provides monitoring and control of the 2736-Z support/storage complex following an upset in the complex HVAC and/or power systems.

5.2.8.1 The 2736-Z Building.

5.2.8.1.1 2736-Z Structural Specifications. The 2736-Z Building is a one story (65 ft long by 56 ft wide) structure constructed of reinforced, 14 in. thick concrete walls supported by cast-in-place concrete columns. The roof is a cast-in-place reinforced concrete slab that is 6.5 in. thick. The 2736-Z Building was designed to meet the design criteria specified in DOE-RL (1982), and has been found to meet design criteria from latter revisions of the Hanford Plant Standard (e.g., DOE-RL 1989). The 2736-Z, -ZA, and -ZB Buildings were designed to the criteria in DOE Order 6430.1A (DOE 1989).

Seismic Analysis. This building was seismically qualified at the time of its construction in the 1970-71 timeframe in Anderson (1971) and Lein (1972). The method used in Lein (1972) was reaffirmed in 1991 by a study that independently verified the building as a rigid structure and validated the appropriateness of the modeling method used at the time of construction (Giller 1991b). The structure was reanalyzed in 1994 for normal-operating and natural-phenomenon loads (Giller 1994a). Equivalent static methods, as

opposed to dynamic methods, were used as recommended by Kennedy et al. (1990) for simple regular structures that have uniform mass and stiffness distributions. All structural members of the 2736-Z Building were found to have positive margins of safety with respect to the material design strengths.

Additional seismic considerations in the mid-1970's provided container integrity assurance through shaker table testing of the pedestal storage configuration, and the establishment of operating specifications for storage that provide controls on container contents and packaging materials. The seismic qualification of storage cubicles, pedestals, and racks were reanalyzed in 1994 (Ocoma 1994). It was found that the precast concrete cubicles and the pedestals in vaults 1, 3, and 4 were adequate to withstand DBE loads as were the two different types of metal storage racks in vault 2 used for storage of 7-in. cans and lard cans; however, it was found that the anchor bolt loads of the storage racks in vault 2 used for storage of lard cans exceeded allowable load capacities. It was also determined that nonrated chains were used to secure the lard cans in their storage cubicles. Originally, nonrated chains were placed across the opening of the racks to prevent lard cans from being shaken out of the storage cubicles during a DBE. These nonrated chains have been replaced with aircraft chains. Overhead bracing has been added to the top of the storage racks. Currently, the storage racks are bolted to the wall they are adjacent to, the concrete floor, and each other. With the bolts and overhead bracing in place, the storage racks can withstand DBE loads; however, it was found that the addition of the overhead bracing has caused some of the base floor anchor bolts to be raised slightly from their respective drill holes. Further strengthening of the floor bolts was carried out in July of 1995 to compensate for the loosening of the base floor anchor bolts.

Wind Analysis. According to Lein (1972), the 2736-Z Building was designed to withstand a tornado wind of 175 mi/h resultant wind speed and various tornado-generated missiles described in DOE-RL (1982), which exceed the DOE-RL (1989) criteria of 90 mi/h extreme wind and a 2 in. by 4 in. wood plank missile for nonreactor facilities.

Snowfall Analysis. The 2736-Z Building roof was analyzed for normal roof loading of a minimum 20 lb/ft^2 in accordance with ANSI A58.1 and DOE-RL (1989) guidelines. The analysis indicates that the roof can withstand the effects of live and dead loads and snowfall (Giller 1990).

Ashfall Analysis. The 2736-Z Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.8.1.2 2736-Z Description.

Function. The 2736-Z Building is designated the primary plutonium storage facility. A cutaway view of the 2736-Z Building is given in Figure 5-36.

Components. The building consists of four vaults (vaults 1, 2, 3, and 4) for plutonium material storage (holding a total of approximately 500 kg), divided by a corridor that runs the width of the building. Each vault is about 28 ft x 28 ft. Vaults 1, 3, and 4 contain precast concrete storage cubicles; vault 2 has steel shelves and open floor storage.

Vault 1 contains 68 storage cubicles constructed of precast concrete panels 8 in. thick (see Figure 5-37). Each cubicle has a cross-sectional area 1 ft by 2 ft and is approximately 8 ft tall. Sixty-six cubicles have pedestal storage rings for fixed array storage and two have shelves so that storage container locations are not fixed. The cubicles are described as follows:

- The fixed array cubicles have a maximum of 45 storage rings per cubicle: 9 storage rings for each of 5 pedestals. Each storage ring is 10 in. from the storage ring above or below and is 6 in. from the nearest storage ring to the side.

- Each shelved-storage cubicle has 15 shelves. All cubicles in this room have two interlocking doors made of 8-in.-thick precast concrete.

The doors of each cubicle are 8 in. thick, made of concrete, flush with the top of the cubicles and have a 0.5 in. gap from the bottom of the doors to the floor. A ventilation duct attached to the top provides continuous airflow through each cubicle and thermocouples located in the top of each cubicle permit air temperature monitoring.

Vault 2 contains shelved-storage space for 700 items of plutonium material. Each cubicle measures 9 in. by 9 in. and is approximately 12 in. deep. Containers are kept on the shelf by a spacing-loaded wire on the front (to load and unload) and a 2 in. lip at the bottom of each shelf. In addition, there are approximately 588 ft^2 of open floor space in this room for fissile-material storage in shipping and storage container arrays up to the limit allowed by the specifications. Ventilation for this room is provided by supply and exhaust ducts mounted near the ceiling on the east and west walls, respectively. The walls of this vault are 14 in. thick.

Vaults 3 and 4 cubicles are constructed of precast concrete panels 8 in. thick. Each cubicle has a cross-sectional area 1 ft by 2 ft and is approximately 8 ft tall. There are 68 of these cubicles per vault, all of which have pedestal storage rings for fixed array storage. The maximum number of storage rings per cubicle is 28 (14 rings for each of 2 pedestals). Each storage ring is 12 in. from the storage ring above or below, and 7.38 in. from the nearest storage ring to the side. Each cubicle has two doors constructed of precast concrete approximately 8 in. thick. The doors, when closed, leave an 8 in. gap between them to allow air circulation by natural convection. There is also a 6 in. gap between the bottom of each door and the floor as a further aid to ventilation. Ventilation for these rooms is provided by supply and exhaust ducts mounted near the ceiling on the west and east walls, respectively. Vault 3 contains selected material that is under International Atomic Energy Agency (IAEA) oversight. Eight cameras in the vault are assigned to monitor selected material and provide videotapes for IAEA oversight review. The materials selected for IAEA oversight also have security seals.

A vault safety and inventory system is installed in vaults 1, 3, and 4 of the 2736-Z Building. This system monitors container temperature, ambient air temperature, dimensional changes of the container, container presence, and container identification number. Data processing equipment located in the 2736-Z Building provide the data logging and processing of information

received from the container monitors. Vault inventory system anomalies are annunciated in rooms 104 and 306A of the 234-5Z Building.

Design Basis and Safety Assurance. See Section 5.2.8.7.

5.2.8.2 The 2736-ZA Building.

5.2.8.2.1 2736-ZA Structural Specifications. The 2736-ZA Building is one story, approximately 40 ft long by 22 ft wide, and is situated approximately 5 ft to the west of the 2736-Z Building. The building is constructed of poured reinforced concrete. The 296-Z-6 stack is 14 ft 8 in. high in a 36 in. by 22 in. rectangular configuration. The stack is constructed of carbon steel.

Seismic Analysis. The 2736-ZA Building was designed and constructed to withstand seismic category I loading in accordance with criteria in Hanford Plant Standards for that time (circa 1971). The 2736-ZA Building was designed to provide a stand alone, two-stage, testable, HEPA filter exhaust system for the plutonium storage vaults in the 2736-Z Building. The exhaust fans and filters are mounted on seismic snubbers and were analyzed by the supplier using dynamic-response techniques and determined to be resistant to a DBE.

The building was reanalyzed in 1994 using an equivalent static analysis method (Giller 1994b) and compared against DOE-RL (1993) seismic loading requirements for safety class 1 or 2 nonreactor nuclear structures. All structural members of the building were found to have positive margins of safety with respect to the material design requirements.

Analyses of the storage vault exhaust system were also performed in 1994 (Ocoma 1994). The specific elements analyzed were the exhaust stack, the exhaust fan and HEPA filter assembly, the diesel generator, and the exhaust interface duct assembly connecting 2736-Z to 2736-ZA. The diesel generator has since been removed and replaced with an intertie to the 2721-Z diesel generators. Though this equipment was assigned a safety class of 3 at that time (now designated as safety significant), it was deemed that the equipment should remain operable following a safety class 1 DBE (0.20 g ground acceleration). It was concluded in Ocoma (1994) that the function and operability of the exhaust system was reasonably provided for following a ground acceleration of 0.20 g for the diesel engine and a ground acceleration of a 0.20 g for the filter housing and exhaust fan/motor assembly. Because of differential motions of up to 0.216 in. in-line displacement and 0.17 in. lateral displacement between the 2736-Z and 2736-ZA Buildings, a light gauge sheet metal portion of the interface duct assembly could undergo shear-tearing failure, leading to very small cracks. The duct, however, will remain in place and provide an acceptable flowpath after the DBE.

An evaluation of the potential for a release of plutonium through the cracks in the duct is shown in Chapter 9.0, Section 9.2.4A.

Wind Analysis. The analysis performed to verify the adequacy of the building to the requirements of DOE-RL (1989) for extreme wind and wind missile indicate that the building can withstand these events (Giller 1990).

Snowfall Analysis. The analysis performed to verify the adequacy of the building to the requirements of DOE-RL (1989) for snow loading on the roof indicate that the building can withstand these events (Giller 1990).

Ashfall Analysis. The 2736-ZA Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.8.2.2 2736-ZA Description.

Function. The 2736-ZA Building houses the ventilation equipment for the 2736-Z Support/Storage Complex.

Components. The 2736-ZA Building consists of two rooms. Room 649 is approximately 11 ft by 11 ft and formerly housed a diesel generator. Room 650 is approximately 26 ft long by 22 ft wide and houses the exhaust fans and filters for the 2736-Z Building. Temperature readout devices for the 2736-Z Building also are located here. The ventilation system exhausts through testable HEPA filters, is sampled and monitored for radioactivity, and exits the 296-Z-6 stack, which projects 30 in. above the roof and 14 ft 8 in. above grade.

Design Basis and Safety Assurance. See Section 5.2.8.7.

5.2.8.3 The 2736-ZB Building.

5.2.8.3.1 2736-ZB Structural Specifications. The 2736-ZB Building is one story (132 ft long by 90 ft wide). The walls and roof are constructed of reinforced concrete. The 2736-ZB Building was designed to provide support facilities for the 2736-Z plutonium storage vaults. These support functions include shipping and receiving areas, a nondestructive plutonium assay laboratory, and a glovebox for repackaging cans of plutonium to support the long-term storage mission of the vault. The floor plan is shown in Figure 5-6, sheet 1.

Seismic Analysis. The project design criteria required conformance to SDC 4.1 safety class 1 seismic design criteria for the 2736-ZB structure and the ventilation system because it was acknowledged that plutonium might be dispersed within the facility during a seismic event from failure of confinement provided by the repackaging glovebox. The structure was analyzed using a rigid response method at 0.25 g. The stresses under static loadings were found to be low and within acceptable code limitations with adequate margins to be qualified (Goakey 1980). The approach used to qualify the mechanical equipment, such as the ventilation supply and exhaust systems, was to procure a frame mounted assembly with snubbers attached to structures embedded in a floor and seismically isolated from ducts using flexible connections. The equipment assemblies were modeled and dynamically analyzed by the vendor and shown to have acceptably low loads, though the supply fans are not seismically rated. The filter housing assemblies used in the ventilation equipment package are commercially available shaker-test qualified equipment.

The 2736-ZB Building was reanalyzed in 1994 using an equivalent static analysis method (Weiner 1994). All structural members of the building were found to have positive safety margins with respect to the material-design

strengths. The repackaging glovebox was also analyzed in 1994 (Ocoma 1994). It was found that the glovebox support frame and anchorage was adequate to withstand DBE loadings (i.e., the anchor loads and stresses in the support frame members, connections between the support frame and the glovebox, and the filter housing support were less than the allowable values). The seismic qualification of the room 636 repackaging glovebox is presented Table 5-5.

Wind Analysis. The 2736-ZB Building was analyzed for extreme wind and wind missiles in accordance with SDC 4.1, Rev 11 (DOE-RL 1989). The building was found to be able to resist such winds and missiles (Giller 1990 and WHC 1990).

Snowfall Analysis. The 2736-ZB Building roof was analyzed for normal roof loading of a minimum 20 lb/ft^2 in accordance with ANSI A58.1 and DOE-RL (1989) guidelines. The roof analysis indicates that the roof can withstand the effects of live and dead loads and snowfall (Giller 1990).

Ashfall Analysis. The 2736-ZB Building roof has not been analyzed for natural phenomena volcanic ashfall loadings. It is assumed that the ashfall loading does not exceed the snow loading and, therefore, the roof does not fail.

5.2.8.3.2 2736-ZB Description.

Function. The 2736-ZB Building is used for plutonium material shipping, receiving, sorting, and packaging and is located immediately to the south of the 2736-Z Building. A cutaway view of the 2736-ZB Building is given in Figure 5-38.

Components. Three shipping and receiving/storage areas (rooms 638, 641, and 642) each provide approximately 1,000 ft^2 of floor space. Each floor space can accommodate a maximum of 100 shipping containers the size of 55-gal drums while maintaining the necessary criticality prevention spacing requirements between the containers, as well as corridor access to staging areas. The three staging and receiving areas are physically separated by walls. Room 638A, 639 and 640 are seviced areas associated with room 638, and room 640A is a sub-room area located in Room 641.

Room 638 is monitored by smoke detectors and protected by a wet-pipe fire protection sprinkler system.

Empty container storage is provided by the 2731-ZA and 2731-Z Buildings.

The staging area provides approximately 1,500 ft^2 of floor space to accommodate the shipping container loading and unloading operations. A gantry and electric half-ton hoist with a manual trolley are used to move drums. This area includes two enclosures: a container-handling equipment storage enclosure and a shipping container decontamination enclosure that is approximately 100 ft^2.

A repackaging area (room 636) that is approximately 680 ft^2 is provided for repackaging plutonium material. The Building 2736-ZB repackaging glovebox is located in this room.

Repackaging Glovebox. This is a standard, seismically qualified glovebox (see Figure 5-39). It is constructed of stainless steel frames and floors and clear, self-extinguishing polycarbonate safety sheets, or glass and wire-mesh panels on the sides and top. The panels are penetrated by gloveports, bag-in/seal-out ports, sphincter seals, solution transfer lines, and instrument and electrical connectors. Thick polycarbonate panels, leaded safety glass, and lead-filled gloves provide neutron and gamma-ray shielding. The glovebox has a dedicated dry air system located in room 602 (see Section 5.4.3.1.3), a hygrometer, quick disconnect fire extinguisher, and an open-face hood for over-sized containers. Heat detectors are situated in the glovebox and smoke detectors are placed in the room.

The glovebox air of the repackaging glovebox is continuously sampled and analyzed for moisture content by the condensation dew point hygrometer, which is set to alarm when the dew point rises above -10 °F. This ensures that the air moisture in plutonium material containers is below 1% to prevent possible moisture adsorption on plutonium powders and subsequent pressurization of the container during storage due to gases generated by the radiolysis of water.

A decontamination room (room 630), equipped with a shower, sink, and other necessary supplies, is provided for personnel decontamination.

Capability for repackaging is provided to handle plutonium oxide powder and plutonium metal. Shielding materials are to be used to keep personnel exposure as low as reasonably achievable (ALARA) and within the limits as discussed in Chapter 8.0.

An NDA laboratory (room 637) is provided to house all of the NDA laboratory and computer equipment. Space is provided for a laboratory standards storage facility and two offices for laboratory personnel. Approximately 1,800 ft^2 of floor space is provided to accommodate the calorimeters (pre-equilibration baths, etc.), segmented gamma scan assay system, gamma energy analysis system (isotopic analysis system), neutron well coincidence counters, associated minicomputers, and NDA equipment. A monorail and manual hoist are provided for handling waste drums. See Chapter 6.0, Section 6.5.4, for additional detail concerning the 2736-ZB NDA laboratory.

The mechanical room (room 602) houses the MICON™ local control unit (LCU), computer terminal, as well as the communication lines to and from the computer system, dry air and instrument air compressors (see 5.4.3 for details on the compressed air systems), HVAC supply fans, fire riser, NDA supply fans and refrigeration cooling coils, and NDA electrical heating coils.

There are no protective clothing requirements associated with the work areas of the 2736-ZB Building except for the repackaging glovebox room.

The 2736-ZB Building has its own HVAC supply and exhaust systems. The building air supply is provided by two systems: one supplies the major portion of the building and recycles a part of the exhaust air from the lunchroom and front offices, and the other provides constant temperature air (with a refrigerated system in summer) for the NDA laboratory. All NDA laboratory exhaust air is HEPA filtered and sampled and monitored. After filtration, approximately 80% of the exhaust air is recycled to the NDA laboratory supply air system. The remaining 20% is exhausted to

atmosphere after filtration through the 296-Z-5 exhaust stack. If the recycled air is found to be contaminated above the allowable limit for breathing air, it is diverted for HEPA filtration and discharge to the atmosphere through the 296-Z-5 exhaust stack. The exhaust and recirculation fans, vacuum pumps, and two 17-in. mercury vacuum pumps (see Section 5.4.5.1.2 for details of the air sample vacuum system) are located in room 600. Discharge to the atmosphere, which is sampled and monitored, exits through the 34 in. diameter stainless steel 296-Z-5 stack. Air supplied to the administrative areas is exhausted to the atmosphere unfiltered and unmonitored. See Section 5.4.1.1.7 for more details on the HVAC system.

Design Basis and Safety Assurance. See Section 5.2.8.7.

5.2.8.4 The 2736-ZC Area.

Details of the enclosed loading dock and corridor are provided here to complete the description of the 2736-Z Support/Storage Complex.

The 2736-ZC is an enclosed off-loading dock and a corridor that allows all-weather access to the shipping and receiving areas. The off-loading dock is external to the 2736-ZB Building and provides an area of approximately 1,700 ft^2 to stage and store cargo-restraint transporters. The cargo-restraint transporters are used for offsite receiving and shipping (Figure 5-40). The dock is enclosed in a metal building with a 15-ft eave height, electric roll-up doors with seal pads, electrical outlets, and lighting. Within this enclosure is a 4,000-lb capacity 360° jib crane with a chain hoist and drum handler for removal and placement of the drums from the cargo-restraint transporter. The cargo-restraint transporters are removed from the Safe Secure Transport by a winch with a 1,000-lb capacity. Airlocks provide access from the enclosed corridor rooms 643 and 644 of the 2736-ZB Building. Separate airlocks are provided for personnel and material access. In addition, administrative controls are developed to maintain safeguards and security control during shipping and receiving operations.

The majority of the shipping containers are waste containers. Other shipping containers contain plutonium oxide powder, plutonium metal, or miscellaneous scrap materials from various onsite and offsite sources.

The plutonium material packages received at the 2736-ZC loading dock are moved into the 2736-ZB Building before opening. In an emergency, temporary CAMs and a greenhouse could be erected to open a package in 2736-ZC.

5.2.8.5 The 2736-ZD Storage Facility.

The 2736-ZD storage facility, located south of 2736-ZC, is a reinforced concrete cylindrical vault 8 ft tall and 9 ft in diameter, with 1-ft-thick interlocking cover and base plate. The vault wall is about 10 in. thick. The cover and base are gasketed and bolted into place by stainless steel bolts. This facility is used to store EBR-II casks (maximum number of casks permitted in the vault is 7). The vault currently contains three EBR-II casks. According to Criticality Prevention Specification (CPS-Z-165-83070), the EBR-II cask is a 60 in. tall, 17 in. diameter steel casing with a 38 in. high, 6 in. diameter central payload cavity. Irradiated metallic fuel is contained inside a primary containment consisting of a 4 in. diameter (Schedule 40)

stainless steel pipe. This vessel is then enclosed inside another 6 in. diameter stainless steel container. Both vessels are weld-sealed and placed inside the cavity of the cask. This facility has no support equipment nor does it receive any Hanford Site utilities. Though this facility has not been analyzed for natural phenomena hazards, the probability of vault storage failure to such phenomena (seismic, wind, wind-generated missile, etc.) would be very low considering the design of the vault. As the lid and base interlock into the cylinder section, these pieces will move as one in a DBE. Overturning of the vault during a DBE is not likely because the ratio of the height to the diameter is less than 1. Failure of the EBR-II casks would also be required before any release of fuel material.

5.2.8.6 The 2721-Z Building.

5.2.8.6.1 2721-Z Structural Specifications. The generator building is 46 ft long by 19 ft wide and is constructed of poured reinforced concrete walls 1 ft thick. It is located approximately 26 ft to the west of 2736-ZB. A floor plan of the 2721-Z Building is shown in Figure 5-6, sheet 1. The 2721-Z Building has been analyzed to determine whether the building meets or exceeds current natural phenomena hazards design (see Tables 5-2 and 5-4).

Seismic Analysis. The 2721-Z Building was built using the same design characteristics as the 2736-ZB Building. As such, the building and its equipment were designed to withstand a 0.25 g DBE (WHC 1990).

Wind Analysis. The 2721-Z Building was built using the same design characteristics as the 2736-ZB Building. As such, the building was designed to withstand a 175 mi/h wind. The building was also designed to meet wind-driven missile criteria for high hazard facilities (WHC 1990).

Snowfall Analysis. The 2721-Z Building was built using the same design characteristics as the 2736-ZB Building. As such, the building can withstand current snowfall loading criteria (WHC 1990).

Ashfall Analysis. The 2721-Z Building roof has not been analyzed for natural phenomena volcanic ashfall loadings.

5.2.8.6.2 2721-Z Description.

Function. The 2721-Z Building provides backup electrical power to the PFP. See Sections 5.4.2.1.9 and 5.4.2.1.10 for a description of the function of this facility.

Components. The 2721-Z Building houses three diesel-driven generators to provide backup power to the PFP facilities. The switchgear room is situated on the north end of the building.

5.2.8.7 Design Bases and Safety Assurance. Shielding, container array, and safeguards were primary design concerns and ensure that personnel exposures are ALARA, in addition to ensuring criticality safety and secured storage and systems for the plutonium material. The vault safety and inventory system provides reduced radiation exposure to personnel conducting inventory of plutonium material stored in the 2736-Z Building, capability for automatically

conducting an inventory of plutonium material, and early detection of container distortion caused by internal pressurization.

The 2736-Z Building is self-contained and does not depend on Building 234-5Z services, except that: (1) the ventilation systems may be controlled from room 714 (MICON™ power control room) of the 234-5ZA Building via local control units (LCU) 5A and 5B located in room 321A of the 234-5Z Building as well as LCU 6 in the 2736-ZB Building, (2) the MICON™ system will support the 2736-Z Support/Storage Complex following an upset in the complex HVAC and/or power system, and Building 234-5Z and Building 291-Z provide normal electric power.

Vaults 1 and 2 and Vaults 3 and 4 of the 2736-Z Building are separated by fire walls. The building has a construction classification of fire resistive. The facility has a tar and gravel built-up roof on a concrete deck. The ceiling, floors, interior, and exterior walls are poured concrete. The 2736-ZA Building is an all-concrete construction building with concrete interior finish. All walls, floors, and finishes are noncombustible. The 2736-ZB Building has a construction classification of fire resistive. The roof consists of built-up tar on a reinforced concrete deck, supported by concrete columns. The exterior walls are reinforced poured concrete, and the interior walls are poured concrete and gypsum wallboard. The gypsum wallboard is sealed, taped, painted, and supported by metal studs. The ceiling varies throughout the building. The office area has a suspended lay-in acoustical tile assembly. The locker rooms, laboratories, staging, shipping, and receiving areas have a suspended gypsum board assembly. The remaining areas are open to the underside of the roof. The floor is poured concrete and finished with tile and paint. The 2721-Z Building is an all-concrete construction building with concrete interior finish. All walls, floors, and finishes are noncombustible. Fire detection, criticality alarms, air monitoring, communications, and other support systems are discussed in Section 5.4.

The NDA laboratory in the 2736-ZB Building is designed to limit the workstation dose rate to 0.5 mrem/h. The 2736-Z, 2736-ZA, 2736-ZB, and 2721-Z Buildings and their services/utilities have been reviewed for compliance with the requirements of DOE Order 6430.1A (DOE 1989). The results of these reviews are presented in Tables 1 through 9 of WHC (1990).

5.2.9 The 243-Z Complex

5.2.9.1 243-Z Structural Specifications. The 243-Z Building, or LLWTF, is a one-story (70 ft long by 35 ft wide) metal structure. The building has concrete flooring and below-grade structures (sump and tank pit).

5.2.9.1.1 Seismic Analysis. The 243-Z Building was designed and constructed in accordance with the 1988 UBC, Kennedy et al. (1990), and criteria in DOE-RL (1989) for safety class 3 SSCs. Therefore, the building was designed for a 0.12 g zero period acceleration.

5.2.9.1.2 Wind Analysis. The 243-Z Building was designed and constructed in accordance with ANSI A58.1, Kennedy et al. (1990),

DOE-RL (1989), for safety class 3 SSCs. This states that the building was designed to withstand a 70-mi/h wind without missiles.

5.2.9.1.3 Snowfall Analysis. The 243-Z Building roof was designed for a dead load of 25 lb/ft^2 and a live load of 20 lb/ft^2. The roof was designed to meet DOE-RL (1993) 20 lb/ft^2 snow loading requirements.

5.2.9.1.4 Ashfall Analysis. The 243-Z Building roof was not required to be designed for natural phenomena volcanic ashfall loadings in accordance with DOE-RL (1993).

5.2.9.2 243-Z Description.

5.2.9.2.1 Function. The 243-Z LLWTF is a low-hazard process facility. It provides the best available treatment of low-level contamination, both chemical and radiological, for PFP effluent that was once disposed to the 216-Z-20 crib. The facility is comprised of two buildings: (1) the 243-ZA Building sump, which holds the influent sump tank, and (2) the 243-Z Building, which holds the remainder of the equipment of the facility. The functions of the 243-Z Complex are controlled by the MICON™ operator station.

5.2.9.2.2 Components.

The 243-ZA Building Sump. Located to the east of the 243-Z Building, the sump contains the influent sump tank (1,000 gal), influent surge tank (5,000 gal), and two 5-hp turbine pumps. The influent sump tank is 7 ft tall with no overflow and is located in the lower sump. The influent surge tank is 18 ft tall with overflow and is located in the upper sump area.

The 243-Z Building. The building consists of five rooms: vestibule (room 101), changeroom (room 102), drum washing room (room 103), drum turning room (room 104), and process room (room 105), as shown in Figure 5-6, sheet 1.

The vestibule (airlock) provides direct access to the changeroom for personnel outside the building. From the changeroom, another door provides access to the process plant section of the 243-Z Building.

The process room contains particulate prefilters, pumps, adsorption media treatment trains one and two, sampler, associated valving and piping (primarily Schedule 80 PVC), and instrumentation needed to operate and monitor the plant.

Adsorption media trains one and two both have 15 replaceable 55-gal drum process canisters with associated piping. Liquid flowing through a media train passes through three stages of adsorption in the following order:

1. Granulated activated carbon (six canisters in each train in parallel)

2. Bone char (six canisters in each train, two stages with three drums in parallel)

3. Cation exchange resin (three canisters in each train).

Each media train can clean influent at a maximum rate of 30 gal/min. Train 1 or train 2 can be removed from service for maintenance without stopping the influent flow to the 243-Z Building. Redundant pumps and filters are included in the process for the same reason. Saturated canisters are uncoupled from the process piping by quick disconnect couplings and transported by hand cart to the drum turning room.

After passing through the media trains, the treated effluent pH is monitored as it is transferred to manhole Z7 to ensure that the effluent from the 243-Z Building does not exceed the environmental release limit stated in *Water Quality*, HNF-PRO-456, and in "Dangerous Waste Regulations," *Washington Administrative Code* (WAC 173-303-090). Exceeding the pH limit will result in an alarm that will notify the MICON™ operator. Total alpha is determined by a composite effluent sample taken from the treated waste stream before it leaves the 243-Z Building. Additional sampling points after each bone char, granulated activated carbon, and cation exchange resin are also available for grab samples to ensure media integrity. If the effluent is tested and found not to meet the requirements for release, it is recycled for retreatment. See Chapter 7, Section 7.2.3, for a description of the waste water treatment process.

The drum washing room is used for washing new 55-gal adsorption canisters (activated carbon and bone char only) to remove small particulates before they are placed into the treatment trains. A floor sump in the south-west corner of the room provides for disposal of wash water to tank 101. New 55-gal canisters are brought into the room using a ramp from outside and held there until ready for placement in a train. A single door provides access into room 103. Sanitary water and process air are provided to this room. Process air takes the form of compressed air, which is used to blow a canister dry after drainage.

The drum turning room is used for draining liquids from saturated 55-gal adsorption canisters before transportation and disposal of the drums. The liquid that is drained is considered radioactively and/or chemically hazardous and is drained back into the influent sump tank.

5.2.9.2.3 Design Bases and Safety Assurance. The 243-Z LLWTF was designed according to *Functional Design Criteria Plutonium Finishing Plant Liquid Low Level Waste System Modification* (Lueck 1992). The building and its service/utility systems have been reviewed for compliance with the requirements of DOE Order 6430.1A (DOE 1989).

The 243-Z Building requires electrical power, process air, and sanitary water services supplied from other buildings. Fire alarms are indicated at the local fire alarm control panel and transmitted to the Hanford Fire Department (HFD) via radio fire alarm reporter.

The LLWTF stream is provided with leak detection and double containment from near the 243-ZA sump tie-in with existing 15-in. PVC coming from manhole Z4 until it leaves the 243-Z Building as treated water. Double containment is accomplished by two methods: (1) a pipe within a pipe with leak detection when routed underground, and (2) the concrete floors of the 243-Z Building are coated with a special protective coating. Nine floor drains all lead to a building sump. If a major leak or rupture occurred, or water from the fire

protection system was released inside the 243-Z Building, the liquids would flow, by gravity, through double-contained floor drain piping to the building sump. Spilled effluent from the concrete sump is cycled through the 243-Z Building for retreatment. Once the liquid is treated, tested, and released, it is no longer considered as very low activity liquid waste and is routed to the sewer system for disposal at the Treated Effluent Disposal Facility (TEDF).

Solution is continuously routed to TK-102 by the feed pumps to 243-Z. A flow control valve can be adjusted to allow more flow or less flow by the MICON™ operator depending on the flow rate into TK-101. MICON™ bypass switches for the TK-101 pumps are located at the 243-Z panelboard for those times when the MICON™ has no control power.

Ventilation exhaust enters into an open-faced enclosure of lower air pressure and then passes through a single-stage HEPA filter before being exhausted out the 296-Z-15 stack (see Section 5.4.1 for greater detail on the HVAC system for the 243-Z Building). Criticality alarm and communications systems are discussed in Section 5.4.10. Fire detection and fire protection are discussed in Section 5.4.11.

5.2.10 Auxiliary Facilities

These structures consist of administrative and support buildings and trailers, various storage sheds, and housing for equipment such as generators and fans. They also include the 2701-ZA/ZB, which houses central security for the PFP. The other structures are described in Table 5-15.

5.3 SUPPORT SYSTEM

5.3.1 Development of Support Requirements

Basic support systems (utilities) for the PFP are required regardless of its processing status. The support services required include ventilation, environmental surveillance and alarms, fire protection alarms, and lighting. This basic support requirement is equated to the reduced load configuration requested in Regulatory Guide 3.39 (NRC 1976).

The minimum utility services required following the maximum Chapter 9.0 hypothetical occurrence have been identified. In case of an emergency event, the plant can be placed in a safe condition in which there is no impact to the onsite or offsite receptor in excess of that discussed in Chapter 9.0. In this safe operational condition the emergency load is used to maintain the integrity of the Chapter 9.0 safety envelope to prevent an unacceptable release. The elements of this emergency load are the safety class and safety significant items determined according to HNF-PRO-704 listed in the *Safety System/Equipment List*, HNF-SD-CP-TI-108. Ventilation and containment and environmental surveillance equipment are the primary elements of concern. The safe shutdown load is a minor one, lasting for the first few minutes of any event, and is supported by the uninterruptible power supply (UPS).

In the 2736-Z Building, continuous ventilation is required to maintain the ventilation confinement designation of zone 2 for the vaults. In this case the normal process load is equivalent to the emergency load.

The support systems were designed and are operated based on the operating configuration of the plant and the process lines. These configurations do not conform strictly to those in Regulatory Guide 3.39 (NRC 1976). The correlation of the support system configuration to Regulatory Guide 3.39 is shown in Table 5-16. System loads for the PFP, as determined from its previous mission, are provided in Table 5-17. Current, reduced process loads fall within those given in Table 5-17, indicating that the PFP support systems can meet current mission requirements. Section 5.4 describes the systems available to provide these load requirements under various operational conditions.

5.3.2 Arrangement of Support Systems

This section summarizes the location of the various support facilities in relation to their functional objectives. Support system arrangements and their safety considerations are described in Section 5.4.

The ventilation support systems are located in the same buildings as the primary services. Compressed air support systems are in the same rooms as the primary services. Other compressed gas support systems involve valving-in or changing cylinders connected to the primary manifold, so the support systems are in the same locations as the primary services. Sanitary water is provided from the 283-W water treatment facility by the 200 West Area water distribution system.

5.4 SERVICE AND UTILITY SYSTEMS

5.4.1 Ventilation Systems

The original documented design bases for the PFP ventilation systems are not available. Normal operating parameters for the ventilation systems and components are presented in this section. Flow quantities for the ventilation systems, if available, are presented in Section 5.4.1. Operating experience has demonstrated that the PFP ventilation systems are functionally adequate.

All buildings served by the PFP ventilation systems are zoned to control confinement of radioactive materials, except for the 243-Z/ZA Complex which does not have zone designations; however, zone designations are not consistent for all of the PFP facilities. Within the 234-5Z, 232-Z, 236-Z, 242-Z, and 291-Z Buildings and 241-Z Complex, by historical convention, zone 1 is designated as those areas where plutonium contamination would not normally be present (e.g., office areas, lunchroom, certain maintenance shops, hallways). No contaminated materials or personnel wearing protective clothing are allowed in zone 1 areas. Zones 3, 3A, and 3B (collectively referred to as zone 3, and which now include areas that were previously identified as zone 2) consist of areas where radioactive materials (e.g., plutonium) are stored or handled in contained form, and where there is potential for contamination (e.g., rooms

where hoods and gloveboxes are located). Zone 4 consists of the inside of hoods, gloveboxes, and process cells, directly exposed to plutonium, that may be grossly contaminated. The DPs are maintained between the zones to assure that airflow is from the lowest potential contamination areas, to intermediate potential contamination areas, to highest potential contamination areas, as shown in Figure 5-41. The DPs for the various zones are shown in Table 5-18. Airflows are correlated with the differential pressure set points as shown in Table 5-18 and are set at the start-up of the HVAC system; however, the airflows change as the filters become loaded.

Zone designations in the 2736-Z Support/Storage Complex were established to meet design philosophy and requirements outlined in DOE Order 6430.1A (DOE 1989) designations. For these buildings, zone 1 is designated as having the highest potential for contamination (e.g., repackaging hood) and zone 4 as the clean zone. In these buildings, DPs also are maintained to assure that airflow is from the lowest potential contamination areas to the highest potential contamination areas.

Radioactive contamination within process areas is confined as close to the point of origin as practical through the use of HEPA filters installed on the exhaust ducts of hoods and on both the supply and exhaust ducts of gloveboxes. Exhaust ventilation air from zone 3 (zone 2 in the 2736-Z facility) areas is filtered through one stage (two stages in the 2736-ZB Building) of testable HEPA filtration before discharge to the atmosphere through a stack. Exhaust ventilation air from zone 4 (zone 1 in the 2736-Z facility) areas is filtered through two stages (three stages in the 2736-ZB Building) of testable HEPA filtration before discharge to the atmosphere through a stack. The HEPA filters (except exhaust filters on gloveboxes) are tested in accordance with criteria established in ASME N510 to demonstrate acceptable performance.

Backup capacity is provided for key features of the ventilation systems (e.g., supply and exhaust fans [see Section 5.4.2.1.2]). Two independent 13.8 kV lines (C8-L1 and C8-L2) supply normal electric power to the PFP facilities. Four supply fans (234-5Z) and four exhaust fans (291-Z) are supplied (through appropriate transformers) from circuit C8-L1. Four supply fans (234-5Z) and three exhaust fans (291-Z) are supplied from circuit C8-L2. Should one circuit fail, manual switching can be done to power all supply and exhaust fans from the remaining circuit. Backup ventilation is provided by the emergency steam turbine dirven exhaust fans.

Detailed accident analyses for the PFP have not identified any scenario where continued operation of the 234-5Z ventilation system is essential to prevent a release of plutonium having unacceptable consequences. Sections 9.1.7, 9.1.8, and 9.2.4 provide a comprehensive overview of the ventilation system as it relates to safety issues. Although a temporary loss of ventilation is acceptable (i.e., onsite and offsite releases), the consequences of a long-term loss has not been evaluated, and the acceptable period of time for ventilation loss is unknown. This finding permits most ventilation equipment to be assigned as Safety Significant. The exception is that when the ventilation system is operating, the final filters and stack CAMs are Safety Class. The PFP seismic accident analysis, found in Chapter 9.0, concludes that operation of the electric exhaust fans following a DBE

does not contribute to an airborne release of plutonium or hazardous materials having consequences above the risk acceptance guidelines.

In the 234-5Z Building, a fire damper is installed in the duct that connected the 9B filter and the 9AB filter (both filters have been removed); the fire damper is located close to where the 9B filter was located. There are only seven other fire dampers installed in the PFP ventilation systems, and three of these are out of service.

5.4.1.1 Major Components and Operating Characteristics. Ventilation for major PFP facilities is provided by six separate systems (each system having a dedicated ventilation exhaust stack):

- 242-Z, 234-5Z, 236-Z, and 291-Z Buildings (exhausted by the 291-Z-1 stack)
- 241-Z and 241-ZA Buildings (exhaust by the 296-Z-3 stack)
- 2736-ZB Building (exhausted by the 296-Z-5 stack).
- 2736-Z and 2736-ZA Buildings (exhausted by the 296-Z-6 stack)
- 232-Z Building (exhausted by the 296-Z-14 stack)
- 243-Z Building (exhausted by the 296-Z-15 stack).

The major components and operating characteristics of these systems are discussed in the following sections. Ventilation is on a once-through basis except for small-volume recycle of room air to supply laboratory refrigeration air-conditioning systems and for the 2736-ZB Building, which recycles air from the administration area and from the NDA laboratory.

5.4.1.1.1 The 234-5Z Building.

Ventilation Supply. Ventilation supply air is controlled as required to limit release of radioactive contaminants to the environment and minimize the spread of contamination.

Zone 1 and 3 Ventilation Supply. Four to five supply fans are normally in use and have sufficient capacity to allow proper balancing of the individual air zones. The remaining three to four fans provide backup for normal fan maintenance activities. The supply fans draw air from outside the building through roughing filters to remove airborne dust and dirt, through pre-heaters, air washers, and re-heaters and then deliver the air to the supply plenum at a year-round temperature of approximately 70 °F, with outside design temperatures of -10 °F to 110 °F. Each supply unit consists of the following:

- Filters
  - Size: 72 filters (24 in. by 24 in. by 8.75 in.) = 288 ft^2
  - Type: commercial dry-type fiberglass
- Preheaters
  - Pressure drop: 0.3 in. w.g.
  - Steam rate: 7,100 lb/h at 30 lb/in^2 (gauge) steam
- Air washers
  - Pressure drop: 0.66 in. w.g.

  - Pump capacity: 165 gal/min at 35 ft head (wet sump type)

- Reheat coils
  - Pressure drop: 0.20 in. w.g.
  - Steam rate: 2,650 lb/h at 30 lb/in^2 (gauge) steam

- Fan
  - Capacity: 76,100 ft^3/min at 5 in. w.g. water static pressure
  - Motor: 125 hp; 1,200 r/min.

Air pressure in the supply plenum is controlled to +2 in. w.g. by pneumatically operated control dampers on two of three operating supply units so equipped. The plenum is protected with relief dampers that relieve to the outside of the building.

A schematic of the Building 234-5Z ventilation system is shown in Figure 5-7. Five ducts lead from the supply plenum chamber to the various building zones ventilated by the system. A sixth, 60-in.-diameter steel duct mounted on the roof of the 234-5Z Building supplies air to the 236-Z Building (a schematic of the typical supply duct flow pattern through the 234-5Z Building is shown in Figure 5-42). Flows for the supply ducts are controlled at the outlet of the plenum by dampers that are modulated by pneumatic controllers based on signals from DP sensors located in the respective zone being controlled. The supply is divided into distribution mains and submains to supply air throughout the building. The duct contains a control damper, at the outlet of the plenum, that is modulated by a pneumatic controller based on signals from a pressure sensor in corridor 47, in the 236-Z Building. Flows from the supply ducts are controlled at the outlet of the plenum by dampers identified as A through F, modulation of which is controlled by pneumatic controllers located within the respective zone being controlled. A simplified view of air flow through the ventilation system of the 234-5Z Building is given in Figure 5-43. Typical flowrates of the supply systems, their controlling dampers, and the areas supplied are found in Table 5-19.

Ventilation air flow in Zones 2, 3, and 4 of Building 234-5Z is based on 30 air changes per hour, whereas the "ASHRAE Design Guide for Department of Energy Nuclear Facilities" (ASHRAE 1993) and the Hanford Site Radiological Design Guide (WHC-SD-GN-DGS-300H) recommends 4 to 8 air changes per hour. The normal design air flow for Building 234-5Z is 239,000 cubic feet per minute. Based on this value, the ventilation air flow is more than adequate to maintain plutonium airborne concentrations within the limits as specified in Appendix A of 10 CFR 835.

Supply fan S-10 takes a small quantity of air from zone 1 (approximately 1,600 ft^3/min) on the second floor and forces it under a slight positive pressure to an annulus space around each zone 3 and zone 4 filter in the large final filter rooms (309 to 316, and 318). The S-10 fan need not operate to perform this function and is currently out of service. The associated damper must be open to prevent unfiltered air from bypassing the filters if the filter gaskets are lost. The S-10 fan is located in room 321.

Recirculating, refrigerant-cooled air-conditioning systems are installed in the following areas: rooms 229, 221-A, 132, 136, 150-151, 306-A, and in PRF rooms 44-45.

Supply fans, supply plenums, and dampers associated with the ventilation supply system for zone 1 and zone 3 areas are constructed of steel. The floor of the main supply plenum is made of metal roof decking covered with a waterproof seal. Ducts are constructed of galvanized steel sheet metal. Ventilation supply air is routed to the various offices, hallways, restrooms, maintenance shops, laboratories, operating rooms, etc., of zones 1 and 3 through supply ducts. Supply air is introduced through ceiling diffusers to provide downflow ventilation to the various areas. Ventilation exhaust grills are located near the floor.

Zone 4 Ventilation Supply. Zone 4 ventilation supply for any specific glovebox is from one of two sources: (1) supply air via associated zone 3 areas through inlet HEPA filters, or (2) air supplied by the dry air system. Those gloveboxes which required dry (i.e., low moisture) air during their processing functions received such air from the dry air system (with the attached conveyor gloveboxes serving as zone 4 dry air supply plenums). The desiccant equipment of the dry air system is currently inactive, so that only normal air is being supplied to dry air gloveboxes from the process fans of the dry air system (about 850 ft^3/min). See Section 5.4.3.1.3 for additional information concerning the dry air system.

Air locks are provided between zones 1 and 3 and at building entrances whenever there is routine personnel traffic. All exterior doors other than those provided with airlocks are equipped with tamper indication devices (e.g., paper seal to detect use), but the doors may be used for emergency purposes. Emergency doors are equipped with signs on both sides indicating that the door is to be used for emergency purposes. Airlocks are equipped with audible alarms that will sound if both doors are open. The airlock doors are not interlocked. Airlock doors are fitted with gaskets to reduce in-leakage to a minimum.

All zone pressures in the 234-5Z Building are controlled automatically by pneumatically operated transmitters and controllers. Pressure sensors in each zone generate signals to control the supply air to each zone by operation of the supply dampers. One sensing signal controls the two dampers supplying zone 3. All supply fan dampers are designed to fail in an open position on loss of powered ventilation. All exhaust fan dampers are designed to fail in a closed position except the dampers to exhaust fans EM-1 and EM-2, which are designed to fail open, to allow natural stack draft to maintain normal ventilation flow direction and a minimal differential pressure across the ventilation zone boundaries. Any zone can be switched to manual control. Each zone is equipped with pressure recorders with readout in the control room (room 321) of the 234-5Z Building. The control room is manned 24 h/day. Typical zone pressures are shown in Table 5-18.

Ventilation Exhaust. Ventilation exhaust from the 234-5Z Building is provided by three systems identified as E-1, E-3, and E-4, which exhaust zone-1, zone-3, and zone-4 areas, respectively (Figure 5-7 shows exhaust flows from zones 1, 3, and 4).

An atmospheric reference system provides a standard reference for use in the measurement of the static pressure of an area. The system consists of a tank and associated piping. The tank, located in room 321 (Figure 5-44), is equipped with a 1 in. diameter line that extends through the roof level to the atmosphere. Just above the roof level, the line bends downward 180° to minimize impacts from the weather because it is an open line. Piping is provided between the atmosphere reference tank and the areas to be monitored for static pressure.

Zone 1 Ventilation Exhaust (E-1). Air is exhausted from the zone 1 areas of the first floor and duct level and some on the second floor by fans EM-11 and EM-12 (the nominal capacity of each is 30,750 ft^3/min; one is a standby) and discharged directly to the atmosphere through the roof without HEPA filtration; however, most of the zone 1 second-floor areas are exhausted through natural-flow gravity counter-weighted dampers in ducts directly to cowls on the roof. Fans EM-11 and EM-12 are located on the second floor of the 234-5Z Building in room 321 (Figure 5-44).

Some equipment in zone 1 is provided with hoods equipped for removal of small amounts of fumes or dust, and exhausted by fans that discharge through the roof to the atmosphere. Air is also exhausted from zone 1 by (1) the S-10 fan, which provides about 1,600 ft^3/min air to the filter frames in the filter rooms and (2) process fans of the dry air system that exhausts a small amount of air directly to the atmosphere. The fans and the supply-air system are located on the second floor of the 234-5Z Building in room 321 (Figures 5-6, sheet 3 and 5-44).

The office annex, associated with the PPSL, on the southwest corner, first floor of the 234-5Z Building, is classified as a zone 1 area. The offices are exhausted to the atmosphere by two small restroom-type exhaust fans and a gravity-type exhaust ventilator. Supply air is provided through wall-mounted heat pumps.

The northern section of the second floor of the 234-5Z Building (which contains offices, a lunchroom, restrooms, and engineering spaces) is also classified as a zone 1 area. Ventilation exhaust from this area is discharged to the atmosphere by exhaust fans (e.g., two lunchroom fans, an 800 ft^3/min exhaust fan, and exhaust fan EM-11).

Zone 3 Ventilation Exhaust (E-3). Air from zone 3 is exhausted through grills near floor-level in the various rooms. The air flows to the E-3 filter manifold. Dampers in the exhaust duct branches facilitate control of airflow through the grills to properly balance the system. The system is maintained at a pressure of -0.15 to -0.05 in. w.g. for contamination control. The air from zone 3 space is filtered through a single stage of testable HEPA filters that are located in seven filter rooms (rooms 311 through 316 and 318), any three of which may be in normal service and the remainder in standby. Each filter room contains 112 HEPA filters (24 in. by 24 in. by 11.5 in.), sealed individually in a steel frame filter wall that divides the room into an inlet side and an outlet side (Figure 5-45). Two manifolds with dampers on the inlet and discharge ducts of the rooms allow selection of any room combination. The exhaust air from the filter rooms (approximately 161,000 ft^3/min) flows into a common plenum (see Figures 5-7) for discharge to atmosphere through the 291-Z-1 stack.

Zone 4 Ventilation Exhaust (E-4). All exhaust air from zone 4 areas (e.g., open-faced hoods, gloveboxes), which are potentially contaminated or known to be contaminated, is routed through at least two testable stages of HEPA filters. Exhaust gasses from the zone 4 areas pass through the first stage of HEPA filtration at the duct-level (second floor) of the 234-5Z Building via dedicated filterboxes. Exhausts from these filterboxes are manifolded and routed to E-4 filter rooms 309 and 310 in the 234-5Z Building (Figure 5-6, sheet 3), which provide a second stage of testable HEPA filtration. Each filter bank room contains 128 filters identical to those used for the E-3 exhaust system previously discussed. During normal operation, one filter room is in operation with the other on standby. The E-4 ventilation exhaust is combined with the E-3 exhaust downstream of the filters in the stack manifold. The combined air flow is directed to the filter plenum, then directed to the 291-Z exhaust plenum (see Figure 5-7 for the airflow diagram of E-3 and E-4 exhaust to the exhaust plenum), passed through the 291-Z exhaust tunnel (see Figure 5-6, sheets 1 and 3 for location of exhaust tunnel) and is finally discharged to the atmosphere through the 291-Z-1 stack (see Figures 5-42 and 5-43 for flow patterns to the various plenums in the 234-5Z and 291-Z Buildings). The E-4 system exhaust flow is approximately 37,000 ft^3/min and the system is maintained at -0.5 to -2.0 in. w.g. to minimize the potential for backflow into zone 3 areas.

Ventilation exhaust from zone 4 gloveboxes and cells are exhausted through non-tested HEPA filters located in the top of the cells and gloveboxes.

The high hazard gloveboxes and powder boxes in the RMC and RMA Lines have remote alarms for high glovebox pressure (see Section 5.4.10). The RMC Line high-pressure alarms for the interconnected HC-2, HC-3, HC-4, and HA-28 conveyor gloveboxes are created by two DP switches that are calibrated annually and are currently in calibration. The RMA E-4 controller/recorder (which controls the RMA glovebox pressure for the RMA interconnecting conveyor) serves as the pressure sensor. This controller/recorder is calibrated annually and is currently in calibration. High pressure in the gloveboxes should be reduced by readjustment of the dampers.

Exhaust ventilation from Zone 4 process gloveboxes, cells, etc. where hydrogen fluoride gas was used, was segregated from the normal E-4 exhaust ventilation system, filtered through two stages of testable HEPA filters and discharged to the exhaust plenum, which handles the filtered E-3 and E-4 ventilation system exhaust air. Capability for diversion to the E-4 filter system (rooms 309 and 310) was provided as a manual backup. The E-4 exhaust streams from gloveboxes typically go through a nontestable HEPA filter before the first stage testable HEPA filter. (Currently, exhaust ventilation from Zone 4 process gloveboxes, cells, etc. where hydrogen fluoride gas was used has been rerouted to pass through Filter Box FB-21, while the original filter boxes have been removed from service. Glovebox HC-9B is disconnected from Filter Box FB-9B, Filter Box FB-9B is disconnected from Filter Box FB-9AB, and Filter Box FB-9AB's supply duct is disconnected from the ventilation system while Filter Box FB-9AB's outlet duct is directed to Filter Box FB-8.)

Inlet air to the 26 in. mercury process vacuum pumps, located on the second floor of the 234-5Z Building, is treated by a demister and two stages of testable HEPA filters (see Section 5.4.5). Exhaust air from the vacuum

pumps is routed to the E-4 filter banks (rooms 309 and 310), which provide a third stage of testable HEPA filtration for this effluent gas stream.

Electrical Driven Exhaust Fans. Seven exhaust fans (EF-1 through EF-7), each rated at 72,500 ft^3/min at 11 in. w.g. and powered by 200-hp electric motors, are installed in the 291-Z Building. Four of the seven fans are operated in parallel to exhaust the desired volume of filtered waste air from the PFP to atmosphere through the 291-Z-1 stack. Two of the installed fans (EF-3 and EF-4) are equipped with modulating dampers, which control the required flow of air through these fans to maintain the pressure in the manifold ducts to the E-3 and E-4 filter rooms at the desired level. Manual valves allows either EF-3 or EF-4 to be a modulating fan while the other fan operates at 100%. Two of the fans (EF-5 and EF-6) have manually set dampers that are air-adjustable for added control of the ventilation exhaust flow.

Steam Driven Emergency Exhaust Fans. Two emergency steam-turbine-driven fans (ET-8 and ET-9), each rated at 108,700 ft^3/min at 4.75 in. w.g., are set to start up automatically if the DP in the plenum chamber, upstream of the exhaust fans, becomes greater than or equal to 3.5 in. w.g. Ventilation supply fans (room 321) automatically shut down on startup of the steampdriven exhaust fans. Operation of the ventilation supply and exhaust fans is controlled from room 321 in the 324-5Z Building.

5.4.1.1.2 The 236-Z Building. The 236-Z supply and exhaust systems were designed and built to use some of the extra capacity of the original 234-5Z Building supply and exhaust systems. Ventilation of the 236-Z Building is provided by a once-through supply and exhaust system. Normally occupied areas of 236-Z (e.g., offices, corridors) are classified as zone 3 and process areas (e.g., gloveboxes, cells, hoods) are classified as zone 4 for confinement of radioactive materials, with ventilation exhaust systems designated as E-3 and E-4, respectively.

Zone 1 and 3 Ventilation Supply. Conditioned ventilation supply air for the 236-Z Building is provided by supply fans located in room 321 of the 234-5Z Building at approximately 42,600 ft^3/min. The air is routed to the 236-Z Building through a 60 in. diameter steel duct mounted on the roof of the 234-5Z Building. This duct is approximately 520 ft long and extends to the 236-Z Building where it is divided into distribution mains and submains for supplying air throughout the building. The duct contains a pneumatic control damper near the outlet of the room 265 supply plenum which is modulated based on signals from a differential pressure sensor located in corridor 47. This sensor, together with a DP transmitter in room 44, senses building ambient pressure changes and controls the supply air to maintain the desired building negative pressure with respect to atmosphere. A number of volume dampers also are installed in duct work on each floor of the building for flow control. Supply air is introduced through ceiling diffusers (rated at 15,670 ft^3/m, 12,370 ft^3m, and 14,560 ft^3m) to provide downflow ventilation to the various building areas. Exhaust ventilation grills are located near the floor.

Zone 4 Ventilation Supply. Zone 4 supply ventilation is from associated zone 3 areas through floor-level HEPA filters installed on the gloveboxes. Supply air to the process cell is provided through HEPA filters located near the ceiling of the second and third levels. Supply and exhaust ventilation of

236-Z is controlled from a panel in room 321 of the 234-5Z Building. The control panel is attended 24 hours a day.

Zone 1 and 3 Ventilation Exhaust. E-3 exhaust air in the 236-Z Building is routed to a west and east vent shaft, which are combined (the west vent shaft is directed to an underground crossover exhaust duct, 48 in. by 48 in., from stairway 2 to room 18) with air sample vacuum system exhaust air (see Section 5.4.5 for additional details of the air sample vacuum system). The combined flow goes to the exhaust plenum for distribution to filter banks A and D in room 26 on the second floor of the 236-Z Building. The filter banks are operated in parallel and provide a single stage of testable HEPA filtration. The E-3 ventilation exhaust air is discharged to an exhaust plenum on the first and second floors, which directs flow to an underground, 52 in. by 84 in. exhaust duct that leads to the 291-Z Building for discharge to the atmosphere by the 291-Z exhaust fans and the 291-Z-1 stack.

Zone 4 Ventilation Exhaust. The ventilation exhaust air from the E-4 system is passed through two independently testable stages of HEPA filtration. The first stage of filtration is by filterboxes near the zone 4 sources and the second stage of filtration is by filter banks B and C in room 26. The E-4 ventilation system exhausts to the plenum, together with the E-3 exhaust, for discharge via underground, 52 in. by 84 in. exhaust duct to the atmosphere by the 291-Z exhaust fans and the 291-Z-1 stack.

Zone 3 and 4 Filter Banks. Four banks of filters (filter banks A, B, C, and D) are located in room 26. Valving capabilities permit use of all four banks for E-3 exhaust filtration with either of the two middle banks (banks B and C) used for E-4 exhaust filtration. The 291-Z exhaust fans, together with dampers and control instrumentation, maintain the 236-Z Building E-3 and E-4 systems at the required negative operating pressures.

The 236-Z Building supply and exhaust ventilation schematic is shown in Figure 5-46.

5.4.1.1.3 The 232-Z Building.

Ventilation Supply. Approximately 2,000 ft^3/min of air is provided by infiltration throughout the deactivated supply system on the second floor of the 232-Z building.

Zone 1 and 3 Ventilation Supply. Zone 1 supply, which is blanked off, consisted of the second-floor room housing the air supply system and ventilation controls, and the first-floor restroom, changeroom, chemical mix room, and electrical switchgear room. Zone 3 consists of the process and storage areas.

Zone 4 Ventilation Supply. Supply air to the zone 4 glovebox and incinerator is from zone 3 through HEPA filters on the glove box and incinerator. The 232-Z Building ventilation supply system is shown on Figure 5-47.

Ventilation Exhaust.

Zone 1 and 3 Ventilation Exhaust. Exhaust air from zone 1, which is blanked off, was to the atmosphere through the use of locally controlled manual off/on switches in the restroom and chemical mix room. Exhaust air from the first-floor electrical switchgear room and from the second-floor ventilation supply and control room, which are also currently out of service, was discharged to the atmosphere by roof exhausters.

Air from zone 3 areas (E-3 exhaust system) was originally exhausted through nine in-floor HEPA filters located throughout the process area. Five of the filters are currently in use and four are now blanked off and out of service. These HEPA filters, operated in parallel, discharge to two exhaust ducts below the building floor.

Zone 4 Ventilation Exhaust. Air from zone 4 (E-4 exhaust system) was exhausted through an installed nontestable HEPA filter and routed through two independently testable stages of HEPA filtration before discharged to one of two exhaust ducts below the building floor to the 291-Z Building. The exhaust system runs from one of the exhaust ducts below the floor through three parallel sets of two HEPA filters in series. Any two sets are in service to filter the required air with the third serving as a standby. Two installed fans, with a nominal rated capacity of 2,000 ft^3/min each, provide exhaust for the 232-Z Building and discharge to the atmosphere through the 296-Z-14 stack. This stack is 21 ft high with a 12 in. dia, and is constructed of stainless steel. Exhaust effluents are sampled and monitored. Either exhaust fan can provide the required ventilation with the second fan on standby.

Confinement of radioactive contaminants was controlled by maintaining controlled DPs between zones 1, 3, and 4. Zone 1 is inactive and unoccupied. The exhaust system is capable of maintaining -0.25 in. w.g. relative to the ambient atmosphere and provides for at least six air changes per hour in zone 3 (process area). In addition the system is capable of maintaining zone 4 (glovebox and scrubber cell) at least -0.5 in. w.g. relative to zone 3. Zone 3 pressure is maintained by a DP controller and zone-4 pressure is maintained by a manual volume damper. Exhaust ventilation is shown on Figure 5-47.

The exhaust system has two-stage testable HEPA filtration (not counting the existing floor filters) and allows filter changeout of either filter without interrupting ventilation service. Redundancy is provided by having three separate banks. Any two sets must be in service to filter the required air with the third as a standby.

A stack monitor on the exhaust system samples the exhaust stream exiting through the stack. The monitoring system alarms locally and in room 714 (MICON™ power control room) of the 234-5ZA Building.

5.4.1.1.4 The 241-Z Complex.

Ventilation Supply. Supply air to the service building is provided by gravity-flow of atmospheric pressure outside air. Supply air to the vault area cells is provided from the service building by leakage around the cell cover blocks and other openings. Supply air to the enclosure that houses the

tank sampler glovebox also is provided by atmospheric pressure outside air. The building is heated with steam.

Ventilation Exhaust. One exhaust ventilation system with two branches serves both the 241-Z tanks and cells. Exhaust ventilation from the tanks is through the vessel vent system, which consists of a 4 in. diameter header with tie-ins to each tank and a demister. A valve in the header, upstream of the demister, controls the vessel vent exhaust flow to 100 ft^3/min. The vessel vent system exhaust joins the cell ventilation exhaust downstream of the demister. The 241-ZA tank sampler glovebox and tank TK-D9 caustic supply tank are also exhausted through the vessel vent system. Exhaust ventilation from the 241-Z cells is through a 15 in. diameter vitreous clay duct. A schematic flow diagram for the 241-Z Complex ventilation exhaust system is shown in Figure 5-48.

Exhaust air from the two systems is heated to protect the HEPA filters from moisture buildup, and routed through two stages of HEPA filtration, in series, before discharge to the atmosphere through the 25 ft tall, 14 in. dia, stainless steel stack. Two sets of HEPA filters provide redundancy and/or capacity as required by facility configuration. Two installed exhaust fans, one with a nominal capacity of 1,000 ft^3/min for normal use and one with a nominal capacity of 2,000 ft^3/min for use when additional flow is required (e.g., in-cell maintenance), provide the desired negative pressure on the tanks and cells. No backup electric power is provided for operation of the exhaust fans. Exhaust air from the 241-Z Complex is continuously monitored and sampled any time forced ventilation is occurring through the stack. The monitoring system alarms locally and in Room 714 (MICON™ power control room) of Building 234-5ZA.

5.4.1.1.5 The 242-Z Building.

Ventilation Supply. Ventilation supply air is provided to the 242-Z Building through the Building 234-5Z supply plenum and the S-3A distribution duct (Figure 5-7).

Zone 3 Ventilation Supply. Supply air is introduced through ceiling diffusers that provide downflow ventilation to the various building areas, and is classified as zone 3 for contamination control.

Zone 4 Ventilation Supply. Air supply to the zone-4 gloveboxes and process cells is provided through HEPA filters installed near the floor. Supply air is manually regulated by dampers to provide a zone 3 pressure of 0.2 in. w.g., with respect to outside atmosphere.

Ventilation Exhaust.

Zone 3 Ventilation Exhaust. Air from zone 3 (exhausted through grills near the floor in the various rooms) was originally filtered through the Building 234-5Z single-stage HEPA filtration system on the E-3 exhaust. Following the 1976 ion exchange column rupture and resultant contamination spread in the 242-Z Building, four in-parallel HEPA filters were installed on the zone 3 exhaust in the Building 234-5Z duct level, upstream of the Building 234-5Z E-3 HEPA filters, to provide treatment through two stages of testable HEPA filters before exhaust to the Building 234-5Z plenum (Figure 5-7).

Zone 4 Ventilation Exhaust. Air from zone 4 is filtered through a HEPA filter installed on the glovebox exhausts and by a single-stage testable HEPA filter in room 308, then routed to the Building 234-5Z E-4 exhaust system where it is filtered through an additional testable stage of HEPA filtration (room 309 or 310) before being exhausted to the Building 234-5Z plenum (Figure 5-7).

As with all zone 3 and 4 filters throughout the building, each filterbox is equipped with local or remote DP measurement devices to monitor filter performance. Pressure readings are recorded as a part of routine building surveillance activities.

5.4.1.1.6 The 291-Z Building and the 291-Z-1 Stack.

Ventilation supply air for the various rooms (except for the plenums in rooms 503, 507, 508, and 510) is provided at the rate of approximately 22,000 ft^3/min by five fans (EC-11, -12, -13, -14, and -15). The five fans are operated as evaporative coolers during the summer. Two fans supply the south end of the building through room 507, two supply the north end, and one supplies rooms 500 and 501. During the summer months, the supply is conditioned by evaporative cooling; otherwise, unheated outside air is supplied.

Supply air is not distributed by duct work and diffusers to this normally unoccupied building. Ventilation exhaust air is discharged to the atmosphere by natural flow, counter-weighted dampers directly to cowls on the roof. The dampers control the exhaust flow to maintain a small positive pressure in the building. The 291-Z-1 exhaust stack has a design flow of 395,700 ft^3/min. Room and equipment locations for the 291-Z Building are shown in Figure 5-6, sheet 1.

One near-isokinetic CAM unit monitors the ventilation exhaust air released through the 291-Z-1 stack at the 50-ft level of the stack. Two sampler pumps, one for the CAM and one for the record sampler, provide continuous air sampling at 2 ft^3/min each. Sample filters are changed periodically, samples are analyzed, and radioactive emissions are calculated. The monitoring system will alarm locally and in room 714 (MICON™ power control room) in the 234-5ZA Building. Backup power is provided for operation of the sampler/monitor and alarm systems.

5.4.1.1.7 The 2736-Z Support/Storage Complex. The 2736-Z Support/Storage Complex consists of the 2736-Z Building (primary plutonium storage facility), the 2736-ZA Building (exhaust ventilation building), the 2736-ZB Building (materials receiving and handling building), 2736-ZC enclosed area, 2736-ZD vault, and the 2721-Z Building, which houses three diesel-powered generators used for supplying standby electric power. The ventilation system for the 2736-Z Support/Storage Complex is shown in Figure 5-49.

The 2736-Z Support/Storage Complex HVAC system is monitored remotely from the 234-5ZA Building, room 714 (MICON™ power control room). A local control unit (LCU), cabinet number 6, located in room 602 in the 2736-ZB Building receives information from the monitoring and measurement instruments (e.g., pressure transmitters and flowmeters) and transmits this information to the PFP distributed control system's (DCS) operator consoles located in rooms 714

and 712. Operator commands initiated at the consoles are routed to LCU-6, which maintains desired zone pressures. Switching equipment on and off (e.g., supply and exhaust fans) is done manually or automatically from the control room. The DCS has internal and external diagnostic capabilities that can alert the operator of equipment malfunction or loss of data communications between the LCU and the operator consoles. If the LCU fails or all power is lost, the HVAC will fail in a predetermined, safe configuration to maintain confinement by shutting down the supply and exhaust fans and positioning dampers to a non-energized state. The PFP DCS is on backup power and UPS.

Ventilation zones for the 2736-Z Support/Storage Complex and their associated controls assure confinement of radioactive materials, although zone designations are reversed from those for other PFP buildings, follow the same confinement philosophy. Air is controlled to flow from areas where radioactive contamination would not normally be present (zone 4) to zones with increasing potential for air contamination by maintaining DPs between zones.

2736-Z Building. HVAC supply air is provided by fans in the 2736-ZB Building, and exhaust ventilation is supplied by fans in the 2736-ZA Building.

Ventilation Supply. Fans SF-5 and SF-6, located in room 602 of the 2736-ZB Building (Figure 5-49), each with a capacity of 6,000 ft^3/min, provide 12,000 ft^3/min of conditioned air during simultaneous operation. The required supply airflow can normally be provided by one fan with the other on standby; however, dissipation of the radioactive decay heat from plutonium material may require simultaneous fan operation to maintain the desired 2736-Z air temperature. Steam coils and temperature control instrumentation provide a controlled supply air temperature during the winter months. During the warmer seasons, refrigerated cooling provides supply air at the desired temperature. Standby electric power for operation of the supply fans, control instrumentation, LCU-6, the criticality alarm system (CAS), fire detectors and alarms, and CAM units is provided by diesel-generators located in the 2721-Z Building.

If normal electrical power fails, storage batteries provide power for the continued operation of the LCU-6/DCS, CAS, fire detectors and alarms. Design capacities of the battery backup systems were based on the load serviced. The battery systems are not seismically qualified and do not provide Institute of Electrical and Electronic Engineers (IEEE) Class 1E power.

The 2736-Z Building contains four vaults for storage of packaged plutonium material and a hallway, with air locks, running the length of the building. Vault 1 contains 68 storage cubicles, each with continuous airflow provided through a ventilation supply duct attached to the top of each cubicle. Thermocouples in the top of each cubicle provide air temperature monitoring. Supply air to vaults 2, 3, and 4 is through ceiling diffusers located near the wall of each vault, adjacent to the hallway. Automatically adjusted dampers control the supply air to each vault in the 2736-Z Building. The CAMS are located in each vault to monitor the status of work-place airspace.

Ventilation Exhaust. Exhaust air from the 2736-Z vaults is collected through ceiling exhaust grills and ducts located near the outside walls (east or west) in each room. Approximately 12,000 ft^3/min of exhaust air from the

2736-Z Building is filtered through two stages of HEPA filters located in the 2736-ZA Building (Figure 5-49). The filtered exhaust air is discharged to the atmosphere through the 296-Z-6 stack, a stack 14 ft 8 in. high in a 36-in. by 22-in. rectangular configuration, which extends 30 in. above the roof of the 2736-ZA Building. The stack is constructed of carbon steel. Two exhaust fans (EF-1-1 and EF-1-2), each with a capacity of 6,000 ft^3/min, and four HEPA filters (two banks of two in-series), which provide two stages of HEPA filtration for the ventilation exhaust, are located in room 650 of the 2736-ZA Building. Either exhaust fan can provide the required ventilation exhaust flow with the second fan and one bank of filters on standby, except that if both supply fans are operating, both exhaust fans also operate.

Filtered exhaust air is near-isokinetically sampled and continuously monitored for airborne radioactive particulate contamination. CAM high radiation, failure, and loss of sample/monitor vacuum alarms annunciate in the room 714 (MICON™ power control room) in the 234-5ZA Building. Air sample filters are periodically changed, analyzed, and radionuclide emissions are calculated (see Chapter 8.0, Section 8.5.2.9 for more details on the ambient air sampling and monitoring systems).

The 2736-Z Building ventilation system control instrumentation normally maintains the building pressure at -0.30 in. w.g. If the pressure increases to -0.05 in. w.g., visual and audible alarms in the 234-5ZA Building MICON™ power control room (room 714) alert the power operator to take action to restore the desired building air pressure. Loss of the EF-1-1 or EF-1-2 exhaust fans is also alarmed in room 714 of the 234-5ZA Building. The 2736-Z Building is classified as a ventilation zone 2 facility. The supply and exhaust systems are shown in Figure 5-49.

The 2736-ZA Building. The 2736-ZA Building, approximately 5 ft west of the 2736-Z Building, consists of two rooms. Room 649 houses controls for operation of the EF-1-1 and EF-1-2 exhaust fans and associated instrumentation and controls, CAMs, a stack sampler, and an instrument air compressor, which are housed in room 650. Backup power for Building 2736-ZA equipment comes from the three diesel-generators in Building 2721-Z via MCC-EP-1 in Building 2736-ZB.

Ventilation Supply and Exhaust. Ventilation supply air for room 650 is normally provided by in-leakage (Figure 5-49); however, in the event that room 650 air temperature is greater than or equal to 95 °F, a temperature controller activates a motor controlled damper that allows filtered room air to be exhausted to the atmosphere through two stages of HEPA filtration by exhaust fans EF-1-1/EF-1-2. Should the room temperature increase to greater than or equal to 105 °F, the temperature controller will activate another motor controlled damper that allows additional filtered room air to be exhausted to the atmosphere through two stages of HEPA filtration by the exhaust fans EF-1-1/EF-1-2. Room air intake for the exhaust system, through either F-3-1 or F-3-2, allows filtered outside air to be drawn into the room. Electric heaters with temperature controls provide winter heating. Figure 5-49 shows the ventilation supply and exhaust systems of the 2736-ZA Building. Supply and exhaust ventilation for room 649 is provided by wall louvers.

The 2736-ZB Building.

Ventilation Supply. Ventilation air for the 2736-ZB Building is supplied by two systems (Figure 5-49).

One system provides conditioned air (steam heated or refrigeration cooled and filtered) by using two supply fans, SF-1 and SF-2, located in room 602 of the 2736-ZB Building. Each fan has the capacity to provide 8,800 ft^3/min of supply air for distribution to all areas of the building except that portion housing the NDA laboratory. Normal supply air ventilation requirements are provided by one operating fan with the other on standby. The fan distributes 2,600 ft^3/min to ventilation zone 4 areas (e.g., lunchroom, offices, restrooms), with the remainder to ventilation zone 2 areas. Air supplied to zone 4 restrooms is exhausted to the atmosphere by exhaust fan EF-3. Air is supplied to the zone 1 repackaging glovebox from the dry-air system discussed in Section 5.4.3.1.3.

The second system provides filtered, conditioned air to the NDA laboratory section of the building with supply fans SF-3 and SF-4 (one operating, one on standby) at a flow rate of 6,300 ft^3/min. The supply air is maintained at the required temperature by electric heating in winter and refrigeration cooling during the warmer seasons. Supply air is distributed to the NDA areas through supply ducts and ceiling diffusers.

Ventilation Exhaust. Zone 1 exhaust air from the repackaging room and glovebox access hoods is filtered through a single-stage HEPA filter (two discharge ports, each filtered). Glovebox exhaust is through a HEPA filter installed on the outlet. These filtered exhausts, together with zone 2 exhaust air; unfiltered vacuum-pump exhaust from room air sampling; and exhaust air from the 2736-ZB Building, room 600 (zone 3), which houses the ventilation exhaust fans EF-1 and EF-2, HEPA filters, etc., are combined, filtered through two additional stages of HEPA filtration, and discharged to the atmosphere through the 296-Z-5 stack. The 296-Z-5 stack is 27 ft 7 in. high with a 34 in. diameter The stack is constructed of stainless steel. One exhaust fan (EF-1 or EF-2) provides the necessary exhaust ventilation flow (approximately 7,200 ft^3/min) with the other on standby. Redundant HEPA filtration is provided by four filter banks, two in parallel operation and two on standby. Stack discharge air is continuously sampled and monitored (Giller 1994a). Stack CAM high-radiation, failure, and loss-of-sample/monitor vacuum alarms are annunciated in room 714 (MICON™ power control room) in the 234-5ZA Building. Room CAM alarms (high rad/failure) alarm in the RCT office (room 631 of the 2736-ZB Building). Sample filters are periodically changed, analyzed, and radionuclide emissions are calculated. Backup power is provided for operation of the monitor, alarm systems, and the 2736-ZB ASV pump.

A heat exchanger system, consisting of two heat transfer coils, a pump, and interconnecting pipes filled with ethylene glycol, is used for recovery of heat/cold from the 2736-ZB ventilation exhaust. A heat transfer coil upstream of the EF-1/EF-2 exhaust fans is heated/cooled by the exhaust flow. When the outside air temperature is below 68 °F or above 80 °F, the ethylene glycol is recirculated to the preheater/precooler coil, located in the air supply duct upstream of the steam heater and the refrigeration unit, to provide preheating/precooling to conserve energy.

Exhaust air is collected from the NDA laboratory by three, HEPA-filtered exhaust ducts. These filtered exhaust flows are combined, filtered through two additional stages of HEPA filtration, and recycled to the NDA supply system by fans RF-1 and RF-2. Recycled air (approximately 400 ft^3/min) is diverted to provide supply air for the mechanical equipment room (room 600). Redundant HEPA filtration is provided by four filter banks, two in parallel operation and two on standby. The recycled air is continuously sampled and monitored for radioactive content by a CAM. If radioactive content of the air exceeds the allowable limit for breathing air (airborne concentrations exceeding 10% of the applicable DAC), an alarm annunciates at the MICON™ power control room (room 714) of the 234-5ZA Building and the RCT office in room 631 of the 2736-ZB Building, and activates EV-19 to allow dampers D-17 to open, D-6 to open, and D-18 to close. This diverts the ventilation recycle exhaust air for discharge to the atmosphere through the 296-Z-5 stack. After radiation levels recede back to acceptable concentration levels, EV-19 is manually reset to place the ventilation air recycling system back into a recirculating mode. The NDA ventilation supply and exhaust now becomes a once-through system until the air monitor indicates that recycling of exhaust air can be resumed. The 2736-ZB Building supply and exhaust ventilation systems are shown on Figure 5-49.

The NDA laboratory is classified as a ventilation zone 2 with the pressure maintained at -0.20 in. w.g. An LCU, located in room 602, controls the dampers, supply/exhaust fans, and the heating/cooling of the laboratory. Loss of pressure control, temperature control, loss of a supply or exhaust fan, and other trouble situations are alarmed in the 234-5ZA Building MICON™ power control room (room 714), which is attended at all times. The operator can assume manual operation of the system to provide the necessary corrective action.

The 2721-Z Building. The 2721-Z Building, located approximately 26 ft west of the 2736-ZB Building, houses three diesel-driven generators and associated switchgear that provide backup electric power for the PFP. Normal supply ventilation is discharged to the atmosphere through wall louvers with exhaust ventilation powered by two electric, through-the-wall exhaust fans, one on the north wall and one on the south wall. A temperature controller turns on the exhaust fans when cooling is required and electric heaters when heating is required. Room air conditioning is provided for the switchgear in Building 2721-Z to provide temperature control for the generator synchronizing and control components.

Additional supply and exhaust airflow is required during operation of the diesel generators. On startup of a diesel generator, a motorized exhaust damper and the inlet damper open simultaneously, which provides air for combustion and for cooling the generator. Each generator cubicle has associated inlet/outlet dampers. The inlet/outlet dampers automatically close when the diesel generator is shut down. Diesel exhaust is discharged to the atmosphere via through-the-wall piping.

5.4.1.1.8 243-Z Building.

Ventilation Supply. Ventilation supply air (approximately 1,400 ft^3/min) is provided to the 243-Z Building by a single manual on/off supply fan. The supply fan draws outside air into the building from an outside air louver and

filter section. The air is heated, when required, by a duct-mounted electric heater with a thermostat. A flow switch shuts down the HVAC system if no air flow is detected after 1 min. A freezestat turns off the exhaust fan and the supply fan when air temperature downstream of the duct heater is 35 °F or less and activates an alarm light in the HVAC control panel.

Three single-package air conditioning units (manually starting only) can be operated during the summer months. These units are interlocked with the exhaust fan and can only be operated when the exhaust fan is operating. Unit heaters are energized by individual remote wall thermostats when the space temperature drops to 45 °F or lower.

Ventilation Exhaust. The exhaust fan will maintain the building under 0.1 in. w.g. by exhausting slightly more air (approximately 1,600 ft^3/min) than is being introduced through the outside air intake. Shutoff dampers will fail closed and seal the building from the outside in the event of power failure, fire, or scheduled fan maintenance. A backdraft damper will close on a reverse of air flow through the intake plenum. Air is transferred through the open-faced drum turning hood enclosure and passed through a prefilter and HEPA filter bank before being exhausted out the 45 ft tall 296-Z-15 stack.

5.4.1.2 Safety Considerations and Controls.

5.4.1.2.1 Ventilation Supply and Exhaust Systems. Supply air for normally occupied areas is filtered, washed, heated as required, and distributed by supply fans, a supply plenum, control dampers, and control instrumentation. Redundant supply fans in room 321 of the 234-5Z Building (Figure 5-44) and in room 602 of the 2736-ZB Building (Figure 5-49) assure that supply ventilation air is provided to the facilities for personnel comfort, process ventilation, contamination control, and for equipment and/or other cooling needs during supply system component failure or scheduled maintenance.

Supply plenum pressure (234-5Z Building) is maintained automatically at +2 in. w.g. by control dampers on supply units 2, 3, and 4, two of which normally operate. The plenum is protected from overpressure by relief dampers that exhaust outside the building.

Pressures in zones 1, 3, 3A, and 3B are controlled automatically by regulation of the supply dampers. Differential zone pressures assure that airflows should be from lowest to highest contamination potential. Zone pressures are provided by instrumentation with indicators located on the panel board in the control room (room 321). The power operator has the ability to override the automatic damper controls to increase/decrease zone pressures to the desired procedural values. Abnormal zone pressures are alarmed visually and audibly in the control room.

The numerical identification of ventilation zones in the 2736-Z Support/Storage Complex is reversed from that used for the major portion of the PFP facilities (e.g., zone 1 is contaminated and zone 4 is clean in this complex). The Zone DPs are controlled by the MICON distributed control system. The software control is contained in the configuration management plan, (HNF 1998). The software program is provided in the computer software document (WHC 1999). The power operator in room 714 (MICON™ power control

room) in the 234-5ZA Building has the capability to override the computer control to increase/decrease zone pressures to the desired values. Abnormal zone pressures also are alarmed visually and audibly in the MICON™ power control room.

Air locks, provided between a clean zone and a potentially contaminated zone, minimize the potential for contamination of the clean zone in the event of a flow reversal. Similarly, HEPA filters installed on ventilation air supplied to a contaminated zone (e.g., glovebox, process cell) minimize the potential for contamination release from the contaminated zone.

Redundant installed exhaust fans (in the 291-Z Building) and redundant operating exhaust fans (in the 2736-ZA and 2736-ZB Building) are provided to maintain desired zone pressures and exhaust flows during component failure and/or maintenance. Two of the seven electric-motor-driven exhaust fans in the 291-Z Building are connected to diesel-generators in the 2721-Z Building to ensure the 234-5Z Building remains under slightly negative pressure in the event normal power is lost (one of the two emergency exhaust fans operates with the other as a standby). Inlet dampers to the emergency exhaust fans are electrically operated (with backup power, if necessary). High pressure indication in the exhaust plenum results in the automatic shutdown of the supply fans in room 321 of the 234-5Z Building to minimize the potential for pressurizing ventilation system zones.

Backup electric power is also provided for operation of the 2736-ZA and 2736-ZB Building exhaust fans and HVAC control and monitoring circuits. Uninterruptible power (storage batteries) will power LCU-6/DCS for ventilation control for a limited time on loss of normal and backup electric power.

Fire dampers and fire screens are only briefly described in Section 5.4.1. A study of fire potential and consequence concludes that fire dampers are not required (Goodwin 1987).

5.4.1.2.2 Air Cleaning Systems. Exhaust gases from potentially contaminated and contaminated ventilation zones flow through HEPA filters before discharge to the atmosphere. Prefilters and filter media are used for air exhausted from zone 3 areas into the E-3 exhaust system duct work. The use of these prefilters helps control buildup of lint and dust within the system duct work. Since there is no way of testing the prefilters, credit for their filtration of radionuclides cannot be taken.

The HEPA filters consist of a continuous sheet of molded glass medium pleated back and forth over itself so that it is self-supporting. The medium is permanently bonded to an outer casing of plywood or metal that extends the full depth of the medium (Figure 5-50). The HEPA filters are tested in place and have a minimum particle removal efficiency of no less than 99.95% and a maximum resistance, when clean, of 1.0 in. w.g. when operated at rated airflow capacity.

Installed HEPA filters are tested in accordance with and meet the requirements of ASME N510. Periodic retesting meets or exceeds ASME N510 requirements and demonstrates that the filters are performing satisfactorily. Those filters that fail to meet ASME N510 requirements are replaced.

The DP readings are taken periodically across the E-3 and E-4 filter rooms and E-4 filterboxes. Those filters that can be visually inspected are inspected periodically for sagging, discoloration because of moisture, or collection of crystals on the filter. If the damage appears to be severe, the filter may be changed out.

If a problem is discovered during examination of a HEPA filter, an NDA of the HEPA filterbox is performed to check for buildup of contamination (e.g., plutonium) on the filter or its containment. This NDA is performed in accordance with approved analytical procedures using gamma ray spectroscopy. Locations on the filterbox, or filter, are marked, and NDA measurements are performed at specified distances in accordance with solid-angle calculations. Attenuation calculations are also performed to account for container material density with calibration based on the self-attenuation of the material matrix being assayed. The procedures used have been reviewed and concurred with by Los Alamos National Laboratory technical staff, Pacific Northwest National Laboratory (PNNL) technical staff, and numerous other outside technical organizations (e.g., Westinghouse Idaho Nuclear Company, U.S. Department of Energy-Headquarters, and Safeguards overviews).

Air from potentially contaminated ventilation exhaust zones (zone 3) is filtered by at least one stage of testable HEPA filtration before discharge to atmosphere (E-3 ventilation exhaust system). Redundant filters or filter banks are provided so that failed filters may be isolated for replacement with continued filtration service provided by the installed spares.

Air from known contaminated ventilation exhaust zones (zone 4) is filtered by at least two stages of testable HEPA filtration before discharge to the atmosphere through a stack (E-4 ventilation exhaust system). The E-4 exhaust systems normally contain a HEPA filter on the glovebox or cell exhausts with the first testable HEPA filter located in a filterbox on the duct level or the second floor of the 234-5Z Building. Exhaust flows from these filters are manifolded to one of two rooms (309 and 310), each containing a bank of testable HEPA filters (second stage), before discharge to the atmosphere through a stack. The HEPA filter inlet air is treated as necessary to prevent moisture accumulation within the filters. The 241-Z below grade storage tanks vent exhaust is heated to preclude HEPA filter wetting.

The ventilation exhaust system which had potential for hydrogen fluoride (HF) gas contamination contained HEPA filters that were segregated from the E-4 exhaust system to preclude HF damage to the E-4 HEPA filters in rooms 309 and 310. Following the cessation of the HF operation, ventilation exhaust from these areas was rerouted through the E-4 filter manifold. Filterboxes FB-9A, FB-9B, and FB-9AB, which were used to filter the potentially HF-contaminated exhaust air, were removed from service and isolated from the RMC Line in 1996 to reduce plutonium holdup in the ventilation system. The FB-9A and FB-9B by-pass line was also removed to reduce plutonium holdup.

5.4.1.2.3 Air Monitoring Systems. Monitoring for airborne radioactive material is performed by CAMs in occupied areas where the possibility of airborne contamination exists. The location and function of these CAMs in the PFP is discussed in detail in Chapter 8, and the associated alarm

communication is discussed in Section 5.4.10. Airflow is provided for the fixed head sampling units and CAMs by the ASV system. Small, portable, self-contained CAM units are also employed to ensure uniform coverage. Airborne radioactivity is alarmed locally, and for some installations, remotely, at the appropriate radiological control office; room 221A radiological control office in the 234-5Z Building, and room 631 radiological control office in the 2736-ZB Building.

CAMs are also provided to monitor selected filter inlet and outlet streams and for gases discharged to atmosphere through the PFP stacks; 291-Z-1, 296-Z-3, 296-Z-5, 296-Z-6, and 296-Z-14. Stack CAM high radiation, failure, and loss-of-sample/monitor vacuum alarms annunciate in room 714 (MICON™ power control room) in the 234-5ZA Building. Backup power, with the exception of the 296-Z-3 stack discussed earlier and the 291-Z air sample vacuum pump which supplies vacuum for the 296-Z-6 sampler and monitors, is provided for operation of the monitor, alarm systems. Stack flows are isokinetically sampled to provide representative samples of stack discharges. Samples are periodically changed and analyzed for radioactive content.

The PFP ventilation supply and exhaust system, the air cleaning system, and the air monitoring system have been reviewed for compliance with the requirements in DOE Order 6430.1A (DOE 1989). The results of this conformance evaluation are presented in Table 3 of WHC (1990).

5.4.1.2.4 Seismic Fan Shutdown System. The seismic shutdown system monitors for seismic activity and shuts down key ventilation supply fans to prevent pressurization of the 234-5Z and 236-Z Buildings if an earthquake of magnitude 0.07 g or greater is detected. The system also shuts off power to the 234-5Z Building exhaust fans, with the exception of the emergency exhaust fans (EM-1 and EM-2). Several other systems are connected to the seismic shutdown switch including the Laboratory Prototype Calciner (See the Laboratory Prototype Calciner addendum to this FSAR, Section 2.3.3.2.12). The seismic fan shutdown system consists of three major components; redundant accelerometers, manual shutdown button, and a dedicated UPS. The seismic accident analysis in Chapter 9.0, Section 9.2.4A assumes that the redundant accelerometer portions of the seismic fan shutdown system are in place and operating. When the 234-5Z Building ventilation system is shut down, the supply fan dampers fail in the open position and the exhaust dampers, except those leading to the emergency exhaust fans EM-1 and EM-2, fail in the closed position. The emergency exhaust fans and their inlet dampers are not connected to the seismic fan shutdown system and may continue to operate following the seismic event should normal or backup power be available and the equipment not significantly damaged in the event. On loss of both normal and backup power, the inlet dampers to the emergency exhaust fans are designed to fail open. This allows natural drafting through the 291-Z-1 exhaust stack.

The primary components in each redundant accelerometer-activated system located on the first floor of the 234-5Z Building in corridor 14 (Figure 5-6, sheet 1) are as follows:

- An accelerometer system with two horizontal force-balance accelerometers oriented in the north-south and east-west directions with a latching output relay

- Two seismically qualified relays
- An online/bypass switch to allow maintenance of the accelerometer without interfering with ventilation system operation.

The redundant accelerometer-activated systems deactivate seismically qualified circuit breakers for the ventilation supply fans in room 266 and seismically qualified contactors for the stage 2 process fans in room 321. No power is required for the redundant accelerometer activated systems to perform these actions.

The manual shutdown system provides a means for an orderly shutdown of the normal ventilation system and a back-up method for a seismic event if both accelerometer-activated systems fail. Activation of the manual shutdown system immediately shuts down all the supply fans and miscellaneous exhaust fans. After a delay of about 20 s, the main exhaust fans (except fans EM-1 and EM-2) in the 291-Z Building are shut down. Manual shutdown of the ventilation system is enacted from the Room 321A power control room in Building 234-5Z. Power for the seismic fan shutdown system is provided by a UPS located adjacent to the accelerometers in corridor 14.

The ventilation seismic shutdown system is also interconnected with Laboratory Prototype Calciner equipment to terminate operations during a seismic event. This minimizes the potential radiological releases from the calciner process equipment resulting from the seismic event. The interconnection with the shutdown system and the resulting effect on the calciner equipment due to the seismic event is described in the Laboratory Prototype Calciner addendum to this FSAR.

5.4.2 Electrical Systems

5.4.2.1 Major Component and Operating Characteristics. Major components in the supply of electric power to the Hanford Site, individual processing plants, processing systems, monitoring systems, and alarm systems are high voltage transmission lines, transformers, large switchgear units, diesel generators, and dc battery stations. These components are designated either as safety significant or general service.

The high-voltage transmission lines are at two voltage levels, 230 kV and 13.8 kV. The building distribution is three-phase 480 V and 208Y/120 V. Three diesel-generators in Building 2721-Z provide Standby electrical power to monitoring equipment, alarm and evacuation systems, and other essential equipment when normal electrical power is not available (see Section 5.4.2.1.9). The PFP also has several UPS systems to provide continuous power to programmable controllers, facility computers, plant monitoring, and plant communication systems (see 5.4.2.1.16).

5.4.2.1.1 Electrical Supply (230 kV) System. Electrical power to the Hanford Site is supplied from the BPA substation at Midway through a 230-kV transmission loop and a 230-kV single transmission line from the H. J. Ashe switchyard. Transmission is at 230 kV, three-phase, 60 Hz, and electrical power for the 200 Areas is received at the 251-W substation (see Figure 5-51).

At the 200 Area substation, 230 kV is stepped down by two transformers to 13.8 kV/three-phase/60 Hz. From the 251-W substation, electrical power is supplied to the 200 East Area and the 200 West Area at 13.8-kV. The transformers, incoming lines, and switches at the 251-W substation are physically separated to prevent failure of one component from involving others. Although the 230 kV system is not seismic category I, the system was designed to BPA standards for public power stations, which included IEEE standards and guidelines current to the time of design.

5.4.2.1.2 Electrical Supply (13.8 kV) System. Circuits C8-L1, C8-L2, C8-L3, and C8-L4 supply the electrical power to the 200 West Area. Circuits C8-L1 and C8-L4 are carried on a common pole at the west side of the 200 West Area and circuits C8-L2 and C8-L3 are carried on a common pole on the east side of the 200 West Area. The 13.8 kV pole transmission lines from the 251-W substation to the PFP are not Seismic Category I. The transmission line system is designed to BPA standards for public power stations, which included IEEE standards and guidelines current to the time of design (though they are not seismically qualified).

13.8 kV, Lines C8-L1 and C8-L2. These lines provide the largest electrical power load to the PFP, 13.8-kV substations, and the principal buildings (Figure 5-52):

- Substation C8-S6 (also known as 252-Z-1) for the 234-5Z Building with transformers C2505F and C2506F, each 1,000 kVA, 13.8 kV/480 V, three-phase, Wye/Delta
- Substation C8-S19 (also known as 252-Z-2) for the 291-Z Building with transformers C0380F and C0385F, each 1,000 kVA, 13.8 kV/480 V, three-phase, Wye/Delta
- Substation C8-S46 for the 2736-ZB Building, with transformer C5874P, 500 kVA, 13.8 kV-480/277 V, three-phase, four-wire, Delta/Wye
- Building 2702-Z, 3-10 kVA, 13.8 kV-208Y/120 V transformer.

Either line, C8-L1 or C8-L2, is capable of supplying power to meet the 13.8-kV connected load requirements of the PFP; however, during normal plant operating condition, the PFP load is divided between the two lines.

- Transformers C2505F, C0380F, and C5874P are connected to line C8-L1
- Transformers C0385F and C2506F and the remaining above listed loads are connected to line C8-L2.

13.8 kV, Line C8-L4. This line provides normal electrical power for the remaining PFP loads and pole-mounted transformers for smaller buildings (Figure 5-52):

- The 2701-ZA and 2701-ZD Buildings, 1-50 kVA, 13.8 kV-240/120 V, pole-mounted transformer via ATS-3.

- The PFP security and operations control facility, the 2701-ZA, 2701-ZD, and 2705-Z Buildings, and the 3-15 kVA, 13.8 kV-208/120 V transformers.

5.4.2.1.3 Not Used.

5.4.2.1.4 Substation C8-S6 (251-Z-1), the 234-5Z Building, Room 266. In substation C8-S6, the transformers are separated physically from the switchgear. The transformers are located outside the building, and the switchgear is located in room 266 on the duct level of the 234-5Z Building. The switchgear is connected to the transformers by bus duct. At the present time normal plant operation is supplied by the >1,000 kVA temporary transformer located in position 2, which is connected to the 13.8-kV line C8-L2. The 1000 kVA transformer located in position 1, which is connected to the 13.8-kVA line C8-L1, is currently out of service. (Note; Once permanent replacement transformers are secured the temporary transformers will be replaced and the system will be returned to its original configuration.) Substation C8-S6 supplies electrical power to the 234-5Z Building and to some small loads in other buildings (see Figure 5-52). The switchgear in room 266 also supplies power to the emergency bus during normal electrical supply to the plant.

5.4.2.1.5 Substation C8-S19 (252-Z-2), the 291-Z Building, Room 500. In substation C8-S19, the transformers are an integral part of the switchgear and the transformers and switchgear are located in room 500 of the 291-Z Building (see Figure 5-52). At the present time normal plant operation is supplied by the >1,000 kVA temporary transformer located in position 6, which is connected to the 13.8-kV line C8-L2. The 1,000 kVA transformer located in position 5 is connected to the 13.8-kV line C8-L1, is currently out of service. (Note: Once permanent replacement transformers are secured the temporary transformers will be replaced and the system will be returned to its original configuration.) The substation provides electrical power to the 241-Z, 241-ZA, 241-ZG, 232-Z, 236-Z, 243-Z, 243-ZA, 243-ZB, and 2736-Z Buildings. The switchgear also supplies power to the automatic transfer switch ATS-2 during normal electrical supply to the plant. ATS-2 loads include emergency exhaust fans EM-1 and EM-2 located in Building 291-Z, the motor control center (MCC) MCC-FC for 243-ZA and 243-ZB, the 291-Z sump pumps in room 501, and panel CP.

5.4.2.1.6 Substation C8-S46, the 2736-ZB Building, Room 602. Substation C8-S46 consists of a 500 kVA pad-mounted transformer outside the 2736-ZB Building, a panelboard (NP-VF-1) north of Building 2721-Z, and load centers in room 602 (see Figure 5-52). During normal plant operation, the transformer is connected to the 13.8-kV line C8-L1. The substation provides electrical power to the 2736-ZA, 2736-ZB and 2736-ZC Buildings.

5.4.2.1.7 Summary of PFP Building Electrical Power Sources. This section provides an overview of the electrical power sources for the listed buildings. Smaller buildings are served by pole-mounted transformers.

- 234-5Z--Electrical power is supplied from substation C8-S6, room 266, the 234-5Z Building.

- 232-Z--Electrical power for building lighting is supplied from substation C8-S19, the 291-Z Building, room 500, bus 500, but the electrical control panel (MCC-1) and neutron panel have been removed. The building is supplied with electrical power from the MCC electrical panel number 1 (MCC-EP-1) in the 2736-ZB Building. A local panel in 232-Z distributes the power for fan control, instrumentation, and stack monitoring.

- 236-Z--Electrical power is supplied from substation C8-S19, room 500, the 291-Z Building.

- 241-Z, 241-ZA, and 241-ZG--Electrical power is supplied from substation C8-S19, the 291-Z Building, room 500.

- 242-Z--Electrical services to the building have been disconnected.

- 243-Z LLWTF--Electrical power comes from substation C8-S19, the 291-Z Building, room 500.

- 270-Z--Electrical power comes from substation C8-S6, the 234-5Z Building, room 266.

- 291-Z--Electrical power is supplied from substation C8-S19, the 291-Z Building, room 500.

- 2736-Z--Normal electrical power comes from the 480-V MCC-1 in the 291-Z Building, room 500. A 25-kVA transformer reduces the voltage from 480 V to 240/120 V for building electrical requirements. Standby electrical power is supplied from panel PCV-3 in the 234-5Z Building.

- 2736-ZA--Normal electric power is supplied from 13.8 kV line (C8-L1) to a 500-kVA, 13.8 kV to 480/277-V, pad-mounted transformer via panel NP-VF-1 located at the north end of Building 2721-Z. Standby power is supplied from the three diesel-generators in Building 2721-Z via MCC-EP-1 in Building 2736-ZB.

- 2736-ZB--Electric power is supplied to the building from the 13.8-kV line (C8-L1) to a 500-kVA, 13.8-kV to 480/277-V, pad-mounted transformer. The main power distribution centers are located in mechanical room 602. Electric power is provided to the 2736-ZC Building.

- 2904-ZA and 2904-ZB--Electric power is provided to these buildings from the 234-5Z 480-V distribution system as 480-V single phase.

- 2704-Z--Electric power is provided from substation C8-S6, the 234-5Z Building, room 266.

- General Area Lighting--Electric power to the general area lighting is provided from various electrical panels. The source of the power is the closest source to the area requiring general lighting.

5.4.2.1.8 240-V, 208-V, and 120-V Service. Power required for equipment less than 480 V (i.e., lighting, cranes, etc.) is provided by 480-208Y/120 V, 13.8 kV-240/120 V, or 480-240/120 V transformers. Power to the stepdown transformer is provided from the 480-V distribution circuit breaker panels.

5.4.2.1.9 Standby Electrical Power Available to the PFP. Standby electrical power is available to the PFP for DOE-, ANSI-, NFPA-, or IEEE-defined emergency systems. These emergency systems include monitoring systems, audible (siren) systems, fire alarm systems, some criticality alarm systems, security systems, emergency lighting, and some building ventilation systems.

Under normal operating conditions, emergency bus loads and the central 125-Vdc stationary battery chargers are supplied with power from normal 480-V buses and panels. The self-contained battery operated emergency lights are being charged by the ac branch circuit powering the normal lighting in the same area. The following standby electrical power sources are available to the PFP.

- Three, 325-kW, diesel generators in the 2721-Z Building, west of Building 2736-ZB, comprise the largest portion of standby power for the PFP.
- A central, 125-Vdc, stationary battery station to provide continuous dc power.
- Self-contained, fully automatic, battery operated emergency light packs.
- UPSs.

In the event that normal power to the 200, 300, and 400 buses are interrupted, the electrical switchgear in room 266 automatically disconnects the 400 bus by opening F8X340, starting the diesel generators, and closing F8X309 to connect the 400 bus to the generators.

5.4.2.1.10 Three, 325-kW, Diesel Generators in the 2721-Z Building. The diesel generators provide standby power to the emergency bus in room 266 of the 234-5Z Building, motor control center MCC-EP-1 in the 2736-ZB Building, automatic transfer switch ATS-2 in room 500 of the 291-Z Building, and automatic transfer switches ATS-3 and ATS-4 in the 2701-ZA Building (see Figure 5-52). The following is a list of emergency loads connected to the diesel generators in the 2721-Z Building on loss of normal electrical power (controlled by the transfer control panel).

- The emergency switchgear in room 266 has four feeder breakers and provides power to the constant voltage panels throughout the PFP, the 125 Vdc battery chargers in room 266, closed-circuit television system, the UPS, evacuation siren, some criticality alarms, communications equipment, and CAM units (see Figure 5-52).
- MICON™ controlled circuit breaker in power distribution panel provides power to the 2736-ZA and 2736-ZB Building emergency loads,

exhaust fans, HVAC control circuits, monitoring circuits, UPS system, perimeter lighting, etc. (see Figure 5-52).

- Automatic transfer switch ATS-2 in emergency position provides backup power to exhaust fans EM-1 and EM-2 and to panel EP-291A in the 291-Z Building (see Figure 5-52). Panel EP-291A feeds Contactor C which is controlled by the MICON™ and is capable of load shedding as necessary to keep the on-line emergency exhaust fan (either EM-1 or EM-2) provided with adequate power.

- Automatic transfer switch ATS-3 in emergency position provides power to the 2701-ZA Building emergency loads, the UPS system, and the EA series panels. The normal power to the automatic transfer switch comes from a 13.8 kV-240/120 V pole-mounted transformer C6323L connected to line C8-LA (see Figure 5-52).

- Automatic transfer switch ATS-4 in emergency position provides power panel A in the 2701-ZA Building. The normal power to the automatic transfer switch comes from a 13.8 kV-208Y/120 V pole-mounted transformer connected to line C8-L4 (see Figure 5-52).

If normal power to the transfer control panel (NP-VF-1) feeding Building 2736-ZB or to any of the transfer switches (ATS-2, ATS-3, or ATS-4) fails or assumes unacceptable limits, automatic circuity in the transfer switches will disconnect the emergency load from the normal power, start the diesel generators in the 2721-Z Building, and then transfer the emergency load to the diesel generators.

The standby power subsystems are tested to assure proper performance upon loss of electrical power. The diesel generators are tested once a month, under load, to verify proper operation of the generators. Testing of the transfer mechanism located in Building 234-5Z is performed semi-annually according to procedure. Room 308 UPS and switchgear batteries are load tested annually to verify capability to meet load demands.

A MICON™ local control unit (LCU-7), located in the 2721-Z Building, monitors and controls proper voltage levels for most of the operations in the PFP. When the computer receives a loss-of-power signal from any of the loads, it starts the diesel generators within the 2721-Z Building. The sequences of events, monitored and controlled by the MICON sytem during loss of normal power or off-normal conditions are shown in Table 5-33. Further discussion is contained in Sections 5.4.2.2.2, 5.4.2.2.3, and 5.4.2.2.8.

Upon the return and detection of normal power, the MICON system offloads the diesel generators and opens breakers 701, 702, and 703 (see Figure 5-70).

5.4.2.1.11 Not Used

5.4.2.1.12 125 Vdc Stationary Battery Station. These batteries provide direct current electrical power to the main switchgear direct current breaker control circuits in switchgear room 269 in the 234-5Z Building; room 500 in the 291-Z Building; evacuation sirens; and siren controls (see Figure 5-52).

5.4.2.1.13 Self-Contained Fully Automatic Battery Lights. These emergency light packs are installed throughout the PFP to meet NFPA 101 requirements and to provide additional lighting in areas not required by NFPA 101 to reduce safety hazard to plant personnel. They are powered by lighting circuits of the area.

5.4.2.1.14 Summary of Backup Electrical Power Source. This section provides an overview of the backup electrical power sources for the listed buildings.

- 234-5Z--Backup electrical power is supplied from the emergency switchgear in room 266, the 234-5Z Building. This is switchgear section four of the main switchgear. In emergency mode, the emergency bus is powered from the three, 325-kW, diesel generators in the 2721-Z Building.

- 232-Z--Backup electrical power for ventilation and stack sampling/monitoring is supplied from motor control center MCC-EP-1 in the 2736-ZB Building.

- 236-Z--Backup electrical power is supplied from the emergency switchgear in room 266 in the 234-5Z Building.

- 241-Z and 241-ZA--CP panel backup electrical power is supplied via the automatic transfer switch ATS-2 circuit supplying power to panel EP-291A.

- 242-Z--Backup electrical power has been disconnected.

- 243-ZA--Backup electrical power is provided to EP-291A panel board by ATS-2 from the diesel generators in the 2721-Z Building.

- 291-Z--Backup electrical power is supplied via the automatic transfer switch ATS-2 circuit supplying power to panel EP-291A, CP panel, and emergency exhaust fans EM-1 and EM-2. The backup power source is the three, 325-kW, diesel generators in the 2721-Z Building.

- 2736-Z--Backup electrical power comes from the constant voltage distribution in the 234-5Z Building to panel E in the 2736-Z Building.

- 2736-ZA--Backup electrical power is supplied from the diesel generators in the 2721-Z Building through a MICON™ controlled circuit breaker.

- 2736-ZB--Backup electrical power is supplied from the diesel generators in the 2721-Z Building through a MICON™ controlled circuit breaker.

- 2701-ZD--Backup electrical power is provided to EA-D panel board by ATS-3 from the diesel generators in the 2721-Z Building.

- 2701-ZA--Backup electrical power is provided to the UPS for the 2701-ZA Building from the diesel generators in the 2721-Z Building through ATS-3. Panel A in the building is supplied with back-up electrical power from the diesel generators through ATS-4.

- General Area Lighting--The general area lighting is not supplied with backup electrical power.

5.4.2.1.15 240-V, 208-V, and 120-V Emergency Power. Emergency power requirements (less than 480 V for the above listed buildings) are obtained by 480-208Y/120-V or 480-240/120 V stepdown transformers. The power source for the stepdown transformers is the electrical emergency system in the immediate area or building.

5.4.2.1.16 Uninterruptible Power Supply System. The PFP has several UPS systems to provide continuous power to programmable controllers, facility computers, plant monitoring, and plant communication systems (Figure 5-53).

All UPS systems are connected to the plant backup electrical system. If power is lost to the plant facility, the batteries associated with the UPS system will continue to provide uninterrupted electrical power to the UPS connected loads. When the emergency electrical system is re-powered by the diesel generators, the UPS load is shifted from the UPS batteries to the emergency electrical system. Although there is no defined service life for the batteries of the numerous UPS systems, they have each been designed and sized to properly function during the transition from loss of normal power to backup power. Each system of batteries is functionally tested and maintained, in accordance with approved preventative maintenance procedures at specified intervals based on the system's safety categorization. The UPS systems installed in the PFP are as follows:

- The 234-5Z Building, corridor 14--Seismic shutdown system

- The 234-5ZA Building, room 308--MICON™ control system and material accountability systems

- The 2701-ZA Building--Security systems

- The 2721-Z Building, room 647--MICON™ local control unit and controller for diesel generators

- The 2736-ZB Building, room 623--Ventilation system, safeguards, computers, security cameras

- The 234-5Z Building, room 267--Private automatic exchange (PAX) switcher

5.4.2.2 Safety Considerations and Controls. The electrical high-voltage distribution system on the Hanford Site was designed and installed as a dual system. The PFP 480-V electrical distribution system was divided between normal electrical loads and emergency loads; emergency loads are those loads that will receive electrical power from diesel generators or batteries when the normal utility power is not available. Switching of emergency loads from

the normal electrical power system to diesel generators or batteries is automatic.

5.4.2.2.1 Historical Background. The electrical distribution system on the Hanford Site was installed in the early 1940's in accordance with codes and requirements in force at the time. The high-voltage distribution system (230 kV and 13.8 kV) was designed as a dual transmission system. With the dual transmission system, all plant loads can be switched to one transmission line, and the plant can continue to operate at full capacity. This system permits maintenance or repair to be performed on one or the other transmission line without affecting plant operation.

The same design practice was instituted in the plant electrical distribution system by dividing heavy plant loads between switchgear sections/transformer banks and by the addition of a plant emergency electrical distribution system. Loads requiring emergency electrical power are connected to this system.

5.4.2.2.2 Loss of Normal Power. When power from the BPA is not available, automatic voltage sensing circuits senses an under-voltage condition and initiate a signal to start the diesel generators. After the diesel generators have reached operating voltage and frequency, the backup power system loads are transferred to the diesel generators. The diesel-generator electrical system is designed to respond to a partial or total loss of normal power to the three automatic transfer switches, MCC-EP-1 in Building 2736-ZB or to the emergency switchgear bus (see Figure 5-52).

5.4.2.2.3 Emergency Load Transfer Method. The three automatic transfer switches respond independently to loss of normal power for the systems they service and transfer the loads to the diesel generators in the 2721-Z Building. The emergency switchgear in the 234-5Z Building, room 266 provides switching by opening the normal supply circuit breaker and closing the emergency supply circuit breaker. These breakers have a three-level electrical interlock, preventing both breakers from closing at the same time. Switching the emergency loads to the diesel generators will take place when the diesel-generator frequencies are synchronized and the diesel-generator voltage is within specified limits. Backup power is supplied to Building 2736-ZB by opening the normal power circuit breaker and closing the backup power circuit breaker in Building 2721-Z.

When normal power is reestablished, the transfer switches are automatically reset to their normal positions. The emergency switchgear has to be manually reset to normal position. Equipment that trips offline during a power interruption normally has to be manually reset.

5.4.2.2.4 230 kV Transmission System Reliability. The Hanford Site 230 kV transmission line loop is supplied with power from two different high-voltage circuit breakers in the Midway substation and a 230 kV transmission line tap connecting the Hanford Loop to the H. J. Ashe substation. The Midway substation is supplied with power from the Grand Coulee Dam powerhouse, Priest Rapids Dam, Wanapum Dam, and John Day Dam. The H. J. Ashe switchyard receives power from Ice Harbor Dam and McNary Dam. The 230 kV system is also backed up by the 500 kV BPA system.

Routine maintenance is performed on the transmission line by the Hanford Utility Group. The entire 230-kV transmission line system is on steel towers. A loss of power at both the Midway and H. J. Ashe substations would have to occur before the plant diesels would start (see Figure 5-51).

5.4.2.2.5 13.8 kV Transmission System Reliability. The PFP is supplied with electrical power by three 13.8-kV transmission lines from two 30,000-kVA transformers in the 251-W substation. The entire PFP electrical load including the electrical load of smaller buildings and trailers can be switched to two of the 13.8-kV transmission lines. Two of the transmission lines enter the 200 West Area on wooden poles on the west side; and the other transmission line enters the area on wooden poles on the east side.

Routine maintenance is performed on the transmission line by the Hanford Utility Group. A loss of both transformers in substation A-8 (251-West Area) would have to occur before the diesel generators would start.

5.4.2.2.6 480-V Plant Distribution System Reliability. The major portion of the 480-V load is divided between two substations. In addition, the PFP has a backup electrical system powered by diesel generators when the BPA transmission system is not available.

5.4.2.2.7 Plant Emergency System Reliability. The PFP is supplied with backup power from three diesel generators, each 325 kW, in the 2721-Z Building. Design practice does not permit the total connected load to the three diesel generators in the 2721-Z Building to exceed the capacity of two diesel units. This permits one diesel unit to be out of service for maintenance or repair.

With the diesel generator start signal, the appropriate number of diesel generators in the 2721-Z Building will start and synchronize on a common emergency bus. After a predetermined time, when the emergency load demand is stabilized and is less than the full-load capacity of two 325-kW diesels, the third diesel will sequence offline and shut down. The same sequence will repeat for the second diesel depending on load, but one diesel will remain online as long as normal power is not available.

The diesel generator fuel system has a storage capacity of 2,000 gal and no less than 1,500 gal should be on hand. Each 325-kW diesel generator (fully loaded) will consume 30 gal of diesel fuel per hour. The fuel supply system will operate the diesel generators for a period of 24 h without refueling. The diesel generator fuel system level and the general conditions of the generators are checked once every 8-h shift.

The diesel generators are run synchronized with the utility system once a month for approximately an hour. The adequacy of these systems to support the potential emergency loads shown in Tables 5-16 and 5-17 has been deemed acceptable. Redundancy exists in the form of three diesel generators; however, the distribution system has many potential single-point failure locations. Historically this backup system has operated whenever required, although the reliability of the entire system has not been analyzed. The MICON™ system provides the capability to test the generators under load. The MICON™ can apply load by sending power back through the Hanford Site power grid.

In either an emergency or long-term shutdown of a process, an important step is to shutoff electrical power. The discussion of process shutdown in Chapter 6.0, Section 6.1.3, demonstrates that the removal of electrical power shuts down the process and places the plant in a safe configuration. An analysis of the loads and shutdown process indicates that backup power, defined as IEEE Class 1E, is not a prerequisite to safe shutdown.

5.4.2.2.8 125 Vdc Battery Station Availability. An additional reliability feature of the electrical system is the 125-Vdc battery system. It is used for monitoring and switching control for both the C8-S6 (252-Z-1) and C8-S19 (252-Z-2) substations. The battery station is located in room 269 of the 234-5Z Building and is continuously charged by either one or both of two battery chargers operating in parallel (see Figure 5-52).

5.4.2.2.9 Not Used.

5.4.2.2.10 Rechargeable Emergency Light Wall Units. Emergency lighting during a power failure is supplemented by individual rechargeable wall units strategically located for personnel safety.

5.4.2.2.11 CAS. The CAS is made up of nine criticality alarm panels. Each panel has an IEEE-rated industrial battery system with sufficient capacity to support the alarm system in normal operation for at least 4 h. A charging system is integral to the panel to maintain the battery's charge. The charger in each panel is wired into a 120-Vac power source, which is a part of the backup system. Readouts on the panel indicate the state of charge and whether the system is on 120 Vac or battery.

5.4.2.2.12 System Reliability Conclusion. The PFP electrical system has been reviewed for compliance with the requirements of DOE Order 6430.1A (DOE 1989). The results of this review are presented in WHC (1990).

5.4.2.2.13 System Design Compliance Conclusion. See WHC (1990) for the PFP system design compliance in accordance with DOE Order 6430.1A (DOE 1989).

5.4.3 Compressed Air Systems

The compressed air systems at PFP are process air, instrument air, dry air, and breathing air. These systems are described in that sequence in Section 5.4.3.1. These systems are Safety Significant or Non-Safety Class. Breathing air systems are discussed in Chapter 8, Section 8.5.1.

5.4.3.1 Major Components and Operating Characteristics.

5.4.3.1.1 Process Air (90 lb/in^2 [gauge]). The design bases for the process air system are not available because of the age of the facility, except that UBC and accepted standards in effect at the time of construction were applied. Compressed air at a nominal pressure of 90 lb/in^2 (gauge) is provided as a general purpose air supply throughout the PFP for air cylinders, aspirators, air tools, etc. The compressed air system equipment is located in room 501 of the 291-Z Building. The equipment consists of a receiver tank and two water-cooled, two-stage, reciprocating compressors, each equipped with built-in inter- and aftercoolers, and a coalescing oil and water separator.

Each compressor is powered by a 100-hp motor and is rated at 530 $stdft^3/min$. An emergency compressed nitrogen gas supply (one cylinder, 228 ft^3, 2,200 lb/in^2, 2-stage regulator with 70 to 90 lb/in^2 outlet pressure) is available to start the compressors.

A backup air compressor for the 291-Z Building (similar to the air compressors located inside room 501), located outside of the building, is available in instances when the air compressors fail or are shut down for maintenance purposes.

The Laboratory Prototype Calciner air requirements are provided by a dedicated compressed air system. A fractional horsepower high air quality portable air compressor is installed in the 234-5Z Building, Room 262, duct level above the PPSL. This compressor supplies high quality compressed air at approximately 65 psig to Room 188 for use by the Laboratory Prototype Calciner (see the Laboratory Prototype Calciner addendum to this FSAR, Section 2.3.3.2.6).

Air is distributed from the receiver tank through a 2 in. diameter line to the 234-5Z Building duct level where the service line becomes an air header for general distribution of air throughout the building. The compressors also provide air to the 234-5Z Building instrument air system through an additional coalescing oil and water filter, a receiver tank, and a series of prefilters, dryers, and afterfilters located in the 291-Z Building.

A 1 in. diameter line to the 236-Z Building provided air for general purpose and this line has been blanked off in 291-Z. The line to the 236-Z Building was routed from near the air receiver in the 291-Z Building, underground to the 236-Z Building, where it is tied into the compressed air system located in the equipment room on the third floor. An air line to the 232-Z Building, also underground, is plugged inside of the building because air service is no longer required there. Other buildings serviced by the process air system in the 291-Z Building are the 241-Z and 243-Z complexes.

Cooling water for the Ingersoll Rand compressors is recirculated through two primary loops, one for each compressor, of the closed loop cooling system (CLCS). The CLCS is discussed in Section 5.4.8.

5.4.3.1.2 Instrument Air. Instrument air is distributed throughout the 234-5Z Building at 90 lb/in^2 (gauge) and is reduced to less than 30 lb/in^2 for general use in instrument controls for the ventilation system, for the process systems, and where non-oily, clean, dry-air is needed. Instrument air is supplied from the same equipment as the process air described in Section 5.4.3.1.1, which is located in room 501 of the 291-Z Building. Instrument air is distributed to the 234-5Z, 291-Z, 242-Z, 2736-ZA, 241-Z, 241-ZA, and 236-Z Buildings.

The 2736-ZA and 2736-ZB Buildings have additional instrument air capabilities. A small compressor in room 650 of the 2736-ZA Building, powered by a fractional horsepower electric motor, serves as backup to the normal instrument air for the 2736-ZA Building (which is supplied from the 291-Z Building system). The 2736-ZB Building, which is not serviced by the instrument air system in the 291-Z Building, uses instrument air from room 602 of the 2736-ZB Building. This system is similar to the small compressor

in the 2736-ZA Building, and serves as a backup to the dry air system described below in Section 5.4.3.1.3.

5.4.3.1.3 Dry Air. An electric dry-air generating system is located in room 321 of the 234-5Z Building. (Note: A backup steam-driven dry-air generating system in room 321 has been deactivated.) The electric dry-air generating system has the capability of providing 1,500 ft^3/min of air. The desiccant equipment of the dry air system is currently inactive, so the dry air system is currently only used to provide normal supply air to those gloveboxes attached to the dry air supply plenum. There is no need for dry air for the building and process operations. See Section 5.4.1 for details of the HVAC system. Flow can be regulated by control valves at each glovebox serviced by the header. In this condition, the process fans on the dry-air generating system still provide air to the process gloveboxes to maintain proper glovebox pressure. The dry-air fans were installed in accordance with standard practices for industrial dry air at that time.

Repackaging Glovebox Air System. Dry air to the repackaging glovebox in the 2736-ZB Building, room 636, is supplied by two air compressors, AC-1 and AC-2, each rated at 55 std ft^3/min at 100 lb/in^2 (gauge). Each compressor is driven by a 15-hp electric motor. Each of two air dryers is capable of supplying dry air with a dew point of -40 °F at 47 std ft^3/min and 100 lb/in^2 (gauge). A 140-gal receiver tank is capable of supplying a 5-min. reserve of dry air to the glovebox in the event of a power failure. This dry air reserve provides sufficient time for personnel to place any hygroscopic material located in the glovebox into a configuration that prevents absorption of moisture. The dry-air generating system serves as a backup to the instrument air system in the 2736-ZB Building and is located in room 602 of the 2736-ZB Building. The dry-air system was installed in accordance with standard practices for industrial dry air at that time.

5.4.3.2 Safety Considerations and Controls. The instrument air supply system was installed in accordance with standard practices for industrial instrument air. The instrument air system requires high reliability and safety assurance because of its function with pneumatic controls for process and ventilation systems. To meet this need, the process and instrument air system in the 291-Z Building is designed so that only one of the air compressors is required to satisfy the compressed air requirements, with the second compressor automatically starting if system pressure drops below 65 lb/in^2 (gauge). A backup diesel-powered compressor, located outside of the 291-Z Building, is also tied into the instrument and process air systems and can provide air if needed. The emergency compressed nitrogen gas supply (one cylinder, 228 ft^3, 2,200 lb/in^2) with a 70 to 90 lb/in^2 outlet pressure is available to aid in starting the air compressors in room 501 of the 291-Z Building.

The instrument air compressor in the 2736-ZB Building, which is not part of the compressed air system based in the 291-Z Building, is tied into the emergency power electrical system serving the 2736-ZB Building. Backup instrument air for the 2736-ZB Building is supplied by the dry air compressors in room 602 of the 2736-ZB Building.

The instrument air in the 2736-ZA Building, which is normally supplied by the system in the 291-Z Building, has a small compressor in room 650 as a

backup. Backup electrical power to this compressor comes from the same backup power system that serves the 2736-ZB Building.

The compressed air systems have been reviewed for compliance with the requirements in DOE Order 6430.1A (DOE 1989). Results of this review are provided in Tables 3, 6, 8, and 9 of WHC (1990).

The MICON™ control system will duplicate monitoring and control functions of the dry air system.

5.4.4 Compressed Gas Systems

Compressed gases are used in the PFP for maintenance, process, and laboratory needs. The gases are procured from industrial sources in standard-size, high-pressure cylindrical tanks referred to as bottles. The bottles are handled and stored in accordance with accepted industrial practices. The locations of the compressed gas storage facilities are shown in Figure 5-54. These gas systems are Safety Significant or Non-Safety Class.

5.4.4.1 Major Components and Operating Characteristics. The compressed gas storage buildings at the PFP are listed in Table 5-20. Each building is designed to accommodate the specific gas(es) in a safe and acceptable manner. As technologies and processes have changed, some of these facilities have either been modified or taken out of service. Current site standards (design, construction, and operations) set forth necessary criteria for the renovation and/or installation of services.

5.4.4.1.1 The 2734-Z Building, Gas Bottle Storage Building. The gas bottle storage building, 2734-Z Building, is located in the southeastern part of the PFP Complex (see Figure 5-54). It consists of a 73 ft by 16 ft concrete pad that is 2 ft 8 in. above ground level, on which is a wood frame building 72 ft by 11 ft by 7 ft high. The 2734-Z Building is currently used for temporary storage of empty drums.

5.4.4.1.2 The 2734-ZA Building, Cylinder Storage. The 2734-ZA Building is located about 3 ft from the south wall of the 234-5Z Building. It provides storage for empty flammable gas cylinders. The structure rests on a concrete slab that is 5 ft 4 in. by 16 ft and consists of concrete blocks on three sides with corrugated transit doors in front. It is 7 ft high at the front; the doors are 4 ft high with open gaps above and below the doors, 1 ft at the bottom and 2 ft at the top. The roof is sloped to the rear and is corrugated transit. The ceiling is 1-h fire-rated wallboard on a steel roof frame.

Two heat detectors are located within the building; they are tied into the zone 45 annunciator, RAFR 2780. Explosion-proof electrical fixtures are installed.

5.4.4.1.3 The 2734-ZB Building, Gas Bottle Storage. The 2734-ZB Building is located against the south wall of the 234-5Z Building. It provides storage for breathing air (compressed air) cylinders. The building is 5 ft by 15 ft 4 in. by 7 ft 6 in. high and consists of a structural steel frame with aluminum roof and siding. The siding is 6 ft high. The building is open above and below the siding on the front and the west side. The

bottles are mounted in vertical racks and held in with link chains. The lighting is designed in accordance with class 1, division 1, group A hazardous installation.

5.4.4.1.4 The 2734-ZC Building, P-10 Storage. The 2734-ZC Building is structurally identical to the 2734-ZA Building (see Section 5.4.4.1.2). This building is used to store oxygen cylinders and cylinders of P-10 (90% argon, 10% methane) gas and supplies P-10 gas to the Analytical Laboratory.

5.4.4.1.5 The 2734-ZD Building, Argon and Oxygen Gas Storage (out of service). The 2734-ZD Building provides storage for empty, non-flammable gas cylinders. It is located within 3 ft of the south wall of the 2734-5Z Building. The building is 9 ft by 13 ft by 7 ft 6 in. high and is built similarly to the 2734-ZB Building (see Section 5.4.4.1.3). Electrical installation conforms to the 1971 edition of the "National Electrical Code," *Fire Protection Handbook*, NFPA (1971).

5.4.4.1.6 The 2734-ZF Building, Gas Bottle Storage. This building, with dimensions of 13 ft by 6 ft by 7 ft 5 in., is constructed of corrugated aluminum and steel and is open to the south wall of the 234-5Z Building. A single 30-in.-wide door leads into the building. The building is used to store argon cylinders.

5.4.4.1.7 The 2734-ZG Building, Nitrogen Storage. This building, with dimensions of 21 ft by 6 ft by 7 ft 6 in., is constructed of corrugated aluminum and steel and is open to the south wall of the 234-5Z Building. Two doors lead into the building; one 42 in. and the other 32 in.

5.4.4.1.8 The 2734-ZH Building, Argon and Nitrogen Storage (out of service). The building is located in a corner formed by the south wall of the 234-5Z Building and the west wall of the 234-5Z Building South Annex. It is about 3 ft from each wall. It consists of a 9 ft by 14 ft 10 in. by 7 ft 6 in. high steel frame structure with aluminum roofing and siding on a concrete pad. Areas above and below the siding are open. The side adjacent to the south annex wall was for acid storage, and is 5 ft by 5 ft 6 in. wide. Two doors are provided, one was for acid storage and one was for gas cylinder storage. Electrical installation conforms to the NFPA (1971).

5.4.4.1.9 The 2734-ZJ Building, Liquid Nitrogen Storage. The 2734-ZJ Building is located in back of the 234-5Z Building on the west side. Vendor-owned equipment is supplied for liquid nitrogen storage. Liquid N_2 is stored in the vendor's tank. An evaporator and a heat exchanger are installed to provide N_2 at 70 °F in the fixed piping headers serving operations and the laboratories in the 234-5Z Building.

5.4.4.1.10 The 2734-ZK Building, Argon, P-10, Nitrogen, Propane, Acetylene, Helium and Miscellaneous Flammable Gas. The 2734-ZK storage structure is located outside the 234-5Z Building on the north wall. This structure is an unheated shelter for storing gas cylinders. Constructed of steel, transit, and isolated from the 234-5Z Building by a rated fire barrier, service lines from 2734-ZK are routed through the wall to the Maintenance Shop for the use of argon gas. 2734-ZK is also used for storage of flammable gas. Ventilation occurs by natural air movement through the expanded metal grating doors, through spaces above (7 in.) and below (3 in.) the access doors.

Airflow from this structure is not monitored. The access doors are not full length.

5.4.4.1.11 Other Compressed Gas Facilities. An argon supply is also kept in an outdoor shed on the north side of the 2736-ZB Building toward the west. Argon service is provided to a capped-off fitting inside the repackaging glovebox in the 2736-ZB Building. The argon is used to inert the repackaging cans while packaging plutonium metal. Oxygen, nitrogen, argon, acetylene and propane are stored in a concrete, transite and steel enclosure at the 234-ZB Building for use by construction personnel.

5.4.4.2 Safety Considerations and Controls. Compressed gases are used for process operations, laboratory operations, and maintenance operations. These gases provide a potential for explosion. The compressed gas systems were installed and are operated in accordance with standard practices for handling industrial compressed gases. There are several engineered barriers included in these standard practices to minimize this hazard.

- Safety relief valves are installed on pressurized tanks.
- Melting pins are installed as a backup pressure relief feature in case of fire.

The administrative barriers that are practiced to minimize the hazard of explosion are as follows.

- Gas bottles are chained to prevent inadvertent tipping or falling over.
- When in use, bottles are checked daily for proper operation.

The compressed gas systems have been reviewed for compliance with the requirements of DOE Order 6430.1A (DOE 1989). Results of this review are provided in Tables 3, 6, and 9 of WHC (1990).

5.4.5 Vacuum Systems

5.4.5.1 Major Components and Operating Characteristics.

5.4.5.1.1 Process Vacuum System (26-in. mercury vacuum). The 26-in. mercury process vacuum system provides high-capacity vacuum service to PFP facilities for vacuum transfers of liquids and other high vacuum requirements. The process vacuum system is Non-Safety Class except for the header liquid detection interlock system, which is Safety Class. A 4 in. diameter stainless steel piping header is routed throughout the duct level of the 234-5Z Building with branches serving process areas and the 236-Z Building.

The air pulled into this system, in many cases, comes from inside contaminated enclosures and is usually moist from use as the source of a vacuum transfer of contaminated liquid, thus, each major branch is equipped with demisters. Liquid effluents in the demisters, which may contain trace amounts of contamination, are routed to the 241-Z Building waste tanks for disposal.

The equipment for the process vacuum system is located in room 308, of the 234-5Z Building. Vacuum is provided by two vacuum pumps, each rated at 950 ft^3/min at approximately 26-in. mercury, and powered by 50-hp electric motors. During normal operations, one pump is operating and one is on standby. The inlet stream to the pump contains two sets of two-stage testable HEPA filters. During normal operations, one set is operational and one set is on standby. The vacuum pumps discharge to a 140-gal water trap-silencer tank to separate the seal water from the discharged gas. The gas is routed out of the trap-silencer tank up through a demister and into the E-4 ventilation system ahead of the final E-4 filter bank. Hence, the vacuum system effluent air is treated by three stages of testable HEPA filtration before atmospheric discharge. A seal-water pump rated at approximately 30 gal/min recirculates the seal water from the bottom of the trap-silencer tank through a glycol-cooled heat exchanger back to the vacuum pumps. A simplified schematic of the 26-in. mercury process vacuum system is provided in Figure 5-55.

The seal water cooling system consists of two water-to-glycol heat exchangers, each rated at 100,000 Btu/h, and a glycol secondary cooling subsystem. The glycol secondary cooling system is located outside and south of the 234-5Z Building. It consists of two evaporative coolers, each rated at 100,000 Btu/h and two pumps, each rated at 40 gal/min and powered by a 5-hp electric motor. During normal operation, one pump is running and one is on standby. Water from the process water supply system is evaporated in the evaporative coolers to remove heat from the glycol cooling loop, which cools the primary process water sent to the vacuum pumps.

The inlet to the vacuum pumps from the vacuum header is a 6 in. diameter stainless steel line. The discharge line from the vacuum pumps is a 6 in. diameter stainless steel line to the trap-silencer tank, and a 4 in. diameter stainless steel line from the trap-silencer tank to the E-4 header. All four HEPA filters on the inlet line to the vacuum pumps are equipped with DP alarms and taps for filter efficiency testing.

To preclude contamination of the glycol secondary cooling system, low DP across the system and the primary-process water-cooling system will shut down the glycol secondary system and seal-water pumps, isolate the glycol secondary system by remote valve actuation, and sound an alarm. Loss of negative pressure from the E-4 header will shut down the vacuum pumps and sound an alarm. High water level and low water level in the trap-silencer tank will shut down the vacuum pumps, the seal-water pump, and sound an alarm; however, fresh water is continuously added to the trap-silencer tank by a rotameter (while the pumps are operating) for bleed-off and make up for seal water lost by normal evaporation. Fresh water can also be added to the trap-silencer tank by the OCS from the MICON™ control station (rooms 712 and 714 of the 234-5ZA Building). Bleed off from the trap-silencer tank goes into the tank drain which routes the waste liquid to the 241-Z or 243-Z facilities (depending on sampling results). Liquid detectors are installed in a liquid detection loop on the inlet line for the vacuum pumps ahead of the HEPA filters. When activated, these detectors will shut down the operating vacuum pump, close both HEPA filter isolation valves, and sound an alarm. The vacuum pumps cannot run or be started unless the seal water pump is running or the manual bypass switch is on. The liquid detection interlock system is independent of the MICON™ control system.

5.4.5.1.2 Air Sample Vacuum System. The Air Sample Vacuum System (ASV) is also referred to as the 17-in. Hg Vacuum System. The ASV system provides the motive force for room fixed-head samplers, CAM units (excluding portable CAMs) and the 296-Z-6 effluent stack sampler and monitors. One system serves the 234-5Z, 291-Z, 2736-Z, 2736-ZA, and 232-Z Buildings. Vacuum pumps for this system are located in Room 501, Building 291-Z. Inlet air to the vacuum pumps is collected and filtered by one stage of testable HEPA filters before discharging directly to the 291-Z Building exhaust fan inlet plenum. These filters are located in Room 308, Building 234-5Z. The seal water for the vacuum pumps is cooled by the CLCS. The ASV failure alarm systems associated with stack CAMs are designated as "Safety Class" (formerly Safety Class 1). The remainder of the ASV system is "Safety Significant" (formerly Safety Class 3).

The 236-Z building has its own complete air monitoring system. Two vacuum pumps are installed in Room 35 of the 236-Z Building, each rated at 400 cu. ft/min at 17-in. Hg and powered by a 25-hp electric motor. The outlet air from the vacuum pumps is discharged into the E-3 exhaust system. The seal water to the vacuum pumps is cooled by the CLCS.

Two vacuum pumps (one operational and one standby) are installed in the 2736-ZB Building to service CAM units, fixed-head samplers and the 296-Z-5 effluent stack sampler and monitor. The capacity of each pump is rated at 180 cu. ft/min at a 17-in. Hg vacuum. Discharge is through two testable HEPA filters then through the exhaust plenum to the 296-Z-5 stack.

5.4.5.1.3 Dedicated Glovebox Exhaust Vacuum System (5-in. mercury vacuum). The 5-in. mercury process vacuum system is a dedicated system that serves to remove offgas generated from the furnaces used for thermal stabilization in glovebox HA-21I. The exhaust flows through a ceramic filter followed by a needle valve, which is used to adjust flow rates with an orifice and DP gauge to maintain flow within limits. The DP gauges are located on a rack located on the mezzanine in room 235 B/C. From there the air passes through two stages of HEPA filtration before entering one of two 2.5-hp blowers28. The blower offgas exhaust is to the 234-5Z Building E-4 exhaust system. The blowers, located in the duct level (room 264) can be started remotely from the control station or directly from the pumps.

5.4.5.2 Safety Considerations and Controls. Except for the header liquid-detection interlock subsystem, the 26-in. mercury vacuum system causes no serious safety concerns if it fails to operate. The header liquid-detection subsystem is designated as Safety Class because it provides one of the double contingency requirements for the prevention of a nuclear criticality. The subsystem is designed to detect and halt the flow of liquids, which might be a solution containing plutonium, to the testable HEPA filters upstream of the vacuum pumps. The testable HEPA filters do not have inherently criticality-safe geometry. The remainder of the 26-in. mercury vacuum system is designated Non-Safety Class since it has no safety function and is designed to be geometrically safe from a criticality point of view. All inlet gases are doubly filtered by testable HEPA filters. Each filter is equipped with a high DP alarm across the filter to warn of potential filter plugging.

Other controls that are installed to enhance confinement include shutting down the vacuum pumps on loss of negative pressure from the E-4 header, and

high and low water-level alarms in the trap-silencer tank that shut down the vacuum pumps and the seal water pump. The seal-water system has a continuous bleedoff. Fresh water is added continuously by a rotameter to make up for normal evaporation. The OCS in the MICON™ control station (234-5ZA Building, rooms 712 and 714) can add fresh water to the seal-water system, as desired. Also, low DP across the water and glycol loops will shut down the secondary glycol cooling system, the seal water pump (SWP-1), and secondary closed loop solenoid valve.

Those parts of the process vacuum system that are most likely to be contacted by product nitrate materials are designed to be safe from criticality by geometry (demisters, drop legs, headers, liquid-detection loops). The HEPA filter housings that are located between the liquid-detection loop and the vacuum pumps are not geometrically favorable. There are no criticality implications of water getting into the filters, but there could be if the liquid is product nitrate.

The ASV system is important to air sampling and monitoring of potentially contaminated areas within the confines of the buildings and to the monitoring of stack effluents. Its failure could result in failure to detect and measure airborne particulate contamination either within the areas monitored or contamination release in stack effluents. In the event of a loss of ASV service, backup systems, such as portable CAMs, respirators, and manual detection devices, would be employed, and operating activities would be curtailed as necessary to minimize the possibility of contamination spread or release. Because the stack CAMs are Safety Class, the ASV failure alarm system servicing those CAMs is also Safety Class.

The vacuum systems have been reviewed for compliance with the requirements in DOE Order 6430.1A (DOE 1989). Results of this review are provided in Table 5 of WHC (1990).

5.4.6 Steam Supply and Distribution Systems

5.4.6.1 Major Components and Operating Characteristics. Steam is supplied to the PFP from an oil-fired package boiler located in Building 234-5Z-BA (outside the PFP security fence) to the north of the PFP, near the 231-Z Building. The steam supply from the 200 East area powerhouse has been terminated. The steam distribution system from the 200 East Area powerhouse has been isolated from the PFP and its dedicated package boiler.

Steam is transmitted from the package boiler to the PFP Complex through an 8 in. diameter, Schedule 40 carbon steel insulated line. The steam line to the PFP from the package boiler has not been qualified to withstand a DBE event. No credit is taken for this line in the Chapter 9.0 accident analysis of the DBE event. Steam is supplied from the packaged boiler at 85-100 lb/in^2 (gauge).

The 8 in. diameter steam supply line enters the north side of the 234-5Z Building in the duct level, at column 16, 200 ft from the west end of the west annex building, 26 ft above grade. The line then extends vertically through the second floor into the second-floor machinery room (room 321), where the steam is supplied to the facilities through three branch

headers identified as the upper, middle, and lower headers. Figure 5-56 is a PFP steam supply flow schematic diagram.

The upper header, a 6 in. diameter line, extends directly south throughout the second floor, then east for approximately 60 ft at which point it enters the duct level and exits the 234-5Z Building south wall and extends to the 291-Z fan house.

Steam at 50-100 lb/in^2 (gauge) is also provided to the 2736-ZB Building from a tie-in to this 6-in. header between the south wall of the 234-5Z Building and the 291-Z fan house. Steam pressure for the 2736-ZB Building (with double valve isolation capabilities) is reduced to 15 lb/in^2 (gauge) for heating of ventilation supply air.

In the 291-Z fan house, the 6-in. line provides 85-100 lb/in^2 (gauge) steam to 5 subheaders: one to the 232-Z Building (which has been isolated inside 291-Z building); one to the 236-Z Building (which has been isolated inside 291-Z building); one header which leaves 291-Z building at 50-60 lb/in^2 gauge and separates into two headers, the 2715-Z paint shed (reduced, as necessary, to 15 lb/in^2 gauge), and the 241-Z Building to provide jet transfer of loquid wastes and for space heat; and one header to each of the steam-driven emergency ventilation exhaust fans in the 291-Z fan house. Steam used to be supplied by underground line from the 291-Z fan house to the 236-Z Building, where the steam is routed through headers to the third floor (corridors 10, 20, 30, and 33) as shown in Figure 5-57. Steam pressure is reduced to 15 lb/in^2 (gauge) for reheating ventilation supply air.

Steam supplied to the middle header in 234-5Z is currently blanked off.

Steam supplied to the lower header in 234-5Z at 50-100 lb/in^2 (gauge) is reduced, as required, to 50 lb/in^2 (gauge) by PRVs. Steam from this header supplies space heating for the 234-5ZA Building. Steam from this header is also reduced to 30 lb/in^2 (gauge) by a PRV and piped to each of the eight ventilation air supply units, located in room 321 of the 234-5Z Building, through a 10 in. diameter line. Steam coils with associated steam traps, condensate drains, and control instrumentation provide heating of the ventilation air supply. Formerly, the 50 lb/in^2 (gauge) steam was reduced by a PRV to 15 lb/in^2 (gauge) to supply a secondary general service loop that was routed to supply additional steam requirements (e.g., supplemental room heating, process service) in the 234-5Z Building. That PRV station has been removed and the piping has been abandoned in place.

5.4.6.2 Safety Considerations and Controls. Steam required for space and process heating and other services, distributed throughout the facilities, has industrial and personnel safety concerns. Design and installation of the steam distribution system provides insulated lines, isolation valves, pressure regulating valves, PRVs, steam traps, and control instrumentation to assure that the steam supply and distribution system can be operated and maintained in a safe manner.

It should be recognized that loss of steam for an extended period of time during very cold weather could result in extensive damage because of the freezing of building water lines that provide fire suppression and other PFP water services.

The steam supply and distribution system have been reviewed for compliance with the requirements in DOE Order 6430.1A (DOE 1989). Results of this review are provided in Table 5 of WHC (1990).

5.4.7 Water Supply and Distribution Systems

5.4.7.1 Major Components and Operating Characteristics. Water for the 200 Area is drawn from the Columbia River at the 100-B Area and pumped to a 25,000,000-gal reservoir. A second pumphouse at the 100-D Area and a separate line provide a backup supply to the reservoir. Diesel-powered pumps provide emergency water on loss of power to the electricity-driven supply pumps. Water from the 25,000,000-gal reservoir is pumped to the 200 East and 200 West Area reservoirs as shown in Figure 5-58. Two lines supply the 200 East Area 3,000,000-gal reservoir. One line supplies the 200 West Area 3,000,000-gal reservoir.

Water from the 200 West Area reservoir is pumped to the 283-W Water Treatment Facility for sedimentation, filtration, chlorination, and testing. Sanitary water produced by the treatment facility is routed to two covered storage vessels (clearwells) with a total capacity of 400,000 gal.

Sanitary water is supplied to the 200 West Area supply headers by four electrically driven pumps, two rated for 2,000 gal/min at 215 ft of head and two rated for 600 gal/min at 250 ft of head. Two steam-driven pumps rated for 600 gal/min at 250 ft of head are provided for backup service on loss of electricity or failure of an electricity-driven pump. The two 600-gal/min electric pumps are normally operated and supply water to the system at 90 lb/in^2 (gauge). Two elevated tanks, a 50,000-gal tank at the Reduction Oxidation (REDOX) Plant (S-Plant) and a 100,000-gal tank located near the 200 West shops, are tied in to the supply system to augment the supply during peak demand periods.

Sanitary water is provided to the PFP Complex from three lines, all originating from the 283-W facility as shown in Figure 5-59 (see Table 5-21 for location descriptions). One 12-in. line enters the complex at the northeast corner where it joins the PFP 10-in. general supply loop. The second 12-in. line is reduced to 10-in. and enters the PFP 10-in. general supply loop in the southeast corner of the complex. An 8-in. line enters the north side of the complex where it connects to the PFP 10-in. general supply loop. The supply lines are equipped with check valves upstream of their loop tie-in to prevent drainage of the loop should a supply line break. A 50,000-gal elevated water tank (drained and not currently in use) formerly served as a backup water supply to the PFP facilities.

All water requirements of the PFP facilities are provided from connections to the sanitary water service loop. Water supplied to the PFP facilities is not metered. A list of connections to the sanitary water loop with locations, line sizes, and services is shown in Table 5-21.

Sanitary water is used for personal needs (e.g., drinking fountains, hot water tanks, restrooms, showers, lunchroom), ventilation supply air washing and evaporative cooling, process services (e.g., chemical makeup, process cooling makeup), CLCS makeup, flushing drums at the 243-Z Building, safety

showers, and fire protection. The majority of the loop connections (see Table 5-21) provide dedicated fire protection water; however, the largest normal use of water is for air washing and evaporative cooling of the ventilation supply air for the PFP Complex. Both sanitary and process water are provided by several service connections to the sanitary water supply header. Wherever this occurs, a reduced pressure, backflow preventive device is installed to prevent cross-contamination of the sanitary water service from the process water loop. The water downstream of the backflow preventive device is termed process water.

Demineralized water is supplied at a minimum flow of 1 gal/h to a calorimeter in the NDA laboratory by a wall-mounted, laboratory-type, cartridge demineralizer. A similar demineralizer is used for supplying demineralized water to the 234-5Z Building standards laboratory, room 221E.

5.4.7.2 Safety Considerations and Controls. The major safety consideration associated with the PFP water supply and distribution system is that water always be available for the fire protection system. These concerns are minimized by the installed system that provides three independent supply lines and a supply loop that encircles the facilities. The supply lines and loop are equipped with isolation valves to isolate line breaks. The fire protection systems are discussed in detail in Section 5.4.11.

A second safety concern is that the sanitary water system, which also provides PFP process water, does not become contaminated. Reduced pressure backflow preventers are installed, wherever the sanitary water supplies the process to prevent cross-contamination. Water that is used for the process and separated from the sanitary water system by a backflow prevention valve is identified as process water. A preventive maintenance program is in place to ensure operability of the reduced pressure backflow devices.

Should the water supply to PFP be lost, plant operations that require water would be shut down. The ventilation system and the air sampling system could be maintained through continued operation of the instrument air system and the ASV system from cooling supplied by the CLCS.

The water supply system has been reviewed for compliance with the requirements in DOE Order 6430.1A (DOE 1989). Results of this review are provided in Table 6 of WHC (1990).

5.4.8 Cooling Water Systems

5.4.8.1 Major Components and Operating Characteristics. The current cooling needs of the PFP are being met by a CLCS and the cooling water spray for the ventilation supply air. The water for these systems, makeup water in the case of the CLCSs, are supplied from the sanitary water system as described in Section 5.4.7.

The first CLCS is associated with the process vacuum system, located in room 308 of the 234-5Z Building. That system uses a primary cooling water (PCW) loop to the vacuum pumps and a glycol secondary cooling loop. Heat is removed from the secondary loop by cooling towers outside of the building.

The process vacuum system, and associated CLCS, is discussed in more detail in Section 5.4.5.1.1.

The second CLCS, which is much larger than the one associated with the process vacuum system, consists of seven PCW loops and one secondary cooling water (SCW) loop. The system operates by circulating PCW through the area/equipment to be cooled and then to a heat exchanger where heat is transferred to the SCW.

The PCW loops each consist of one circulating pump, an expansion tank, and a heat exchanger (with the SCW loop) located in the same rooms as the equipment serviced by the PCW loop. The PCW loops service the following areas and pieces of equipment.

- PCW loop 1--Various process equipment in the east and west gallery, gloveboxes in the 236-Z Building (PCW loop equipment is in room 35 of the 236-Z Building).
- PCW loop 2--ASV 1 in room 35 of the 236-Z Building (cooling and seal water).
- PCW loop 3--ASV 2 in room 35 of the 236-Z Building (cooling and seal water).
- PCW loop 4--ASV 1 in room 501 of the 291-Z Building (cooling and seal water).
- PCW loop 5--ASV 2 in room 501 of the 291-Z Building (cooling and seal water).
- PCW loop 6--Air compressor 1 in room 501 of the 291-Z Building.
- PCW Loop 7--Air compressor 2 in room 501 of the 291-Z Building.

The SCW is circulated through two fluid coolers located outside of the 236-Z Building. The building designation for the fluid coolers and co-located equipment is the 243-ZB Building. In addition to the two fluid coolers, the 243-ZB Building contains the two circulation pumps used for the SCW loop.

The ventilation supply air for the PFP buildings is conditioned by a water spray directed at inlet filters. Water is applied to the filters only during the summer, providing for cleaning and evaporative cooling to the supply air. The system is supplied by the sanitary water system, which is described in Section 5.4.7.

5.4.8.2 Safety Considerations and Controls. If the CLCS that is associated with the process vacuum system were to fail, then the process vacuum for the PFP would be lost. This failure would impact operations but is not significant to safety.

The other CLCS provides PCW services to select process gloveboxes, the instrument air compressors in the 291-Z Building, and the ASV pumps in the 236-Z and 291-Z Buildings. It is designed so that the loss of one PCW loop

has no impact on the other PCW loops, allowing operation of alternate equipment. For example, if the PCW loop to ASV 1 in room 35 of the 236-Z Building were to fail, ASV 2 would be brought online and would be cooled by a different, unaffected, PCW loop.

If the SCW loop of this CLCS were to fail, then all PCW loops would be shut down because of an inability to transfer heat. In this event all process glovebox, instrument and process air, and ASV cooling services would be lost. Chapter 6.0 contains the discussions of glovebox operations and processes, if any, that may be used in these gloveboxes, including the use of cooling water. Loss of process and instrument air would result in the loss of air-controlled equipment and eventual shut down of the ventilation system to a safe configuration. Loss of process vacuum or ASV service would result in the loss of operations using process vacuum, operability of room CAMs, fixed head air samplers, and the 296-Z-5 and 296-Z-6 stack samplers and monitors. Normal operations would be interrupted upon loss of the ASV, though portable CAMs would be used where necessary in surface contamination areas and temporary vacuum pumps would be installed to serve as the motive force for the stack samplers and monitors.

To help reduce the chance of contamination entering the PCW loops from process areas/equipment, the SCW loop is maintained at a greater pressure than the PCW loops. Thus, a leak between the SCW and PCW loops would result in a flow of water from the SCW loop to the PCW loops.

5.4.9 Liquid Effluent Systems

There are four types of liquid effluent streams from the PFP Complex: (1) a sanitary sewage stream, (2) a waste water stream, (3) a RLW stream from the 241-Z Building, and (4) a French drain effluent stream. See Chapter 7.0 for more details on the PFP waste water effluent systems processes.

5.4.9.1 Sanitary Sewage. Two sanitary sewage systems, shown in Figure 5-60, collect wastes from the PFP restroom sinks, showers, toilets, and from lunchroom sinks for disposal in septic tanks and tile fields. The systems collect wastes from the 234-5Z Building, mobile office trailers, the 2704-Z office building and the 2701-Z, 2701-ZA, 2701-ZD, and 2705-Z Buildings, and route it to septic tanks and pump stations and to the 2607-W1 regional drain field located to the east approximately one-half mile away. The sanitary sewer system effluents, by their nature, are neither chemically nor radioactively hazardous.

Sanitary sewage wastes from the mobile office trailers next to the 2705-Z operations control facility are routed to the 2607-WB septic system, pump stations and to the 2607-W1 regional drain field. Sanitary sewage wastes from the 270-Z office building, 2701-ZD Security Building, and operations control facility are also routed to this system through a tie-in to the line that parallels the north wall of the 234-5Z Building. Sanitary sewage wastes from the 2736-ZB restrooms and from the 234-5Z south annex are routed to a second septic tank, and then to the pump station and 2607-W1 regional drain field.

5.4.9.2 Facility Waste Water. Waste water discharged from the 234-5Z, 236-Z, 291-Z, and 2736-ZB Buildings is routed through a system of drain headers (drain headers D1, D2, and D3) and manholes to pump station 1 where the effluent combines with waste water from T Plant and the 222-S Laboratories before being pumped to the TEDF in the 200 East Area (see Figure 5-61 for waste water streams and manholes). Tables 5-22 through 5-25 identify the particular waste water streams, their building of origination, their collection header, and the discharge point.

The drainage system for the north side of the 234-5Z Building handles the effluents from the ventilation supply fans, steam condensates, and north side storm drains. The original designation for this drainage system was the 234-5Z ventilation steam condensate/dry air compressor cooling water. Because the majority of the waste water now comes from the supply fans following the inactivity of the dry air compressors, the drainage system has been renamed the supply fan waste water stream. Thus, the manholes and storm drains along this waste water stream are labeled S-1 through S-7. The stream then flows through manholes C-2, C-3, C-4, and finally to Pump Station 1.

The drainage system consists of 15 or 18 in. diameter vitreous clay pipe. The vitrified clay pipe originally installed in 1948 was comprised of 3-ft lengths of pipe. Past process misroutings contaminated the pipe from the 236-Z Building through manholes Z-3 to Z-9 and the 216-Z-20 crib. The LLWTF removes contamination from the effluent stream after contacting the pipe. New PVC pipe was installed downstream of manhole C-1 where the effluent was rerouted from the 216-Z-20 crib to the TEDF. The piping between the LLWTF outlet and manhole C-1 was remediated using an in situ-form liner to fix the contamination in place and provide a new, clean pipe formed inside the old pipe. This liner and clean pipe surrounding the old pipe provides double containment of the waste water effluents as the effluents are sent from the PFP Complex to the TEDF. The in situ-form liner and new pipe also were installed on the pipe from manhole Z-2 to manhole Z-7 to stop leaks in the line. These leaks were caused by earth settling on the pipe during the operational lifetime of the pipe. The PVC drain pipe installed by the TEDF project, was arbitrarily labeled pipe C and the manholes C-1, C-2, etc.

The 216-Z-20 crib is located southeast of the PFP facilities, as shown in Figure 5-61. The crib, which was designed and constructed in 1981, was activated in January 1982 and deactivated in June 1995. The crib consists of two parallel runs of 6 in. diameter perforated PVC pipe and one additional 10 in. diameter PVC pipe running between the parallel pipes. These pipes are 7.5 ft below grade. The pipes lay on a bed of small rock 12 in. in depth. An additional 12 in. of rock was placed atop the pipes. A biological barrier in the form of a 20 mm thick sheet of PVC was placed on top of the gravel. The edges of the PVC sheet were overlapped and sealed for 3 in., then the area was filled with gravel. A manhole (identified as Manhole 9) was located at the head end of the crib. The manhole served as the connection point for two former existing drain lines. One drain was a 15 in. clay pipe that carried liquid waste from PFP and the second drain was an 18 in. clay pipe that carried liquid waste from the 231-Z Building.

The 216-Z-21 seepage basin (also referred to as the 207-Z retention basin) is located approximately 300 ft northeast of the 216-Z-20 crib and covers an area of approximately 10,000 ft^2 (Figure 5-61). The basin was taken

out of service in May 1995 when its effluent stream was rerouted from manhole S-7 to the TEDF. The old pipe to the basin was capped off with grout.

To the east of manhole Z-7 is the inactive 2904-ZA sample building (Figure 5-61). This 12-ft by 12-ft pre-engineered, corrugated-metal building housed the online alpha monitor as well as a composite sampler and a flow meter. A single riser penetrates the effluent line for purposes of sampling the stream. The building and its equipment was deactivated in February 1994.

The inactive 2904-ZB sample building is located next to the deactivated manhole Z-9 (Figure 5-61). This building provided a sample point at the entrance of the 216-Z-20 Crib. This building was deactivated in May 1995 when the waste water stream was rerouted from the 216-Z-20 Crib to the TEDF. The old drain pipe downstream of manhole C-1 to manhole Z-9 was plugged with grout and manhole Z-9 was filled with concrete.

The 225-WC waste water sampling facility is located above the effluent stream, 20 ft east of manhole C-4 (Figure 5-61). The 225-WC facility is a pre-engineered building made of corrugated metal. Normal electrical power is supplied via pump station 1. Backup power is currently not supplied to this facility. The 225-WC facility contains six risers that penetrate into the effluent pipe to allow access to the stream for sampling and monitoring purposes. This facility monitors pH, flow, and conductivity in the liquid effluent. The pH monitor has a recorder. The conductivity probe is used to detect electrolyte-type (salt or acid) liquids that might come into the effluent stream. The sampling equipment and effluent source descriptions are discussed in Chapter 7.0.

5.4.9.3 The 241-Z Complex Stream Wastes. The TRU waste streams from various sources within 234-5Z and 236-Z (i.e., labs, 26-in. mercury vacuum, PRF solvent extraction, and RMC scrubber) are contaminated or have a high potential of being contaminated. These waste streams are transported by an extensive drain system (headers D4, D5, and D6) through a double-encased steel line with leak detection to the TK-D8 waste accumulation tank in the 241-Z Building. Wastes are transferred from the TK-D8 tank to the TK-D5 tank for storage and treatment before being discharged to the 244-TX receiver facility. Tanks TK-D4, TK-D7, and the TK-D7 overflow tank serve to retain overflow from the TK-D8 and/or TK-D5 tanks (see Chapter 7.0 for a detailed description of the 241-Z Complex waste treatment processes). (See Figure 5-62 for a diagram of the 241-Z radioactive waste treatment system.)

5.4.9.4 French Drains. Liquid wastes with insignificant potential for radioactive contamination (e.g., steam condensates from traps on outside steam supply lines) are locally disposed to the ground through French drains. A French drain consists of a buried vertical section of perforated cement or vitreous clay pipe, filled with rock and gravel, which provides local disposal of liquid waste waters. French drain waste disposal is discussed in Chapter 7.0, Section 7.2.2.

5.4.10 Safety Communication and Alarm Systems

The role of safety communication and alarm systems in the PFP Complex is to provide audible and/or visual information concerning abnormal conditions.

The communication systems provide standard and emergency communication exchanges. Standard alarm signals (e.g., horns, sirens, gongs) are used at the PFP Complex to provide notifications of specific abnormal conditions. All PFP safety SSCs interface with specific communication and alarm systems.

Safety Class stack alarms are associated with stack CAM systems. They provide notification of excessive release from the plant that could result in offsite and onsite releases above site guidelines. Safety Significant alarms are associated with other environmental monitoring, CAS, and liquid effluent monitoring systems or provide notification to personnel for fire, evacuation, warning, or radiation protection. The PFP Complex communications and alarms systems consist of the following:

- Plant (commercial) telephone system, including crash system phones
- Internal PAX telephone and public address system
- Siren system (evacuation and take cover warning)
- Emergency lighting
- Fire alarm/notification system
- CAM system
- CAS.

The 270-Z Building houses the PFP emergency control center and functions as a staging area in case of evacuation. For most emergencies reentry efforts would be planned in and conducted from this center.

Backup power is available for the various alarm systems from three diesel generators in the 2721-Z Building. In addition, the fire alarm system, emergency lighting, and the CAS have battery backup power systems. The following sections provide details of system components and the function of components in response to normal, abnormal, and accident conditions.

5.4.10.1 Major Components and Operating Characteristics.

5.4.10.1.1 Plant and Crash Telephone Systems. Voice communications within the PFP facility and with other Hanford Site locations are accomplished using the plant telephone system. This equipment consists of standard commercial telephone equipment with telephone sets placed in offices and other locations throughout the facility.

The crash alarm telephone system is a feature of the plant telephone system. This system, primarily used for area or site emergencies, allows a message to be given over selected phones throughout the facility. The messages given provide information to the building emergency director and the facility workers, and may serve to initiate other alarms, such as the evacuation or take-cover alarms. The crash alarm phones are marked and are strategically located in the facility.

5.4.10.1.2 Private Automatic Exchange System. A PAX telephone system provides communications within the plant. The PAX also has public address capability. The PAX switcher and public address systems are powered by a UPS located in Room 308 of Building 234-5Z. In turn, the UPS is powered off the Building 234-5Z emergency bus by the Building 2721-Z diesel-generators. In the event of an emergency, the PAX can be used to provide emergency

instructions to plant personnel. Additionally, intercom services are provided for the RMC Line and the PRF.

5.4.10.1.3 Emergency Audible Alarm (Siren) System. The emergency siren system at the PFP consists of 32 sirens and one siren controller. Two sirens are 120 Vac, located in the 270-Z Building; two are 480 Vac, located in the ventilation plenum and on the roof of the 234-5Z Building; and the remaining 28 are 125 Vdc, located throughout the rest of the PFP Complex. The siren controller regulates the tone of the sirens, indicating the proper action to take; a steady tone indicates an evacuation response, while a wavering tone indicates a take-cover response. There are siren control switches in several strategic locations in the PFP Complex: the Power Control Room (Room 321) in the 234-5Z Building; Patrol's AMS building (2701-ZA); and the Operations office in the 2736-ZB Building. Both the Power Control Room and the AMS are manned 24 hours a day, while 2736-ZB is manned whenever any type of vault operations are performed. All sirens, and the siren controller, are powered from emergency power panels in the 234-5Z Building. The all clear signal for the evacuation/take-cover alarms can be communicated by voice using the PAX system or crash alarm phones.

5.4.10.1.4 Emergency Lighting. Emergency lighting in the PFP complex is provided by stand-alone units located along evacuation routes as required by NFPA 101 and additional units located to reduce safety hazard to plant personnel. The stand-alone units consist of incandescent lamps with a battery and battery charger. The units are connected to the normal lighting circuits and activate when power is lost to the normal lighting circuit.

5.4.10.1.5 Fire Alarms. The fire alarm system for the PFP consists of a high-reliability, supervised system to notify the HFD of an alarm at any one of the fire alarm control panels. The system consists of low-voltage circuits. Fire alarms can be triggered by activation of any automatic suppression system, signals from smoke or heat detectors, and by manual activation of auxiliary alarm pull boxes in the building or at master alarm boxes. Any fire alarm activates all fire alarm gongs and alerts the 200 Area fire station. Section 5.4.11 contains more detailed information on the fire alarm system of the PFP.

5.4.10.1.6 CAM Systems. For the purposes of this discussion, there are two types of CAM systems at the PFP: room/portable CAMs and stack CAMs. The room CAMs are designed to detect elevated levels of airborne alpha contamination in a work environment and sound an alarm to warn affected personnel. Operational requirements for room CAMs are described in HSRCM-1, *Hanford Site Radiological Control Manual* (DOE 1994). Room CAMs are located in areas indicated by the guidelines of HNF-PRO-331, *Work Place Air Sampling*, and where recommended in PNNL air sampling evaluations for the PFP. Representative CAM locations at the PFP Complex are shown in Chapter 8.0.

CAMs and their associated alarm function mitigate some potential facility worker hazards at PFP. In general, during stabilization activities, the primary boundary to release of radionuclides to occupied rooms are gloveboxes, process systems, or sealed plutonium storage containers. The primary boundaries to plutonium release inside PFP can fail through several potential mechanisms, such as improper maintenance, equipment degradation, or abnormal glovebox pressurizing events. In many cases, there is no obvious indication

that a plutonium release has occurred. The CAMs serve to validate the satisfactory performance of the barriers to plutonium release. If one of these primary barriers fail and plutonium is released into PFP, then alarms will be actuated when the alarm setpoint is reached. Upon actuation of the alarm, facility workers are trained to promptly evacuate the affected air space. This action serves to reduce the potential plutonium inhalation dose received by the affected facility workers. The public and onsite workers are not significantly affected by these potential plutonium releases inside PFP because the exhaust air flow is filtered by the applicable exhaust ventilation system prior to release outside of PFP.

In the event of a loss of normal power, some room CAMs are provided with backup power from the diesel-generators for the CAM alarms, detectors, individual vacuum pumps (where applicable), flow rate measurement equipment, and counting and failure lamps, from the backup power system (diesel generators). All CAMs alarm locally and some CAMs alarm remotely. All room CAMs use the ASVs described in Section 5.4.5.1.2.

If for some reason a room CAM is not able to perform its function, or is not available, portable CAMs with their own vacuum source can be used. These CAMs can also be used in areas without room CAMs but where maintenance or other activities might cause a release of airborne contamination. Portable CAMs are designed to detect elevated levels of airborne alpha contamination.

Stack CAMs are provided to monitor the release of gaseous effluents to the environment. This helps to ensure the integrity of the HEPA filtration system and provides prompt indication of elevated plutonium concentrations in effluent streams. All stack CAMs are powered by the normal electrical distribution system of the PFP with backup power received through diesel generators. The stack CAMs, remote alarms, and the failure alarm portion of their associated vacuum system, are Safety Class; however, the CAMs are only required to be operable when forced ventilation is occurring through the stack being monitored. Only the failure alarm portion of the vacuum system is Safety Class because if the vacuum fails, then appropriate action can be taken to monitor the associated stack effluent or filters by other means. All stack CAM failure and alarms are indicated on a panel in room 714 (MICON™ power control room) of the 234-5ZA Building.

The 291-Z-1 stack CAM (234-5Z, 236-Z, and 242-Z Buildings), the 296-Z-3 stack CAM (241-Z Building sumps and tanks), and the 296-Z-14 stack CAM (232-Z Building) are self-contained, providing their own vacuum source from portable vacuum pumps. The 296-Z-5 (2736-ZB Building) and 296-Z-6 (2736-ZA Building) stacks use the ASV system as described in Section 5.4.5.1.2.

5.4.10.1.7 CAS. The CAS is intended to supply continuous monitoring for high-radiation (criticality) events within the PFP Complex. It initiates a criticality alarm to affected personnel and establishes the approximate time of the event. Two methods of detection are used by the CAS at the PFP: gamma detectors and neutron detectors. The gamma detectors are used throughout the PFP Complex while the neutron detectors are used only in the 2736-Z Building.

The requirements for CAS equipment location, testing, and calibration are given in HNF-PRO-546, *Nuclear Criticality Safety Manual*; HNF-IP-1115, *Nuclear Criticality Alarm Manual for the Plutonium Finishing Plant*; and HNF-SD-CP-SDD-

003, *Definition and Means of Maintaining the Criticality Alarm System Portion of the PFP Safety Envelope*. Under these requirements, criticality detector stations, horns, and blue-flasher lights are located strategically throughout the PFP Complex associated with the following buildings: 2736-ZB, 236-Z, 234-5Z, 2736-Z, and 241-Z Building. Nine criticality alarm panels, each coordinating the detectors in a single zone, are located in the following buildings: one in 241-ZG, one in 2736-ZA, four in 234-5Z, two in 236-Z, and one in 2736-ZB. Upon detection of a criticality by no less than two detectors in a single zone, the criticality alarm panel initiates an audible (horn) and visual (blue flashing light) alarm. Eight of the nine criticality alarm panels are interconnected to enable a single alarm to activate all eight. The ninth panel (CAP 8), in the 241-ZG Building, is not interconnected to the other zones.

A typical individual CAS zone consists of the following equipment: criticality detector stations with three criticality alarm detectors each, a criticality alarm panel and associated components, criticality alarm horns and blue flasher lights (zone 7 in the 241-Z Building and zone 9 in the 2736-ZB Building only), and backup battery power supply (zone 7 has an additional UPS). Other equipment related to the CAS, such as the remote monitoring equipment, multiplexer unit, criticality alarm annunciators, and alternating current loss relays, may be available but are not essential for the detection or alarming of a criticality event.

Upon initiation of a CAS alarm, the time delay on the Access Delay Doors within the plant is overridden. This allows immediate egress of all areas of the plant to minimize potential personnel exposure.

5.4.10.1.8 Miscellaneous Radiation Protection Systems. The PFP can provide portable radiation detection devices to areas of concern within the PFP Complex.

5.4.10.1.9 Safety Annunciator. An annunciator (ANN-714) for the stack effluent monitor alarms, process vacuum leak detector alarms, and the seismic fan shutdown system disabled alarm is located in room 714 (MICON™ power control room) of the 234-5ZA Building. The stack effluent and seismic fan shutdown alarms are either safety class or safety significant. Currently, the process vacuum leak detector alarms are not the primary alarms and thus are not safety alarms. These alarms will be reclassified when the controls for the process vacuum system are connected to the MICON™. The normal power for the annunciator is the 308 UPS. This power is monitored by a special annunciator window that is powered by the room 269 switchgear control batteries.

5.4.10.2 Safety Considerations and Controls. The functioning of alarm systems and appropriate actions are detailed in the building emergency plan for the PFP HNF-IP-0263-PFP. The communication and alarm systems have been reviewed for compliance with the requirements of DOE Order 6430.1A (DOE 1989). Results of this review are provided in Tables 4, 5, and 7 of WHC (1990).

5.4.10.2.1 Emergency Signals and Responses. The following sections describe the emergency signals.

Evacuation Signals. Two distinct evacuation signals can be relayed by the alarm systems. One is activated by a criticality, and the other is a general evacuation alarm. A steady siren is sounded for general evacuation. In addition, the PAX may be used to announce evacuation.

Failure of the CAS or loss of normal power supply initiates an annunciator. The CAS operates from a 24 volt storage battery system with a float charger to maintain the batteries. The battery system is designed to operate the CAS system in normal operation for at least 4 h without an operable battery charger. Each individual criticality alarm panel can then be switched back to ac power provided that the backup diesel generators are operating or normal power has been restored.

In the event of a criticality, the local sensors (except criticality alarm panel 8 in the 241-ZG Building) signal the system and howlers (ah-oo-gah horns) are sounded throughout the complex. In addition, there may be visual signals to nearby personnel from flashing blue lights. Panel Z-8 only actuates howlers in the immediate area of Building 241-Z. Personnel are instructed to run a minimum of 100 ft from the facility and assemble at prearranged staging areas.

Fire Alarms. Fire alarm gongs are sounded in response to smoke, heat detectors, pull boxes, and upon the activation of any suppression system. All personnel are required to evacuate in an orderly manner from the affected building to the primary staging area in response to an activated fire gong alarm.

Take Cover Signals. A wavering take cover siren is available to signal personnel of an event where evacuation may be a hazardous action. Take cover instructions may also be relayed by means of the crash alarm phones or the PAX.

Continuous Air Monitors. The CAM systems provide both local and annunciator panel responses at various locations. The local signal varies with the specific type of CAM, but usually includes a bell and a flashing red light. Remote annunciation is provided by the CAM system (including stack monitors) at various selected locations. In addition, failures of selected equipment associated with selected CAMs, such as air sample vacuum pumps, are annunciated on panels. All CAMs alarm locally. Selected CAMs also alarm on annunciator panels located in radiation monitoring offices.

Access Denial System. This system is classified and, therefore, not discussed.

5.4.10.2.2 Off-Normal Conditions. This section describes the functioning of the alarm and communications systems during off-normal conditions such as power failure, loss of ventilation, loss of water, loss of steam, or loss of air.

Loss of Normal Power. Criticality alarms are battery-powered and can function independently of the normal power supply. Three diesel generators supply backup power to the 234-5Z, 291-Z, 2736-ZB, 2736-ZA, 2701-ZA, and 2701-ZD Buildings. Evacuation fire alarm bells and lights are connected to their own individual battery packs for backup power. There are also separate

emergency-generator and battery-powered lights in all occupied areas. The PAX phones are equipped with UPS to allow phone communication during power loss. The public address amplifiers are connected to emergency power to allow paging capability. The fire alarm control panels have battery backup and can function independently of the normal power supply.

Loss of Ventilation. The PFP ventilation is described in Section 5.4.1. Loss of negative pressure is annunciated on OCSs in the MICON™ control station (rooms 712 and 714 of the 234-5ZA Building). Actions to be taken can be announced over the PAX system. At minimum, personnel will evacuate zone 3, except those wearing respiratory equipment. The 241-Z Complex ventilation will shut down on loss of power. As noted in Section 5.4.1, following detection of high pressure by the DP switches in the RMC Line interconnected conveyors (HC-2, HC-3, HA-4, and HA-28), an alarm (both audible and flashing light) is activated in the MICON™ control station. High pressure in the RMA Line interconnecting conveyor also will activate an alarm (both audible and flashing light) in the MICON™ control station (room 714). The alarms will cease after pressure has been reduced to acceptable levels.

Loss of Water. Impending loss or reduction of water supply to the PFP Complex may be verbally communicated to appropriate management and effective water conservation measures undertaken in accordance with the building emergency plan.

Loss of Steam. There are no effects of loss of steam upon the alarm and communication systems. However loss steam will alarm indicating a loss of steam turbine emergency exhaust system.

Loss of Compressed Air. There are no effects of loss of compressed air including instrument air upon the alarm and communication systems. A loss of compressed air will result in a loss of normal ventilation.

5.4.11 Fire Protection Systems

The fire protection systems cover many of the buildings that make up the PFP Complex. Descriptions of the plant and the individual buildings are given in Sections 5.1 and 5.2. This section discusses the fire protection systems and relevant fire protection design features of the PFP Complex and individual buildings. The fire protection sprinkler coverage for the PFP Complex is shown in Figure 5-63.

5.4.11.1 Design Bases.

5.4.11.1.1 Maximum Fires and Fire Hazards. The criteria for fires are given in the FHA (McKinnis 1998). Details of the design basis fire analyses are given in Chapter 9.0. The following sections provide summary descriptions of design basis fires, special hazards and exposure hazards, and fire protection design features of individual buildings. Design basis fires evaluated in the FHA include the Maximum Possible Fire Loss (MPFL) and the Maximum Credible Fire Loss (MCFL). Based on DOE Order 5480.7A, estimates of the MPFL assume that one automatic suppression system will fail, and manual fire fighting efforts are also ignored. Estimates of the MCFL are based on the assumption that the fire protection features, including automatic

sprinkler systems, function as designed. For these cases where the MPFL is equal to the MCFL, there are either no automatic suppression systems present or the automatic suppression systems are not expected to significantly reduce the damage potential.

The 234-5Z Building. A detailed description of this building can be found in Section 5.2.1. Fire hazards are described as follows:

The fire hazard in building 234-5Z is limited since the building is largely constructed of non combustible materials and the combustible content is limited. The fuel loading in 234-5Z consists primarily of ordinary combustibles located in the office and lab spaces on the first and second floors. Typical combustibles consist of office furniture and supplies. The total quantity of combustibles and flammable liquids in use in the laboratory is less than 5 gallons. Several active and inactive gloveboxes contain plutonium bearing and combustible materials. A fire which breaches a glovebox could spread contamination.

Liquid propane is used infrequently for a variety of types of maintenance. The quantity of LPG is administratively restricted to 465 g (16.4 oz) per cylinder, with no more than 2 cylinders allowed in any single room and no more than 6 cylinders allowed in a building containing an inventory of transuranic material. An analysis given in Rogers 1996 indicated that a fire involving a release of propane is not credible (frequency of occurrence is less than 10^{-6}/yr). The propane fires are therefore not considered. Fire scenarios involving propane could be required if administrative controls on the propane were revised.

A maximum possible fire scenario was developed in the FHA for the 234-5Z office and laboratory areas. The worst case fuel load is 430 kg (946 lb) cellulose content and about 30 kg (66 lb.) of plastic or approximately 511 kg (1,124 lb.) wood equivalent. The results indicate that a fire involving this combustible loading is not expected to cause structural failures. Fire involvement is expected to be contained within the analytical lab areas. See Section 6.3.2 of the FHA (McKinnis 1998) for more details of this scenario.

A fire in the glovebox area is also possible. The FHA indicates that fuel load in this area is equivalent to 2790 kg of wood. A fire in the glovebox area is expected to be the worst case for fires within the contaminated areas (Zone 3). Structural failure is not expected. The area of an unmitigated fire is expected to be confined to the C line and A line glovebox area and to adjoining offices and laboratory spaces. The concrete walls are expected to limit fire spread as discussed in Section 6.3.2.5.3 of the FHA.

A leak or accidental discharge from the hydraulic elevator pump located in Room 321 could result in 568 liters of hydraulic oil being spilled on the floor. If ignited, the oil could present a significant fire hazard. The most severe fire results from a breach of the hydraulic elevator pump, piping or reservoir located in Room 321. The FHA analysis (Section 6.3.4) indicates this fire can lead to significant building structural damage. Structural failure of columns and roof assemblies can potentially collapse the wall separating the front side from the back side. Worst case assumptions can result in the collapse of the E-4 filter bank walls, exposing the contaminated

filter to the fire. However, activation of the sprinklers, while not extinguishing the liquid fire, will prevent the fire from spreading throughout the second floor. The cooling effect of the water is expected to prevent significant structural damage to the facility. The automatic sprinklers will therefore prevent contamination releases.

Pu bearing materials such as plutonium nitrate and Pu filtrate solutions are stored in Rooms 172 and 236. These materials are normally confined in vented containers. The solutions can generate hydrogen which can result in a potential fire/explosion hazard. If the ventilation system is operational, the steady state hydrogen concentration will be much less than the lower flammability limit. If the ventilation system is not operational, flammable concentrations could build up over long periods of time. However, even using very conservative assumptions, analyses in Section 6.3.5 of the FHA indicate that while a hydrogen detonation could result in metal shrapnel fragments that could cause local damage in the room, the resulting shock wave is not expected to cause failure of the room walls or ceilings.

The building is protected from exposure hazards as follows.

- The 242-Z, 243-Z, 234-5ZA, 236-Z, 2736-Z (vault corridor), and 2736-ZA Buildings are protected with automatic sprinklers and the transformers on the north side of the building are protected with an automatic deluge system.

- The separation distance, noncombustible construction, and limited number of openings in the 2727-Z and 2731-Z Buildings.

- The 291-Z Building is located belowgrade and has fire resistive construction.

Fire Protection Design Features. Noncombustible materials were used whenever possible in the construction of the 234-5Z Building. Where combustible materials were essential, every effort was made to minimize the quantity. The roof is a FM Fire Class I approved roof over a pre-existing metal deck. Corrugated 16-gauge aluminum over 1.5 in. rock wool insulation supported by structural steel comprise the exterior walls. The interior walls are metal partitions, plaster on metal lath, gypsum board on metal studding and, in the case of vaults and process areas, 8 in. thick, reinforced, poured concrete. The floors are generally poured concrete, which is finished with tile in some areas. Exceptions are the main supply plenum floor in the ventilation supply plenum and the duct-level deck, which are made of metal roof decking covered with waterproof seal. Gloveboxes are constructed of stainless steel and have panels made of polycarbonate (over half of the gloveboxes have these) or safety glass. Stairwells 1, 2, 6, 12, and 13 are currently isolated with fire barriers. Fire-associated risks and accident analyses are discussed in Chapter 9.0.

Feed items for the RMC Line process that originated in PRF potentially contain tributyl phosphate (TBP). One of the thermal decomposition products of TBP is butene. Butene, in the proper concentrations, is flammable. Combustion of large amounts of butene gas could cause a rupture in the glovebox. It is unlikely that sufficient gas could be generated to rupture

the glovebox. Four independent barriers are in place to prevent hazardous flammable levels.

- All sludge items originating from PRF (or if origin is uncertain) are sampled for organic content. Material with greater than 10 g organic per charge will not be fed into the furnaces.

- Any flammable gases are removed and diluted by continuous circulation through the furnace of about 2 to 3 ft^3/min of air.

- A cover gas of CO_2 is introduced into the furnace in the temperature regime where flammable gas could be generated. The CO_2 is fed into the furnace at a flow rate of 30 to 35 ft^3/h. Before each cycle, the operator will verify that one of the CO_2 cylinders is at least one-eighth full.

- The material is slowly heated at a ramp rate of 5 °C/min at 175 °C and held at this temperature for 1.5 h. This will assure that all of the TBP has decomposed before reaching the auto ignition temperature of butene, which is 324 °C.

The automatic sprinkler systems and deluge systems will limit damage from fires outside gloveboxes in the building. The laboratory or office areas will suffer limited damage.

In accordance with FHA recommendations, a berm has been placed around hydraulic elevator components. The elevator components are mounted on or near a wall, such that the berm comprises three sides of the containment, with the wall serving as the fourth. The berm, sized to contain two times the maximum volume potentially spilled, limits the spread of a hydraulic oil fire thereby limiting the number of structural members exposed to the fire. Because the hydraulic system is pressurized, spray shields have been installed around pressurized components to prevent oil from spraying outside the berm should a small leak develop in the system.

The hydraulic oil fire presents a special problem since the sprinklers can carry floating burning liquids from the source to other areas. The automatic sprinklers will however contain the fire to within the fan room, and there is no contamination spread from the liquid pool fire scenario.

Controlling a fire in a glovebox before significant damage occurs can be achieved by an automatic fire suppression system. Currently there are three different types of existing automatic fire suppression system used in the PFP gloveboxes:

1. Total flooding Halon systems
2. Dry chemical systems
3. Limited water bottle stations.

The type of fire suppression required depends on the process conducted in the glovebox, and whether the glovebox is active or not. The suppression systems are shown in Table 5-32. The suppression systems are discussed in section 7 of the FHA and glovebox fires are discussed in detail in Chapter 9 and the FHA. Based on the analyses performed at the time the Halon systems

were installed in the RMC line, it was determined that Halon concentrations at or near 75% could result in adverse conditions or reactions with burning metals. Thus there is no potential for an adverse reaction between Halon and burning metals because Halon concentration is less than 10%.

The 236-Z Building. The 236-Z Building houses the inactive PRF process equipment and services for MT, slag-and-crucible dissolution, filtrate concentration, feed preparation, plutonium solvent extraction, product concentration, and waste treatment processes. The PRF is currently used for storing in-process residues and solids that are awaiting processing to vault-storable form. A detailed description of this building can be found in Section 5.2.2.

Fire Exposure Hazards. The 236-Z Building is subject to exposure from fires in adjacent structures or objects (see Figure 5-1). The building is protected from exposure hazards as follows.

- The 234-5Z and 242-Z Buildings are provided with automatic sprinkler protection, so they do not present an exposure hazard.
- The 2727-Z Building is a noncombustible building and the west wall of the 236-Z Building is concrete. This arrangement mitigates any exposure hazards that could be presented by the 2727-Z Building.

The fuel loading in 236-Z is generally limited. The canyon area is currently inactive and contains almost no combustibles. The building is constructed of fire resistant construction. The major fire hazard is a fire in the gloveboxes. Because of the limited fuel load, fires in the gloveboxes are not expected to spread beyond the rooms containing the gloveboxes. The fires could however result in contamination being released from the glovebox. Glovebox fire consequences are addressed in the accident analysis section of this FSAR.

Fire Protection Design Features. This building has a construction classification of fire resistive. The roof is tar and gravel over a concrete slab on a metal deck. A product directories of UL-listed class A polyurethane foam has been applied over this assembly. The exterior walls and floors are poured concrete and concrete block. The interior walls consist of plaster on metal lath, poured concrete, and concrete block. Fire barriers isolate stairwells 1 and 2.

The 232-Z Building. This building was formerly used to house an incinerator and dry radioactive waste recovery process. The building is now in layaway status. There are no special hazards associated with this building. See Section 5.2.3 for a detailed description of this building. Analyses in the FHA indicate a fire will not result in structural damage to the building.

Fire Exposure Hazards. The 232-Z Building is subject to exposure from fires in adjacent structures or objects (see Figure 5-1). The building is protected from exposure hazards by the separation distance, noncombustible construction and limited number of openings in the 2736-ZC, 2736-ZB, and 2731-ZA Buildings.

The 241-Z Complex. A description of this complex is provided in Section 5.2.4. The 241-Z Complex is referred to as the Liquid Waste Treatment Facility. The 241-Z Building consists of five below-ground concrete enclosures with concrete cover blocks, each containing a 4,300-gal tank and covered at grade level by a corrugated metal building (a weather cover to permit all-weather operation of the vent and electrical systems; the concrete coverblocks of the below-grade tank enclosures serves as part of the flooring of the metal building). These tanks accumulate RLW from various PFP process and laboratory sources. The building is located approximately 330 ft south of the 234-5Z Building. The 241-ZA, 241-ZB (scheduled for removal) and 241-ZG Buildings are corrugated metal structures. The 241-Z-RB is a concrete waste water retention basin (and is scheduled for removal).

Special Hazards. There are no special hazards associated with these buildings other than the presence of RLW. There are no exposure hazards. The tank sumps are constructed of noncombustible materials and are belowgrade. The 241-Z Building houses the tanks containing RLW and has essentially no combustible contents. The roof, exterior walls, and interior walls are corrugated metal. The floor is poured concrete.

The 242-Z Building. This building is located between and attached to the 234-5Z and 236-Z Buildings. The building contains some unused process equipment. See Section 5.2.5 for a detailed description of this building.

Fire Exposure Hazards. The 242-Z Building is subject to exposure from fires in adjacent structures or objects (see Figure 5-1). The building is protected from exposure hazards because the 234-5Z, 236-Z, and 242-ZA (TC-66) Buildings are protected throughout by automatic sprinklers.

The 291-Z Building. The exhaust fan house, also called the compressor and fan house, is a reinforced-concrete structure with an interior finish of noncombustible materials. It is located approximately 25 ft south of the 234-5Z Building. The 291-Z-1 stack is an auxiliary structure to the 291-Z Building. The 291-Z Building houses ventilation exhaust fans for the 234-5Z, 242-Z, 232-Z, and 236-Z Buildings. There are seven electrically-driven exhaust fans. In addition, there are two deactivated steam-driven fans that were formerly used for emergency exhaust (the function originally provided by the steam-driven exhaust fans has been replaced by providing backup power from diesel-generators to two of the seven electrically-driven exhaust fans). The building also houses vacuum pumps, process and instrument air pumps, evaporative coolers, and two oil-cooled, 1,000-kVA transformers. See Section 5.2.6 for a detailed description of this building.

Special Hazards. Two oil-cooled, high-voltage transformers in the building present a special hazard.

Fire Exposure Hazards. The 291-Z Building is subject to exposure from fires in adjacent structures or objects (see Figure 5-1). There are no unacceptable fire exposure hazards to the 291-Z Building because of its location belowgrade, its fire resistive construction, and the presence of automatic sprinklers in the 234-5Z, 243-Z, and 2736-ZB Buildings.

The 291-Z Building has a construction classification of fire resistive and has a polyurethane coating over a built-up tar and felt roof on a concrete

deck. The deck is supported by concrete beams and columns. The ceiling, walls, and floor are reinforced poured concrete.

The most notable fuel load in Building 291-Z is located in the electrical room where there are two oil filled transformers. Each of the transformers contains 1,890 L (500 gallons) of oil. A worst case evaluation was made in the FHA assuming the entire content of one of the transformers spills on the floor and ignites. Structural failure of the ceiling is possible for large spill diameters. A deluge system is available to mitigate fires in the transformer but would not entirely prevent damage from an oil spill fire. The damage from the oil spill fire would however be limited to the transformer room (Room 500) and possibly some thermal damage to equipment in Room 501.

The 2736-Z Building. The 2736-Z Building consists of four vaults used for the storage of plutonium material. A corridor running the full length of the building divides the vaults and connects to the 2736-ZB Building. See Section 5.2.8.1 for a detailed description of this building.

Fire Exposure Hazards. The 2736-Z Building is subject to exposure from fires in adjacent structures or objects (see Figure 5-1). There are no unacceptable exposure hazards to the 2736-Z Building since the 234-5Z, 2736-ZA, and 2736-ZB Buildings are protected with automatic sprinklers, and the 2731-Z Building is constructed of noncombustible materials. In addition, the east wall of the 2736-Z Building serves as a fire wall.

The 2736-Z Building contains four vaults designated 1, 2, 3, and 4. Between vaults 1 and 2, as well as between vaults 3 and 4, are fire walls. The building has a construction classification of fire resistive. The building has a tar and gravel buildup roof on a concrete deck. The ceiling, floors, interior and exterior walls are poured concrete. The FHA concluded there are no credible fire scenarios which present a hazard to the structure or to the plutonium material stored in the vaults.

The 2736-ZB Building. The primary function of the building is shipping and receiving waste containers, plutonium oxide powder, and plutonium metal. The product is received from the 234-5Z Building and offsite and is transferred to the 2736-Z Building. It then goes through the NDA laboratory where it is counted for various values (isotopic and heat content). The product is either stored in the 2736-Z Building or shipped offsite.

The 2736-ZB Building has an NDA laboratory; a staging, shipping, sorting and receiving room; a changeroom; a mechanical equipment room; offices; a repackaging room; and a lunchroom. The NDA laboratory contains all the NDA and computer equipment. The equipment includes a calorimeter, a segmented gamma scan assay system, a gamma energy analysis system, a neutron-well coincidence counter, and associated minicomputers. Repackaging activities are carried out in a glovebox in room 636. See Section 5.2.8.3 for a detailed description of this building.

Fire Exposure Hazards. The 2736-ZB Building is subject to exposure from fires in adjacent structures or objects (see Figure 5-1). The building is protected from exposure hazards as follows.

- The 2736-ZA and 2721-Z Buildings are protected throughout with automatic sprinklers. The 291-Z Building has fire-resistive construction and is basically located belowgrade, and the joining wall between the 2736-Z and 2736-ZB Buildings is of fire-resistive construction. The fire alarm service in 232-Z remains in operation to alert the necessary personnel although the water to the automatic sprinklers has temporarily been capped.

- The east and south walls of the 2736-ZB Building are of fire-resistive construction, which mitigates the exposure hazards of the buildings on these sides.

The 2736-ZB Building has a construction classification of fire resistive. The roof consists of built-up tar on a reinforced concrete deck, supported by concrete columns. The exterior walls are reinforced poured concrete and the interior walls are poured concrete and gypsum wallboard. The gypsum wallboard is sealed, taped, painted, and supported by metal studs. The ceiling varies throughout the building. The office area has a suspended lay-in acoustical tile assembly. The locker rooms, laboratories, staging, shipping, sorting, and receiving areas have a suspended gypsum board assembly. The remaining areas are open to the underside of the roof. The floor is poured concrete and is finished with tile and paint. There is an extension on the south side of the building that consists of a prefabricated metal structure (2736-ZC).

The heaviest fuel loading in Building 2736-ZB is in the office space and the NDA lab. The worst case fire scenario is considered to be bounded by the fire scenario for the office/lab spaces in Building 234-5Z, which did not result in structural failures. Fire spread into the storage vaults is not anticipated because of the solid concrete walls separating these areas. The NDA lab contains plutonium bearing materials and therefore a fire in the lab can potentially contaminate the building. Contamination to the outside is not expected since the fire will be contained within the lab and office spaces, and there are no direct openings to the outside.

Auxiliary Facilities. In most cases, fire scenarios in these facilities result in minor damage and no contamination spread. Exposure hazards from these structures are discussed under the individual main process buildings.

5.4.11.1.2 Seismic Requirements. Details and results of seismically induced fire scenarios are discussed in Chapter 9.0

5.4.11.1.3 Codes and Standards. Codes and standards used in the design of the fire protection system for the PFP are considered in Chapter 4.0.

5.4.11.1.4 Fire Hazards During Construction. Construction consists of upgrades to the facilities and maintenance activities. The upgrade and maintenance activities pose a hazard by the introduction of excess quantities of combustibles (solids and liquids) not normally found in the operating facilities on the plant site. Also, disturbance of electrical systems, including temporary hookups, can serve as fire initiators.

5.4.11.2 System Description. The fire protection systems for the PFP consist of many individual communication and operating systems that inform or provide some action in regard to fires and fire fighting. The system also includes

compartmentalization and placement of fire barriers to protect against exposure hazard and provide for fire isolation to limit damage and allow personnel egress. The systems include the following:

- Piping systems that contain and transport the extinguishing agents
- Fire alarm systems, some of which notify the HFD when initiated
- Heat or products of combustion detection systems that initiate an alarm and/or initiate a suppression system
- Automatic wet-pipe, dry-pipe, pre-action, and deluge sprinkler systems
- Halon suppression systems (RMC Line gloveboxes, 2704-Z vault and 2701-ZA Buildings)
- Dry-chemical suppression systems
- Portable fire extinguishers and MgO sand
- Limited water suppression systems for hoods and gloveboxes
- Supervised valves in the water supply system
- Fire barriers to isolate parts of buildings, thus slowing progress of fire, reducing damage, and providing personnel safety in the means of egress.

5.4.11.2.1 Water Supply. The water supply and distribution system is described in Section 5.4.7. Water for both fire protection and domestic requirements is provided from connections to the water supply and distribution system 8-in. sanitary water service loop. The PFP facilities are serviced by 8 hydrants. Water flow tests for hydrant 10Z indicated a flow of 1170 gpm. This flow meets the requirements of DOE Order 6430.1A which requires a 1000 gpm. Tests to determine if the sprinkler water supply was adequate indicated a total demand of 718 gpm at 235-RZ second floor, primary filter and duct area, and a total demand of 854 gpm for 236-Z, fourth floor, Rooms 41 to 44. The water supply for fire protection service for the PFP complex satisfies the requirements contained in NFPA 13 in terms of required flow for the sprinkler systems.

Supply lines to the sanitary water service loop are fitted with check valves upstream of their service loop tie-ins. The check valves help maintain service loop water pressure and prevent loop drainage if a supply line breaks. Isolation valves in the supply lines and service loop ensure that a line break will not cause a lengthy loss of the PFP water supply.

The fire hydrants and the 8-in. sanitary water service loop are shown in Figure 5-59. The service loop is also provided with isolation valves and post indicator valves. All the post indicator valves are equipped with tamper switches that alarm at the HFD and the 234-5Z Building.

5.4.11.2.2 Normal Power Supply. The power distribution system is described in Section 5.4.2. The fire protection system is normally powered by mains from the 251-W substation feeds. The 13.8-kV supply is stepped down to 480 V by a transformer in the 234-5Z Building and fed to switchgear bus 300. A normally closed breaker then feeds to the emergency distribution bus, bus 400. This breaker opens on loss of normal power supply.

5.4.11.2.3 Backup Power. Backup power distribution to the fire protection systems is normally provided by batteries. Some fire control panels also get power from panels supplied from the backup power system supplied by the diesel-generators.

5.4.11.2.4 Fire Alarm System. The 234-5Z Building is equipped with a Flex 500A fire alarm control panel located in corridor 14A (see Figure 5-6, sheet 1 for location of the corridor). This panel also serves fire zones in the 236-Z, 242-Z, 2727-Z, 2729-Z, 2734-ZA, 242-ZA (TC-66), 234-ZC, 234-5ZA, and 2734-ZC Buildings. Each fire zone is transmitted to the HFD by radio fire alarm reporters (numbers 2780 and 2781). The fire-alarm control panels (FACPs) and remote fire alarm relays (RFARs) associated with other PFP buildings are shown in Table 5-27. The fire alarm and protection systems located in PFP auxiliary facilities are shown in Table 5-28.

Local and remote alarms may be initiated by heat detectors, smoke detectors, activation of any automatic fire suppression/extinguishing, and manual pull boxes. In addition, electrical and physical supervisory systems are provided to monitor electrical performance and critical component position. Electrical supervision consists of using alarm circuits to provide trouble signals when a circuit problem occurs. Physical supervision uses switches (valve tamper, low pressure, etc.). The electrical system will cause annunciation locally at the supervisory control panel located at 14-A and at the HFD for off-normal events.

5.4.11.2.5 Sprinkler Systems. Several types of sprinkler systems are employed in PFP building locations. They include wet-pipe, dry-pipe, preaction, limited water for hoods and gloveboxes, and deluge systems. Most of the sprinkler systems are pipe schedule designed rather than hydraulically calculated, which provides more conservatism. Foam is not used in PFP sprinkler systems. Sprinkler coverage for PFP buildings is shown in Figure 5-63. Fire protection features for all other buildings are described in Section 5.4.11.3.

Hardware included in the sprinkler systems meets NFPA codes and standards. Components are UL listed or FM approved for their intended use. The sprinkler systems were installed to meet design basis event analysis. The sanitary water supply to the fire system, however, is not seismically qualified. Several areas have glycol antifreeze loop systems.

5.4.11.2.6 Special Protection Systems. Systems or components not described above, but common to all PFP facilities, are discussed in this section. Some buildings are equipped with portable fire extinguishers. These extinguishers are approved for the type of application where they are located, inspected regularly, and meet all other NFPA 10 requirements (NFPA 1979b).

A Halon 1301 system provides fire protection inside RMC Line gloveboxes. The system is actuated in individual gloveboxes by heat detectors and is completely separate and independent of other fire suppression systems. Actuation does not cause pressurization, as demonstrated by the acceptance test procedure, and provides a 5% concentration for 10 min. The Halon system is interlocked with the RMC emergency exhaust fire damper.

Many other gloveboxes and hoods in the 234-5Z Building that are not protected by Halon 1301 are equipped with limited water bottle stations or heat detectors. Banks of water storage containers are located on the duct level of the building and provide a nominal 5-gal water supply to a glovebox or hood. A N_2 system provides pressure to each limited water bottle station to compensate for air leaks. Water flow will initiate fire alarm annunciation. Special inerting atmospheres are not used in place of automatic fire suppression systems at PFP.

A dry chemical system is installed in glovebox HA-21I in room 235B of the 234-5Z Building and is maintained in accordance with NFPA requirements, though the manual pull station and control panel for the dry chemical system are currently out of service. The MgO sand is also available in gloveboxes to aid in extinguishing plutonium metal fires.

Fire hose stations are located throughout the 234-5Z Building, served from sprinkler riser 1 (located in corridor 14B; see Figure 5-6, sheet 1 for location of corridor). As part of a site-wide policy change, the fire hoses have been removed from these locations, though the water supply still remains. The hose station valves and piping are still maintained and are available for manual fire suppression by HFD fire fighters.

5.4.11.3 Individual Facility Descriptions. Fire protection system features and other information unique to individual buildings located in the PFP facility are discussed in this section. In addition to the material provided in this chapter, information on building construction and process function is located in Section 5.2 of this document.

Discussions pertaining to DOE Order 5480.7 (DOE 1987) compliance, including loss amounts, are discussed in an internal memorandum from Taylor (1989). Specific DOE Order 6430.1A (DOE 1989) compliance items are addressed in WHC (1990).

5.4.11.3.1 The 234-5Z Building. In addition to the previous discussions and the discussion in this section, fire protection features located in the PFP AL, standards laboratory, and PPSL are detailed in Section 5.4.14.

The 234-5Z Building has four levels: one level belowgrade, one level on grade, and two levels above grade. The building is equipped with floor drains, but most of these are inoperable. Liquid run-off from the upper floors would flow to the levels below, primarily through the stairwells. The exception to this is the duct level. Liquid run-off from this level would penetrate the metal floor and enter the concealed space above the first floor ceiling. This would cause additional damage, especially in the contaminated areas of the building.

The building is equipped with wet-pipe, dry-pipe, and deluge sprinkler systems. The areas covered by sprinklers is shown in Figure 5-63.

The 234-5Z Building is in compliance with the potential-property-loss requirements of DOE (1987). The MPFL has been determined to be $27,000,000. The MCFL is $4,300,000. The maximum-possible property loss has been determined to exceed $25M (Taylor 1989), which is not in full compliance with DOE (1987) requirements. The programmatic loss of 3 months from the potential-property-loss fire is in compliance with DOE (1987). Because of the magnitude of the dollar loss in the maximum possible property loss fire, it is questionable if the plant would be refurbished. Project B-631, "PFP Fire Safety and Loss Limitation," corrected these noncompliance issues so that the building would meet DOE Order 5480.7 (DOE 1987). The following plant upgrades done under Project B-631 consisted of the following:

- Installing automatic sprinkler system with flow alarms
- Modifying or constructing new personnel emergency egress routes
- Upgrading the plant fire alarm system
- Providing fire area separations by upgrading wall structures and duct protection.

5.4.11.3.2 The 236-Z Building. The building is not equipped with any special liquid run-off control features. The run-off from the upper floor levels would be to the levels below, and would run down the stairs and through the floor openings. Therefore, on/off type heads were installed to reduce water flow.

Both interior stairwells are provided with smoke-detector-operated fire dampers. The east stairwell is also equipped with fusible-link-activated fire dampers in the ventilation openings that penetrate the stairwell from the outside. The building is in compliance with "improved risk" criteria established in DOE (1987).

The MPFL and MCFL have both been determined to be approximately $1,800,000. These losses are in compliance with DOE (1987). The 94-1 stabilization project would be shut down by a first floor fire affecting the thermal stabilization line. A delay of approximately 6 months is estimated.

5.4.11.3.3 The 232-Z Building. This building is awaiting decontamination and decommissioning. The maximum loss for this building is less than $100,000. Because of the low loss from the maximum fire, this building complies with all loss-limitation provisions of DOE (1987). The building also complies with all life-safety requirements and improved risk criteria.

5.4.11.3.4 The 241-Z Complex. A detailed description of the 241-Z Complex is given in Section 5.2.4. The 241-Z Building consists of five separate concrete sump cells, each containing one stainless steel waste tank. The cells and cell covers are built of reinforced concrete, with the covers located at approximately grade level. A pre-engineered corrugated metal

building houses support equipment and provides weather protection. The remaining buildings are made of corrugated metal and/or concrete.

The 241-Z Building is not normally occupied by personnel. The very low consequence of a fire in the 241-Z Building ($250,000 loss for either the MPFL or MCFL) or the rest of the complex does not warrant a special fire analysis. Based on the above considerations, the building complies to applicable portions of DOE (1987) for loss limitation, life safety, and improved risk.

5.4.11.3.5 The 242-Z Building. The latest fire protection survey (McKinnis 1998) indicates an MPFC of $5,300,000 and an MCFL of $16,000.

5.4.11.3.6 The 291-Z Building. The building has one level belowgrade. Liquid run-off from the probable fire scenario is expected to remain in the room because this area is provided with curbs. These curbs can retain up to 2,220 gal of fire water.

The MPFL and MCFL are the same,with a loss of approximately $530,000. The amounts are in compliance with DOE (1989). The downtime is about 2 weeks.

5.4.11.3.7 The 2736-Z Building. The building is constructed entirely of concrete and contains four vaults designated 1, 2, 3, and 4. Vaults 1 and 2, as well as vaults 3 and 4, are separated by a fire wall. A corridor divides the building in half. A general fire survey has determined that the fire protection systems are adequate to protect the building.

Vault 2 is provided with scuppers 0.5 in. above the floor. The scuppers discharge to the corridor, which has a sealed drain. The drain is sealed to prevent the discard of contaminated water. If the water is determined to be within specification requirements for waste water discharge, the seal can be removed.

The MPFL and MCFL are each associated with the security system wire raceway. The loss for either the MPFL or the MCFL would be $800,000, which is in compliance with DOE (1987).

The potential programmatic loss for both scenarios would be basically the same. There would be an inconvenience to the building security operations; however, it would not have a significant impact on the function of the building.

5.4.11.3.8 The 2736-ZB Building. The building has one level on grade. Liquid run-off would be to adjacent rooms and to the exterior. There are no special control features in the building. A general fire survey has determined that the fire protection systems are adequate to protect the building.

The MPFL is approximately $2,227,000 and the MCFL is equal to the MPFL. These potential programmatic losses are in compliance with DOE (1987). The building also complies with improved risk and life-safety criteria established by DOE (1987). There would be no operational loss since other laboratory facilities could be used to maintain programmatic schedules.

5.4.11.3.9 The 243-Z Building. This structure consists of a total of five rooms. Room 401 is a vestibule; room 402 is a changing room; room 403 is a drum washing room; room 404 is a drum turning room; and room 405 is the process room for waste water filtration. See Section 5.2.9 for more details of the building and Chapter 7.0 for details of the building processes.

The 243-Z Building has adequate exposure protection from fire in other buildings because of the fire protection measures in these other buildings and the distance separating the 243-Z Building from adjacent buildings. The 243-Z Building does not contain large quantities of combustible materials, is built of noncombustible materials (e.g., concrete and corrugated metal) and the process material of the facility is noncombustible (e.g., waste water). The 243-Z Building is covered by a wet-pipe automatic sprinkler system. Upon activation of the automatic sprinkler system, the fire alarms will be indicated at the local fire alarm control panel and transmitted to the HFD by the radio fire alarm reporter. The MPFL is $500,000 and the MCFL is <$500,000. The building complies with DOE 1987.

5.4.11.3.10 Auxiliary Facilities. The compliance of these facilities is shown in Table 5-29.

5.4.11.4 Inspection and Testing Requirements. The plant fire protection systems are inspected and tested in accordance with NFPA and DOE Order 5480 series criteria and HNF-PRO-351, *Fire Protection System Testing/Inspection and Maintenance*. A routine preventive maintenance program for fire protection systems meets the requirements identified in the documents named above. Procedures are in place to provide assurance that fire system inspection and testing requirements are met.

Loss-prevention programs are established at PFP to assure proper operation and maintenance of fire system equipment. These programs include routine procedural visual inspections, preventive maintenance, and other activities as specified in HNF-PRO-351, *Fire Protection System Testing/Inspection and Maintenance*, HNF-PRO-352, *Fire Protection System Discrepancies*, HNF-PRO-345, *Fire Protection Corrective Actions* and HNF-PRO-371, *Hanford Fire Department*.

5.4.11.5 Personnel Qualification and Training. The HFD maintains a training program for fire fighting, fire testing, and fire inspection. These training programs have been designed to meet NFPA and DOE Order 5480 series criteria.

A separate work force provides maintenance activities associated with fire protection systems. This work force is provided on-the-job training, which is augmented by vendor-supplied training and instruction. The vendor training is also available to anyone involved with the fire protection systems.

5.4.12 Maintenance Systems

Maintenance for the PFP is provided by its own maintenance group reporting to the PFP Plant Manager. Certain craft specialties such as vent and balance are obtained by work order, and work to PFP-approved work orders

and instructions. Training of the staff is outlined in Chapter 10.0. All maintenance is performed under ALARA guidance as outlined in Chapter 8.0.

5.4.12.1 Major Components and Operating Characteristics. During the initial design and construction phases of the PFP, the nationally recognized allowable radiation exposure was higher than today. The guidance came from (NBS 1938) (NBS 1949) and (NBS 1953). While the allowable exposure was higher, there existed a caveat that all radiation exposure be kept to the minimum. In 1954, as low as possible, the predecessor of ALARA, became the design guidance (see Chapter 8.0).

Routine maintenance has been conducted since the PFP went into operation in 1950. Since that time, there has been a continuous effort to ensure that the exposure to operators and maintenance personnel alike be maintained ALARA. While it is not possible to characterize all of the design features that have been included in the plant over the years to accomplish this, the following are examples of some of them.

- A major feature of the plant that minimizes exposure during maintenance is the small size and the compartmentalization of the process lines. This feature localizes the source term to that in the immediate maintenance area. This is important when contact maintenance is required.

- Remote maintenance of process equipment in the 236-Z Building. The facility was designed for conducting the majority of the maintenance work in a designated maintenance cell or glovebox.

- Service connectors to gloveboxes are protected with nontestable HEPA filters or sealed to prevent contamination of the service lines.

- The RMC Line high-use gloveboxes were retrofitted with gloveports that provide a higher degree of containment during glove change out.

- The gloveports on new gloveboxes are located to permit ease of maintenance of process equipment.

- Coving and the use of special interior surface finishes for gloveboxes minimizes the buildup of contamination and makes decontamination easier.

- A vacuum cleaning system is installed in some of the RMC Line gloveboxes and was used for removal of residual powders to reduce exposure from surface contamination. The vacuum cleaning system is partially dismantled.

- Movable radiation shields, known as ALARA panels, are available for installation to reduce the exposure to operators and maintenance personnel.

5.4.12.2 Safety Considerations and Controls. Required maintenance activities routinely involve work in contaminated and/or radiation areas. Controls associated with the ALARA program are described in Chapter 8.0, and cover all operations including maintenance.

Examples of measures in place to ensure work is performed with the lowest reasonable radiation dose to the workers includes the following.

- All work is formally planned. A work plan is required for any work. A job safety analysis/hazards analysis of the work planned indicates the potential problems. Based on the analysis, additional precautions are identified and added to the work plan. The work plan is coordinated between maintenance, radiation protection, quality assurance, and operations to ensure complete support of the plan. When the job safety analysis dictates, an additional review is performed by Nuclear Facility Safety. An ALARA management worksheet is needed for work plans above 2K dpm and nonroutine work.

- Extensive use is made of greenhouses (plastic containment tents) to provide containment during maintenance. These operations are tightly controlled and discussed in Chapter 8.0, Section 8.5.2.

- When required in the work plan, additional radiation shields, known as ALARA panels, are installed (Chapter 8.0, Section 8.3.2).

- The source term in processing equipment and gloveboxes is removed to the extent possible, thus minimizing the exposure to operating and maintenance personnel.

- Quality assurance (QA) is provided to ensure that acceptable materials are used and that the replacement or repairs function properly.

- Preventive maintenance is scheduled into the operations plan to minimize production downtime. Scheduled production shutdowns are used for equipment maintenance, repair, and replacements.

In all cases, emphasis is placed on personnel safety and ALARA. The PFP management integrates all phases of operations, maintenance, and engineering to accomplish these goals consistent with personnel safety, ALARA, and environmental protection.

5.4.13 Cold Chemical Systems

Cold (nonradioactive) chemical systems consist of storage, transfer, and makeup of chemical solutions that were used in plutonium processing and are currently used in plutonium material stabilization and laboratory functions. Small quantities of chemicals stored and used in the laboratories present no significant hazard other than that normally associated with industrial laboratories.

Chemical storage for the PFP is located in both external and internal areas of the facility. Accidental release of chemicals from a storage container could endanger the integrity of the building or its occupants. External storage is limited to the 2734 series of gas storage buildings (discussed in Section 5.4.4), DR876, E Dock, G Dock, and W Dock.

Inside storage in the 234-5Z Building is limited to rooms 392 and 338 for dry and wet chemical storage, respectively, and the chemical makeup areas (rooms 336 and 337). Small quantities of chemicals normally associated with industrial uses (such as industrial laboratories) are typically stored in the following areas: rooms 141, 154, 302, and 321, and corridor 4, 4B, and 4D. Additional chemical storage areas in the laboratories are identified by room in Section 5.4.14.

Chemical makeup areas are located in rooms 336 and 337 of the 234-5Z Building (Figures 5-6, sheet 3 and 5-20), and room 40 of the 236-Z Building (Figures 5-6, sheet 4 and 5-64). Chemical makeup involves mixing chemicals to provide solutions or organic mixtures for various processes supporting plutonium operations at the PFP.

5.4.13.1 Chemical Prep Room 336/337 (234-5Z Building). Facilities in rooms 336 and 337 (Figure 5-20) were used to prepare and supply chemicals to the RMC Line and may be currently used to prepare solutions for acid dissolution processes. Tanks are arranged along the south wall of the rooms in a low-walled sump. Room 336 contains tanks H, I, F1, F-2, C, D, D-1, D-2, G-1, G-2, E-1, E-3, and HF1-1. Room 337 contains tanks KOH-1 (TK-1), KOH-2 (TK-2), D-15, J-11, S2-X, HN-8, D-34, D-16, HN-A, and K-3. Both rooms are hooded and ventilated through roof exhausts. The room is equipped with safety showers, floor drains, and fire sprinklers. Walls and ceiling are constructed of 0.75 in. thick plaster on metal lath. Motor controls for outside chemical pumps are located in room 337. An overview of the chemical makeup activities in rooms 336 and 337 is provided as follows.

- Strong HNO_3 solution--Concentrated HNO_3 (57 wt%) was received and stored in a 7,000-gal tank outside and east of the 234-5Z Building. The inventory of HNO_3 in the PFP was reduced by removing excess HNO_3 from the tank during FY 1996 and transferring 350 L of acid to the chemical prep room 40. Any future need of concentrated HNO_3 would be met by bringing 55-gal drums into the PFP and transferring the solution to the 7,000-gal tank for distribution. When needed, 57 wt% HNO_3 is pumped from this tank through a pipeline to tank C, located in room 336, where the concentration is verified by sampling and analysis or by measuring the density with a hydrometer. Acid from tank C is pump transferred to tanks G-1 and G-2 for production of dilute HNO_3 solution.

- Dilute HNO_3 Solution--Dilute HNO_3 (1.8-2.2 M) is made up in tanks G-1 and G-2, which are located in room 336, by first adding the specified volume of distilled water to the tank. Concentrated HNO_3 (57 wt%) is then added by pump transfer from storage tank C. The solution is agitated, sampled, and analyzed for HNO_3 molarity. Dilute HNO_3 is piped by gravity-drain to gloveboxes HC-227S to be used for adjustment of process solution acidity and as a flush solution during the cleanup phase of the tanks and floors of the PRF. Either tank G-1 or G-2 is valved in to the process while the second tank is being refilled or in standby.

5.4.13.1.1 Potassium Hydroxide Solution. The potassium hydroxide (KOH) solution is purchased as 45 wt% solution, in 55-gal drums. The major drum inventory is stored outside of the 234-5Z Building, with several drums

stored in room 336. The KOH is pumped from the drums, by either a small electrically or air operated pump inserted into the drum bung, to one or two 900-gal stainless steel tanks (KOH-1 and KOH-2; also identified as K-1 and K-2, respectively) located in room 337. The 45 wt% KOH solution was gravity-transferred through piping to the KOH scrubber in glovebox HA-46. One of the tanks (KOH-1 or KOH-2) normally was used for supplying KOH while the second tank contained water used for flushing the line from the tank to the KOH scrubber after each transfer. The tank containing water also received water flushes of the pump after the desired number of drums had been emptied to the makeup tank.

5.4.13.1.2 Chemical Hazards Mitigation. The rooms are equipped with eyewash stations and safety showers for water flushing should operators come in skin or eye contact with chemicals. Two operators are required for chemical makeup so that one can assist or call for aid should an accident occur to the other.

Activities performed in chemical makeup rooms 336 and 337 have personal protective equipment designated by the applicable work procedure, or on a job-by-job basis by the work plan. The procedures and work plans are reviewed by industrial safety specialists to ensure adequate protection of workers and compliance with applicable regulations and controls. Required protective equipment is dependent on the inherent hazards of the chemicals handled and might include face shields, goggles, acid suits, rubber gloves and boots, and/or supplied air respirators.

Each group of tanks is situated in a concrete sump to catch spills or liquid from ruptured tanks. Elevated floor drains in the sump allow an accumulation of liquid, with excess liquid being drained to the 2735-Z Catch Tank. The 2735-Z Catch Tank rests in a sump to collect its overflow. An NO_x monitor is positioned over room 336 tanks C, G-1, and G-2

5.4.13.2 Chemical Prep Room 40 (236-Z Building). This room contains the tanks, scales, and associated equipment used to prepare the organic solvent and other chemicals that were used in solvent extraction and other processing activities in the 236-Z Building (Figures 5-6, sheet 4 and 5-64). All makeup vessels are closed and vented to the E-3 ventilation system. All vessels are located within a diked area for spill control that empties to a catch tank for collection. The diked area accommodates the contents of the largest vessel. All PRF processes are currently inactive remaining in the PRF tanks and process lines are managed and dispositioned in accordance with HNF-2977, *Plutonium Reclamation Facility (PRF, Building 236-Z) Layup Plan* (BWHC 1998). Electrical power to instrumentation in the room has been isolated.

The following is a list of the tanks and their former uses:

- Tank A-103 formerly contained NaOH Solution
- Tank A-105 formerly contained HNO_3 Solution
- Tank A-106 formerly contained Aluminum Nitrate Nonahydrate Solution

- Tank A-116 formerly contained Antifoam solution
- Tank A-117 formerly contained B-acid and C-acid.

5.4.13.3 Indoors Chemical Storage. The main chemical storage area within the processing buildings is room 338 (Figure 5-20). Chemical makeup rooms 336 and 337 store drums of KOH solution and DOW antifoam 1410. Reducing and oxidizing chemicals are stored separate from each other.

5.4.13.3.1 Room 338--Chemical Storage. The following chemicals are stored in room 338:

- Oxalic acid--$C_2O_4H_2$ Activated carbon
- Sodium carbonate--Na_2CO_3.

5.4.13.3.2 Rooms 334 and 335--Former Calcium Storage. Each room is 8 ft by 9 ft with an 8 ft 9 in. high ceiling. The interior walls of rooms 334 and 335 are constructed of 0.75 in. thick vermiculite plaster on metal lath on metal studs. The walls of adjoining rooms are ordinary plaster installed similarly. These walls are not load-bearing and have a fire resistance rating of 1 h. The floor of rooms 334 and 335 is constructed of 4 in. thick reinforced concrete with a fire-resistance rating of more than 1.75 h. Automatic sprinklers are installed in the concealed space above the ceilings of rooms 334 and 335 to protect the roof from ignition. The ceilings are constructed of vermiculite plaster on metal lath on suspended metal studs. A nonflammable waterproofing material was applied to the ceilings of rooms 334 and 335 when the sprinkler system in the attic was installed. The bays enclosed by the waterproofed ceilings above rooms 334 and 335 are equipped with drains that will limit the water level in the bay to less than 2 in. These drains discharge to the corridor immediately south of rooms 334 and 335, which are not themselves equipped with sprinklers. Fire detection equipment consists of two fixed-temperature heat detectors in room 335, and one combination rate-of-rise/fixed-temperature detector in room 334. Air supply vents near the fire-rated doors and gravity vents to the roof are equipped with fire dampers. The room is equipped with metal shelves with front rails that are attached to the walls.

5.4.13.3.3 Room 165. Room 165 is 9 ft 6 in. by 12 ft 3 in. and serves as an anteroom to vault room 166. The north, east, and west walls and ceiling are made of 0.75 in. thick plaster on metal lath with lighting fixtures recessed in the ceiling. The south wall is an 8-in. concrete wall. The room is equipped with wet-pipe sprinklers and rate-of-rise heat detector. A ceiling diffuser delivers the S-3 room air, which can exit the room to some extent through a 0.38-in. space under the 40-in.-wide door. The room is used as a local supply room. Piping connected to the argon supply system is available in the room and was once used to provide an argon atmosphere inside a stainless steel vessel that held a can of calcium. Though calcium has been removed from the room, the argon supply has not been capped and is available to provide 15 lb/in^2 (gauge) pressure of argon. The argon piping is equipped with a pressure regulator set at 15 lb/in^2 and a pressure reducing valve set at 18 lb/in^2.

5.4.13.3.4 Chemical Hazards Mitigation. Activities performed in rooms 336, 337, and 338 have personal protective equipment designated by the

applicable work procedure, or on a job-by-job basis by the work plan. The procedures and work plans are reviewed by industrial safety specialists to ensure adequate protection of workers and compliance with applicable regulations and controls. Required protective equipment is dependent on the inherent hazards from the chemicals handled and might include face shields, goggles, acid suits, rubber gloves and boots, and/or supplied air respirators.

5.4.13.3.5 Room 165--Argon. Argon was supplied to the room and is not currently used.

Argon Handling. Argon piped to room 165 was used for purging the atmosphere in calcium storage cans. Since a hazardous condition could develop in the form of an oxygen depleted atmosphere, the following precautions are taken.

1. The room is ventilated and heavier than air gases (argon) are swept out under the door by air pressure from the S-3 air supply.

2. Argon flow is regulated to a maximum of 200 ft^3/h.

3. It is normally unoccupied and entry is administratively controlled.

5.4.13.4 Outside Chemical Storage. The following chemicals are stored in outside storage facilities at the PFP (see Figure 5-54).

5.4.13.4.1 East End of the 234-5Z Building. The 2735-Z Facility consists of the following:

- The ANN bulk storage tank (7,000-gal ANN)
- The HNO_3 bulk storage tank (7,000-gal 57% HNO_3)
- The 2735-Z ANN/HNO_3 containment basin.

Truck shipments were transferred directly to the ANN and HNO_3 storage tanks. The ANN was transferred to PRF chemical makeup tank A-106. The HNO_3 was transferred to PRF chemical makeup tank A-105 and the RMC Line chemical makeup tank.

5.4.13.4.2 Loading Docks East of the 236-Z Building (Drum Storage). Various drums of chemicals are stored on the loading dock east of the 236-Z Building as listed below.

- Propylene glycol
- Ferrous sulfamate
- Caustic potash (45% solution KOH)
- Tributyl phosphate
- Anhydrous Na_2CO_3
- Waste drums of crushed fluorescent light tubes and polychlorinated biphenols (PCB) ballasts.

5.4.13.4.3 Gas Bottle Storage, 2734-Z Building. The 2734-Z Building is empty and scheduled for replacement.

5.4.13.5 Chemical Hazards of the PFP Chemicals. A list of the principal chemicals used in PFP processing is shown in Table 5-30 and for other large

quantities of chemicals used in the PFP in Table 5-31. These tables provide the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and NFPA health, fire, reactivity, and persistence hazards rating for each chemical. This information was obtained from material safety data sheets for the chemicals. Sheets for all chemicals used at the Hanford Site are available from the Records Management Information System (RMIS) and from Waste Management Federal Services of Hanford Inc. (WMH). These data sheets also provide fire and explosion data and toxicity, health effects and first aid information, as well as applicable transportation regulations. The Chemical Management Programs are discussed in Section 10.4.5.

Most of the other materials at PFP (not listed in Tables 5-30 and 5-31) are used in small quantities in the laboratories. The material safety data sheets are also available for these materials from the RMIS or WMH.

5.4.13.6 Chemical Spill Management. A chemical spill management program is in place at the PFP. A trained response team is available at the PFP, as are approved procedures for handling leaks or spills of hazardous materials. In any large spill, (e.g., tank failure or drum puncture) this team would be supported by the hazardous materials response team of the HFD. Members of the response teams have completed generator hazards safety training.

The PFP has design features that will contain or mitigate a spill. The chemical preparation areas of PFP are equipped with diked-in sump areas that would contain the contents from any one tank failure. Leaks resulting from a water hose, nitric acid, or ANN pump left running may exceed the level of the sumps. A spill exceeding the capacity of the sump would overflow into the 2735-Z catch tank. Leaks or spills from the chemical makeup area and the sinks also drain to the 2735-Z catch tank. Before authorization is given to dispose of wastes generated from spill response actions to the waste water effluent stream, process engineering and plant management, interfacing with site solid waste engineering, shall determine whether the waste is regulated. Regulated wastes are packaged for disposal. Release/spill notification and reporting is performed in accordance with applicable federal, state and local regulations and DOE Orders.

5.4.14 Laboratory Facilities

There are three laboratory facilities in the 234-5Z Building: PFP AL, the standards laboratory, and the PPSL. The PFP AL, located in rooms 131 through 157A of the 234-5Z Building (Figure 5-6, sheet 1), is used to perform analytical and physical test analyses on plutonium samples supporting process control, product quality verification, and nuclear material accountability. The samples come from PFP plant processes, the research laboratory within PFP, and a few special test samples from other locations. The standards laboratory in rooms 221C, 221D, and 221E (Figure 5-6, sheet 1) is devoted to the formulation, verification, packaging, and distribution of actinide-containing destructive and nondestructive standards needed in the laboratories.

The PPSL is located in the southwest corner of the 234-5Z Building in rooms 179B through 191, room 202, and room 235C (Figure 5-6, sheet 1). The laboratory is chartered to operate chemical demonstration facilities involving both nonradioactive and radioactive materials. The PPSL also analyzes

nonroutine samples for process support and develops new methods which are then transferred to other organizations after the methodology is well established and the need becomes routine. The PPSL also processes limited quantities of plutonium material to demonstrate processes whenever the PPSL has exclusive expertise.

Chemical safety for laboratory operations is governed by *PFP Chemical Hygiene Plan*, ZAP-000-010. (See Section 10.4.5)

5.4.14.1 Functions, Equipment, Services, and Safety Considerations. In the subsequent sections, these definitions apply.

- Hood (open-faced and fume)--A standard laboratory hood is a stainless steel, open-faced fume hood that exhausts out the top. A pull-down front is provided in glass, reinforced glass, or Plexiglas™ to protect workers. The front of a fixed-faced hood is fixed in place with open ports to provide access.

- Glovebox--A typical laboratory glovebox is a stainless steel glovebox with rectangular viewing windows and 8-in.-diameter gloves. Gloveboxes are usually about 3 ft wide at the base, 3 ft high, and about 4 ft above the room floor; the length varies. A slight indent is provided partway up the sides to provide easy viewing of the glovebox floor.

- Trouble alarm--This is a foot-activated switch located along the floor of the room, on the bottom outside edge of the gloveboxes and hoods, to allow the worker to signal an alarm without exiting from the gloves. A buzzer sounds simultaneously in the office area indicating the affected area when the switch is hit to summon help in the labs.

- CAMs--CAM Physical description, functions, and location are provided in Chapter 8.0.

5.4.14.1.1 PFP Analytical Laboratory Layout. All laboratory open-faced hoods and gloveboxes are exhausted through the E-4 system. While no HEPA filters are attached directly to open-faced hoods, they are isolated from the environment by two stages of independent testable HEPA filtration. The amount of uncontained plutonium in dry, solid form is limited to 0 g in all open-faced hoods. Two gloveboxes in rooms 143 and 144 are also limited in the amount of uncontained plutonium in dry, solid form to 0 g and less than 0.2 g, respectively. These unique gloveboxes are also isolated from the environment by two independent and testable stages of HEPA filtration. All gloveboxes and hoods designed to be supplied with air from the dry air system (which currently supplies non-dry air; see Section 5.4.3) and have inlet nontestable HEPA filters. All gloveboxes are isolated from the environment by at least two independent stages of testable HEPA filtration. Placement of CAMs in the Analytical Laboratory is discussed in Section 5.4.10.1.6.

Room 131, Chemical Assay Laboratory.

Function and Equipment. Room 131 is used to analyze samples by weight for plutonium concentration. It contains one glovebox (supplied by the dry

air system; see Section 5.4.3) made up of three sections used for dissolution and analysis of product quality plutonium as follows.

- Section 1 contains a muffle furnace used for fusing plutonium oxide samples.
- Section 2 provides a working area where samples are dissolved, heated, titrated, and liquid waste is accumulated.
- Section 3 contains an argon-purged balance used in the titrations.

This is a standard laboratory dry air glovebox with an outlet HEPA filter. All HEPA filters on laboratory gloveboxes are pretested for efficiency before installation. In-place testing is not possible based on design limitations; however, in-place testing of primary filterbox HEPA filters servicing all laboratory gloveboxes and open-faced hoods is performed annually. The glovebox is exhausted through the building E-4 exhaust system and is supplied with vacuum.

Alarms and Protective Features. Room 131 has a smoke alarm and is protected by the building fire sprinkler system. A trouble alarm, located in room 131, will sound in the shift office (room 151). Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 131 is provided with vacuum, argon, 220-Vac, and process air (to Section 3) services.

Room 132, Mass Spectrometer Laboratory.

Function and Equipment. Room 132 contains two thermal ionization mass spectrometers for the isotopic analysis of extremely small quantities of plutonium and uranium. There is one E-4 drop to the mass spectrometers.

Alarms and Protective Features. Room 132 has one breathing air sampler. One room air sampler and a portable fire extinguisher are located in the room. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 132 is provided with instrument air, nitrogen, water, and 120- and 220-Vac services.

Room 133, Dark Room.

Function and Equipment. Room 133 contains the grating and camera portions of a 2-m emission spectrograph and equipment for developing the film. It also contains an explosion-proof refrigerator for film storage. No radioactive materials are allowed in the room.

Alarms and Protective Features. No CAMs or passive air samplers are in the room.

Services. Room 133 is provided with water and 120-Vac services.

Room 134.

Function and Equipment. Room 134 is used to prepare samples for analysis on the mass spectrometer. It contains four open-faced hoods used as follows.

- Hood 1 is used to contain the equipment that mounts samples onto filaments for analysis by mass spectrometry.
- Hood 2 is used to purify samples for the mass spectrometer anion exchange resin columns. The anion resin columns are 3 in. long and contain 2 mL of resin.
- Hoods 3 and 4 are laminar downflow open-faced hoods with testable HEPA filters used for chemical preparation and sample mounting. These hoods are used for single filament mounting (e.g., pulse counting) using only nanogram quantities of plutonium filament. Both hoods are exhausted to the E-4 exhaust system.

Hoods 1, 2, 3, and 4 are typical laboratory hoods and are exhausted through the E-4 exhaust system.

Alarms and Protective Features. The four hoods in room 134 have installed fire suppression systems. In hoods provided with fire suppression systems, each hood or glovebox is equipped with a temperature-sensitive head. When the temperature in the hood activates the sprinkler head, approximately 5 gal of water is discharged into the glovebox from an individual pressure water tank pressurized with air to provide the necessary motive force. These tanks are alarmed to indicate low air pressure and annunciate through the fire detection system. The room also has a trouble alarm and alpha survey instruments.

Services. Room 134 is provided with vacuum and 120-Vac services.

Room 135.

Function and Equipment. Room 135 is used to store and mount samples in support of the mass spectrometer laboratory. It contains four hoods used as follows.

- Hood 1 provides mounting of samples to be analyzed on the mass spectrometers.
- Hood 2 provides temporary storage of samples to be analyzed throughout the laboratory.
- Hood 3 is used for chemical preparation of samples in support of the mass spectrometer laboratory (not used).
- Hood 4 is used for chemical preparation of samples in support of the mass spectrometer laboratory (not used).

All hoods are typical laboratory hoods and are exhausted through the E-4 system.

Alarms and Protective Features. The four hoods in room 135 have installed fire suppression systems provided by limited-volume sprinkler heads. No shielding is required. The room is provided with a smoke alarm, an intrusion alarm (not active), and a workstation trouble alarm. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 135 is provided with vacuum, P-10 to the alpha counter, and 120-Vac services.

Rooms 136 and 137.

Function and Equipment. Room 136 contains an emission spectrophotometer and a quantometer. Room 137 contains the arc stand for the two-m film spectrograph. These instruments are used in trace element analyses of plutonium and uranium products. Each room contains a glovebox made up of three sections, used as follows.

- Section 1 contains equipment for sample preparation. Plutonium metal, nitrate and oxide samples are heated to 950 °C in a muffle furnace. Samples are then moved to Section 2.
- Section 2 contains equipment for the preparation and weighing of sample electrodes, after which they are transferred to Section 3.
- Section 3 contains the arc stand where the sample electrodes are shot in a moist argon-oxygen atmosphere.

This is a standard laboratory glovebox with both inlet/outlet HEPA filters and is exhausted through the E-4 system.

Alarms and Protective Features. Each room has a smoke alarm, trouble alarm, and intrusion alarm (not active). Section 1 of each glovebox contains a fire detection tube. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Rooms 136 and 137 are provided with vacuum, oxygen, and argon services and includes an Applied Research Laboratory power supply with an output to 1,000 Vdc.

Room 139.

Function and Equipment. Room 139 contains six interconnected gloveboxes supplied with air from the dry air supply system (see Section 5.4.3). These gloveboxes are used to process and store all plutonium oxide powder and plutonium metal received by the laboratory for analysis. The gloveboxes are used as follows.

- Glovebox 1 contains the airlock for the entire system. Equipment and samples may be entered into the hood through the airlock.
- Glovebox 2 contains a balance that was used to weigh plutonium metal and plutonium oxide samples for analysis.
- Glovebox 3 is used for storage.

- Glovebox 4 contains a V-blender. The plutonium oxide samples are blended in this hood before the start of analysis.

- Glovebox 5 is a storage hood containing 50 racks, each capable of holding 42 25 to 35 mL glass or plastic sample bottles.

- Glovebox 6 contains two balances and a programmable furnace used for loss-on-ignition analysis. Samples for other analyses are weighed in this hood.

The room contains a storage rack with three storage positions (each storage position may contain up to 400 g), and a bench where three electric can sealers for 7-in. food pack and soup cans are located. These are standard laboratory gloveboxes with nontestable outlet HEPA filters that are exhausted through the E-4 system.

Alarms and Protective Features. Room 139 is provided with a smoke alarm and intrusion alarms (active with category II only). No shielding is provided. Each workstation has a trouble alarm. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 139 is provided with 120-Vac services and vacuum.

Room 141, Cold Laboratory (Storage Area).

Function and Equipment. Room 141 is used to analyze cold samples that support the building process (e.g., aqueous makeup samples and viscosity on elevator oil). It contains a partitioned cold (nonradioactive) hood that is exhausted through the E-4 exhaust system, a sink, and a water purifier. Additional equipment, a hot plate, and muffle furnace are located in the hood. The room contains additional furnaces. No radioactive material is allowed in the room. The room also contains an acid storage cabinet that stores the main supply of laboratory concentrated acids.

Alarms and Protective Features. The room 141 hood is equipped with a limited-volume sprinkler head fire suppression system.

Services. Room 141 is provided with vacuum, water, and 120-Vac services.

Room 142.

Function and Equipment. Room 142 consists of four vented storage cabinets, the first two shelves per cabinet being used to store standards for the radiochemical standards laboratory and the other two for standards and sources for the PFP AL. The four vented storage cabinets are used to store up to 250 g plutonium (oxide, metal, and nitrate) and/or ^{233}U per shelf. All standards or samples are double contained. Each cabinet is equipped with built-in spacers to adhere to the criticality prevention specification. The cabinets are 0.13 in. stainless steel. All four exhaust through the E-4 system. No HEPA filters are located in the cabinets.

Alarms and Protective Features. No shielding is used.

Services. Room 142 is provided with 120-Vac service.

Room 143.

Function and Equipment. Room 143 is used for handling liquid waste that is not compatible with the waste recovery system and disposal of low-level waste to 241-Z Building. Room 143 contains four hoods and one glovebox. The hoods and gloveboxes are used as follows.

- Hoods 1 and 2 are used by PFP AL waste-handling personnel to store liquid wastes (flammable and organic). These are open-faced hoods.
- Hood 3 and Glovebox 4 were used to treat plutonium solutions with $H_2C_2O_4$ to form a plutonium oxalate precipitate.
- Hood 5 is no longer used. The hood contains a waste aspirator to transfer the waste from the 4-L bottles to the sink drain.

These are typical laboratory hoods and glovebox, and they are exhausted through the E-4 system. There are no HEPA filters provided at the hood or glovebox.

Alarms and Protective Features. Shielding is not normally used. For samples with high dose rates, extension tools and/or smaller size samples are used. The room includes station trouble alarms, and all hoods and the glovebox have limited-volume sprinkler head fire suppression devices. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 143 is provided with vacuum, water, and 120-Vac services.

Room 144, Plutonium Chemistry Laboratory.

Function and Equipment. Room 144 contains eight hoods and one glovebox. The work performed in this room provides the primary analytical support for the PFP and PPSL plutonium samples. Among analyses performed are plutonium concentration, visual percent solids, americium concentration, uranium laser, and acid/base determination. Both aqueous and organic samples of high- and low-level plutonium concentrations are analyzed. This room also has facilities to dissolve plutonium metal and plutonium oxide. The hoods and glovebox are used as follows.

- Hood 1 is used to package/repackage samples for shipment.
- Hood 2 is used for temporary storage.
- Hood 3 (storage hood) is used for sample storage. It contains one 4-L waste bottle and one 500-mL trap bottle connected to a 26-in. mercury vacuum.
- Glovebox 4 (breakdown glovebox) is used to break down samples received from customers, dissolve plutonium oxide, plutonium metal samples, and solids contained in process samples. All high-level solutions (greater than or equal to 60 g/L plutonium) are disposed of in a 500-mL glass bottle.

- Hoods 5 and 6 are used for oxalate and KOH analysis and uranium laser analysis. Hood 5 has reagents while hood 6 has the uranium laser.

- Hood 7 is used for temporary storage.

- Hood 8 (storage hood) is used as temporary storage.

- Hood 9 contains two 4-L waste bottles connected to a 26-in. mercury vacuum and electrical outlets.

Hood 9 is subdivided into six hoods. These hoods provide routine process support to include americium, low- and high-level plutonium analysis, density, and acid and base titration. The following analyses are done in hood 9.

- High-level (greater than 60 g/L plutonium) radioassay--The sample is placed in a vial and the vial is sealed and taken to the counting room for analysis. Analyses are done by the solution counter method.

- Low-level (less than 60 g/L plutonium) radioassay--The sample is placed in a vial and the vial is sealed and taken to the counting room for analysis. Analyses are done by the solution counter method.

- Americium analysis--The sample is placed in a vial and the vial is sealed and taken to the counting room for analysis. Analyses are done by the solution counter method.

- Organic sample--Acid and base titrations.

- Low-level plutonium extraction hood--The samples are placed in vials and the vials are sealed and taken to the counting room for analysis. Analyses are done by the solution counter method.

- Specific gravity by densitometer--The samples are taken into the chamber of the densitometer, their specific gravities are measured, and the samples are discarded as waste.

All open-faced hoods are typical laboratory equipment and are exhausted through the E-4 system. HEPA filters are not provided in the hoods and glovebox in this room.

Alarms and Protective Features. Shielding is not provided. Extension tools or smaller sample sizes are used to reduce exposure for samples of high dose rates. Each hood and glovebox is equipped with installed limited-volume sprinkler head fire suppression. Each workstation includes a trouble alarm and intrusion devices that are currently not active. Alpha survey instruments are provided for detecting plutonium contamination.

Services. Room 144 is provided with 120-Vac, vacuum, and water services.

Room 145.

Function and Equipment. Room 145 contains a glovebox that is no longer in use. This glovebox originally was used in support of sinterability and bulk and tap density measurements on plutonium oxide, and for preparation of plutonium oxide standards for the emission spectrometer. This glovebox was supplied with dry air. The glovebox contains two sections, used as follows.

- Top section--Contains a programmable furnace (normal operating temperature of 1600 °C), balance, sintering press, bulk and tap density equipment, mortar and pestle, and screens.
- Bottom section--Was used to prepare plutonium standards for emission spectrograph analysis. It was supplied with dry air.

This is a typical laboratory glovebox and is exhausted through the E-4 system.

Alarms and Protective Features. No shielding is installed. Each workstation has a trouble alarm.

Services. Room 145 is provided with process air, vacuum, and 120-Vac services.

Room 145-A, Stockroom.

Function and Equipment. Room 145A is used to store supplies routinely used in the laboratory.

Alarms and Protective Features. None provided.

Services. None provided.

Room 146.

Function and Equipment. Room 146 is used for waste repackaging and analyzing percentage organic samples.

- Glovebox (hood 5) is used for waste repackaging.
- Hoods 1 through 4 are used to prepare and analyze samples for percentage organics.

These are typical laboratory gloveboxes and hoods and are exhausted through the E-4 exhaust system.

Alarms and Protective Features. Room 146 is protected by the building fire sprinkler system, two laboratory trouble alarms, and a glovebox dry powder extinguishing system. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 146 is provided with process water, nitrogen, oxygen, compressed air, vacuum, and 120-Vac services.

Room 147. Room 147 is used as an office.

Room 148.

Function and Equipment. Two cleaned-out open-faced hoods are located in the room. The remainder of the room is used as the laboratory chemical satellite area. The gloveboxes are exhausted through the E-4 exhaust system.

Alarms and Protective Features. Room 148 hoods have installed limited-volume sprinkler head fire suppression. Each workstation has a trouble alarm. No shielding is installed. Alpha survey instruments are provided for detecting plutonium contamination.

Services. Room 148 is provided with 120-Vac and 440-Vac services.

Room 149.

Function and Equipment. Room 149 is used for packing and unpacking shipping containers. This room contains an open-faced hood, a hood converted into a glovebox, and a scrubber hood. Because relatively large amounts of plutonium compounds were to be dissolved in the glovebox, the glovebox exhaust was engineered to pass through a scrubber (in addition to the nontestable HEPA filter set in the exhaust duct of the glovebox). The glovebox has not been used to date since it was converted. These are typical laboratory hoods and gloveboxes and they exhaust through the E-4 system.

Alarms and Protective Features. Room 149 has a trouble alarm. The glovebox has wire-mesh glass windows. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 149 is provided with vacuum, 120-Vac, and hot/cold water services.

Rooms 150 and 151, Counting Room/Shift Office.

Function and Equipment. Room 151 serves as the shift office and 150 as the counting room.

Alarms and Protective Features. Rooms 150 and 151 are not provided with CAMs or passive air samplers. No shielding is provided.

Services. Rooms 150 and 151 are provided with electrical, vacuum, and liquid nitrogen services. P-10 gas (available from gas lines) is used in the counting instruments of this room. Liquid nitrogen is contained in dewars (which are filled from cart-portable liquid nitrogen tanks).

Room 152, Waste Laboratory.

Function and Equipment. Room 152 contains a load-in hood and a glovebox. It is used to reprocess liquid laboratory plutonium wastes. The hood and glovebox are used as follows.

- Open-faced hood 551 initially receives the waste container. The waste is sampled for H+ and plutonium and visually inspected for organic content (phases).

- Glovebox 552 (no longer in use) consists of three storage tanks, a distillate tank, vacuum trap, steam concentrator, caustic scrubber, water condenser, and a load-out tank.

These are a typical laboratory hood and glovebox and are exhausted through the E-4 system.

Alarms and Protective Features. Room 152 has an installed sprinkler head fire suppression system. The glovebox is equipped with a heat detector and the hood is equipped with a limited-water-supply sprinkler system. No shielding is provided. Each workstation is provided with a trouble alarm. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 152 is provided with vacuum, 30-lb steam, and water services.

Room 153.

Function and Equipment. Room 153 consists of four open-faced hoods and one glovebox. The open-faced hoods are used to support PPSL projects. This work is performed in the four hoods and glovebox described below.

- Hood 1 is used to analyze samples in support of PPSL processes. This hood can have up to 150 g plutonium present. It also is used as a storage hood.

- Hood 2 contains apparatus for measuring total inorganic carbon.

- Hood 3 is used to analyze total organic carbon samples using a tube furnace. The samples are injected with a syringe and needle into the system in the hood. There is a CO_2 calumniator and printer outside the hood.

- Hood 4 is used for storage of plutonium oxalate waste.

- Glovebox 5 (no longer in use) contains equipment to perform surface area analysis. The instrument is located on a bench outside the hood and the line runs into the hood. This glovebox may contain up to 250 g plutonium, and liquid nitrogen is used inside the glovebox during the analysis.

These are typical laboratory hoods and gloveboxes. The HEPA filters are on the inlet/outlets of the glovebox. All are exhausted through the E-4 exhaust system.

Alarms and Protective Features. The hoods and glovebox are protected by individual fire suppression systems (limited-volume sprinkler heads in the hood). The room includes a smoke alarm, intrusion alarm (not active), and trouble alarm. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 153 is provided with vacuum service and contains high-purity oxygen bottles.

Room 154.

Function and Equipment. Room 154 contains a glovebox partitioned into three sections and is used for both oxide and metal samples. Carbon, sulfur, and nitrogen are analyzed in this glovebox. The glovebox contains two carbon, sulfur and nitrogen analyzers with furnaces. The plutonium samples are placed in a furnace and fired to 1200 °C, The glovebox and Section 2 are not authorized for any activity. Section 3 can contain up to 150 g plutonium. The glovebox is exhausted through the E-4 exhaust system.

Alarms and Protective Features. The glovebox includes an individual fire suppression system (sprinkler head in box distributes 5 gal of water when activated). The room also includes a smoke alarm, intrusion alarm (not active) and trouble alarm. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 154 is provided with 220 Vac, vacuum, oxygen and compressed air (piped in from outside to support C analysis), helium (not used), and nitrogen (not used) services.

Room 155.

Function and Equipment. Room 155 contains four hoods and associated equipment.

- Hood 1 contains an ultraviolet spectrometer for measuring trace quantities of nitrate and nitrite.
- Hood 2 is used to measure nitrate and nitrites.
- Hoods 3 and 4 use the infrared spectrometer to analyze specific samples for organic content.

Alarms and Protective Features. The hoods include individual fire suppression systems equipped with a temperature-sensitive, limited-volume sprinkler head. The room includes a smoke alarm and an intrusion alarm (not active). Each workstation has a trouble alarm. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 155 is provided with vacuum and 120-Vac services.

Room 156.

Function and Equipment. Room 156 contains two hoods and one glovebox partitioned into two sections. The glovebox, which is vacant,is HEPA-filtered and exhausted through the E-4 systems. Hoods 3 and 4 are used for specific ion analyses of PPSL samples using fluoride and chloride ion concentrations.

Alarms and Protective Features. The hoods and glovebox are covered by individual fire-suppression systems. Each hood is equipped with a temperature-sensitive, limited-volume sprinkler head. The room includes a smoke alarm and an intrusion alarm (not active). Each workstation has a trouble alarm.

Services. Room 156 is provided with vacuum and 120-Vac services.

Room 157.

Function and Equipment. Room 157 consists of four gloveboxes with furnaces and a sample cell, which are used to support plutonium oxide work. The function and equipment of these gloveboxes are described below.

- Gloveboxes 1 and 2 have been sealed and are no longer in service.
- Gloveboxes 3 and 4 contain equipment for particle size determination. Particle size is anticipated to be in the range of 0.1 to 1 μm. These gloveboxes are new and have not been used yet. Future use of these gloveboxes would be for temporary storage.

Alarms and Protective Features. The gloveboxes in room 157 are covered by individual limited-volume sprinkler head fire suppression systems. The room includes a smoke alarm and an intrusion alarm (not active). By each workstation is a trouble alarm. Each glovebox has access to alpha survey instruments.

Services. Room 157 is provided with 220-Vac, water, and vacuum services.

Room 157A. Room 157A contains a sink.

5.4.14.1.2 PFP Standards Laboratory.

Room 221B. Room 221B is dedicated for use by Radiological Control.

Room 221C.

Function and Equipment. Room 221C contains a glovebox supplied by the dry air system. This glovebox is used to prepare ultrapure plutonium oxide standards for the PFP AL. The glovebox is equipped with a balance and oscillating blender. Various materials are blended with plutonium oxide to produce quality control standards. Initial preparation of oxide material will also occur in this box. The glovebox is equipped with both inlet and outlet HEPA filters. The glovebox is exhausted through the building E-4 exhaust system. A hygrometer is also located in the glovebox to measure the dew point of the air. Room 221C also contains two hoods and a vented storage cabinet. Their purposes are as follows.

- Hood 1 is used for decontamination of glassware. It contains a sink.
- Hood 2 uses plutonium to 350 g/L (sheet standards).
- Vented storage cabinet is used to store radioactive materials.

All hoods are exhausted through the E-4 system.

Alarms and Protective Features. Room 221C is protected by the building fire sprinkler system, a fire alarm on the glovebox, a CAS, an alpha survey meter and a safety shower. Room 221C also handles the criticality detection

and alarm system for rooms 221C, 221D, and 221E. The glovebox is equipped with a heat detector.

Services. Room 221C includes hood sinks that drain to the 241-Z Building (currently inoperable). The room is also provided with 26-in. mercury vacuum, process air to glovebox, nitrogen and oxygen (neither are used), and 120-Vac services.

Room 221D.

Function and Equipment. Room 221D contains equipment used for makeup of plutonium standards and for characterizing plutonium nitrate. It contains four hoods and a glovebox used as follows.

- Hoods 1 and 2 (southwest wall of 221-D) are used as open-faced hoods for the pipetting of plutonium solutions. Hood exhaust is HEPA-filtered.
- Hoods 3 and 4 (southeast wall of 221-D) are used for plutonium nitrate characterization. Hood exhaust is HEPA filtered.
- The glovebox is for storing plutonium nitrate (but is not currently used).

The glovebox is equipped with both inlet and outlet HEPA filters, and is exhausted through the building E-4 exhaust system.

Alarms and Protective Features. Room 221D is protected by the building fire sprinkler system, fire alarm in glovebox, an alpha survey meter and a safety shower.

Services. Room 221D includes hood sinks (drain to the 241-Z Building; not currently operable) and is provided with vacuum, process water/demineralized water, nitrogen and oxygen (not used), and 120-Vac services.

Room 221E.

Function and Equipment. Room 221E contains equipment for the preparation of thorium and uranium standards, low-level plutonium, low-level sheet, and ampulizing applications.

Alarms and Protective Features. Room 221E is protected by the building fire sprinkler system. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 221E is provided with 120-Vac, vacuum, deionized water to glovebox (from laboratory deionizing unit), nitrogen, and hot water tank and dishwasher (not used) services.

5.4.14.1.3 Plutonium Process Support Laboratories. In general, gloveboxes and hoods are connected to the building E-4 ventilation system except where noted. All gloveboxes except glovebox 179-1 are served by building water, pressurized air, and vacuum utilities. Pressurized air is

supplied at 90 lb/in^2 (gauge) but can be controlled to lower pressures. Much of the equipment in the PPSL is portable and may be relocated, as required, to support laboratory activities.

The PPSL has no equipment on backup power and no need for backup power is foreseen. Equipment could be connected to backup power in the future on a case-by-case basis. Room 202, corridor 10, room 179, room 183 (located in Figure 5-6, sheet 1), and other strategic locations have emergency lighting.

Room 179.

Function and Equipment. This room is used for working with plutonium and other transuranic chemicals in support of DOE needs. The room contains six gloveboxes and three hoods used for general and frequently changing purposes as existing work is completed and replaced by new projects.

Typical activities in gloveboxes 179-4, -6, -9, -10, and -12 are dissolutions, precipitations, chemical mixture preparations, chemical alteration reactions (e.g., hydrolysis of organic chemicals), calcination or similar decompositions, ion exchange studies, archive sample storage, particle size analyses, and equipment analysis, troubleshooting, and adjustment. Glovebox 179-1 was dedicated to the PPSL radioactive thermal analysis system but the thermal analyzer cooling water has been isolated and can no longer be operated. Satellite accumulation areas for waste radioactive chemicals are set up within gloveboxes whenever needed.

The gloveboxes contain electrically heated furnaces, hot plates, and small rotary mixers. Personnel using the furnaces and hot plates normally remain working in the area so that access to any hot surfaces by other personnel is impeded. Verbal warnings and signs are used when a furnace or hot plate must be left unattended temporarily. In addition, work projects in this room seldom require access to the same work area by personnel working on different projects. Rotary mixers are used only when submerged magnetic stir bars cannot be used. The same warnings and/or signs used for hot plates are employed.

Typical activities in hoods 179-2, -3, and -11 include access to glovebox air locks for equipment/chemical entries, plutonium storage, sample preparation and storage, and equipment decontamination. All three hoods in room 179 are currently restricted to use only for access to the glovebox air locks because the exhaust ventilation no longer meets current requirements. Work plans are in place to modify ventilation from these hoods to provide required double filtration of hood exhaust which will allow these hoods to be returned to active use.

These are typical laboratory hoods and gloveboxes and are exhausted through the E-4 exhaust system. The HEPA filters are installed on the inlets/outlets of the gloveboxes.

Alarms and Protective Features. Room 179 is protected by the building fire sprinkler system. There is an alarmed door to the outside. Room 179 has two safety showers and one alarm activation device. Hoods and gloveboxes are equipped with individual limited-volume fire-suppression systems that include pressurized water containers, low-pressure alarms, piping, sprinkler heads,

and heat detectors. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 179 is provided with vacuum, 120- and 220-Vac, gas cylinder station, telephone/PAX system, water, and D-4 drain services. A flammables cabinet is kept here.

Room 180.

Function and Equipment. Room 180 is used for a nonradioactive thermal analysis system. The thermal analysis system includes a mass spectrometer, which is used to assist in determining decomposition products and can run radioactive sample cells for radioactive analyses from otherwise nonradioactive lab instruments. There is a hood in this room in which processes involving radioactive materials are allowed. This room also contains an ultraviolet-visible light (UV-VIS) spectrometer for aiding in organic chemical identification. This unit is mounted on a cart for mobility and is moved to other rooms frequently, as needed.

Alarms and Protective Features. Room 180 is protected by the building fire sprinkler system. It is also equipped with an alpha CAM, alpha survey instruments, and a record air sampler.

Services. Room 180 is provided with E-4 ventilation, argon cylinder stand, and D-3 drain services (not in use).

Room 182.

Function and Equipment. Room 182 is used to house the scanning electron microscope and its accessories (e.g., energy dispersive X-ray microanalysis capabilities for elemental analysis.)

Alarms and Protective Features. Room 182 is protected by the building fire sprinkler system.

Services. Room 182 is provided with hot/cold water, 120-Vac, and D-4 (taped) services.

Room 183.

Function and Equipment. Room 183 is used for liquid scintillation counting and storage of waste drums before they are removed from the building. The room contains one glovebox that is currently not in use.

Alarms and Protective Features. Room 183 is protected by the building fire sprinkler system, one fire extinguisher and a safety shower. This room holds a chemical carcinogens/flammablse cabinet.

Services. Room 183 is provided with 120- and 220-Vac and RLW drain (drains to the 241-Z Building; not currently in use) services. This room has eight cabinets for chemical storage: two storage cabinets, a corrosives cabinet, two acids cabinets (north and south wall), flammables cabinet, acid/corrosive cabinet, and a resin cabinet.

Room 186.

Function and Equipment. Room 186 houses only electronic switches and wiring for the vertical calciner seismic shutdown system. Due to the safety class nature of this equipment, additional uses are forbidden while this system remains in use.

Room 187.

Function and Equipment. Room 187 is used for smaller-scale and general radioactive activities for various DOE needs. Room 187 contains five open-faced hoods. The open-faced hoods (designated 1, 2, 3, 4, and 5) are used for general plutonium support. Typical activities in these hoods include small-scale radioactive dissolutions, precipitations, chemical mixture preparations, chemical alteration reactions, calcinations or similar decompositions, ion exchange studies, sample preparation and storage, and equipment analysis, trouble shooting, and adjustment. Equipment contained in the room includes hot plates, other heating devices, and centrifuges. These are typical laboratory hoods that are HEPA-filtered and exhausted through the E-4 exhaust systems.

The room also contains a high-gradient magnetic filter unit (with associated recirculating chiller) for studying solution decontamination by paramagnetic migration. The unit contains fixed internal cobalt contamination.

Alarms and Protective Features. Room 187 is protected by the building fire sprinkler system, one safety shower and one alarm activation device.

Services. Room 187 is provided with vacuum, hot/cold water, gas cylinder station, 120-Vac, telephone/PAX system, and D-4 drain (not currently in use) services. A storage cabinet is located here.

Room 188.

Function and Equipment. Room 188 contains one glovebox, designated 188-1, that contains the Laboratory Prototype Calciner which is not authorized for operation at this time. The laboratory calciner is used for the direct denitration of various types of plutonium-bearing solutions to a stable, storable solid and to test materials of construction to contain those processes. The laboratory calciner consists of (1) a vertical denitration calciner and (2) ancillary support equipment. The Laboratory Prototype Calciner addendum to this FSAR provides a detailed description of the equipment and process associated with the laboratory calciner. Glovebox 188-1 is a typical laboratory glovebox that is HEPA-filtered (inlet and outlet). Ventilation is supplied by room air and is exhausted to the E-4 exhaust system.

Alarms and Protective Features. Room 188 is protected by a fire sprinkler system, a motion detector for security purposes, a CAM, a fixed head air sampler, high voltage alarm, lights and a safety shower. Glovebox 188-1 contains a fire detector but does not contain fire sprinklers. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Room 188 is provided with vacuum, hot/cold water, 120- and 480-Vac, dedicated high quality compressed air, D-4 drain system, and telephone/PAX system services. The 55-gal drums of scrubbing reagent (30% NaOH) are carted into the room to supply the calciner offgas scrubber in the glovebox with reagent.

Room 189.

Function and Equipment. Room 189 contains an ion chromatograph and houses the "carbon sputterer" for coating scanning-electron-microscope samples.

Alarms and Protective Features. Room 189 is protected by a room fire sprinkler system, a fire extinguisher, a safety shower, and a motion detector for security purposes.

Services. Room 189 is provided with vacuum, hot/cold water, 120-Vac, and D-3 Drain (not currently in use) services.

Room 190 (Vault).

Function and Equipment. Room 190 is used to store stable plutonium material that is not currently needed for ongoing projects and demonstrations. The equipment is limited to storage racks for fissile material.

Alarms and Protective Features. Room 190 is protected by the building fire sprinkler system and an alarm (criticality incident alarm siren). A security alarm is also provided.

Services. Room 190 is provided with 120-Vac service.

Room 191.

Function and Equipment. Room 191 is used as a cold (nonradioactive) laboratory for solution makeup and chemical preparation. There are three hoods and two countertop areas used for solution makeup to support projects in the radioactive laboratories. These are typical laboratory hoods and are exhausted through the E-3 exhaust system. This room also serves as chemical storage.

Alarms and Protective Features. Room 191 is protected by a room fire sprinkler system and an eyewash station.

Services. Room 191 is provided with vacuum, hot/cold water, gas cylinder station, 120-Vac, and D-4 and D-6 drains (not currently in use) services.

Corridors 8 and 9.

Function and Equipment. These corridors provide access to the laboratory rooms and make several safety devices available.

Alarms and Protective Features. These corridors are protected by the building fire sprinkler system, surveillance camera, an alarmed outer door, a fire alarm bell and system control, a radiation detector, a criticality horn,

and a trouble-alarm panel. Alpha survey instruments are provided for detection of plutonium contamination.

Services. Corridors 8 and 9 are provided with 120 Vac and telephone/PAX system services.

Rooms 81 through 90 and Dock 5. These rooms are used as offices. Dock 5 is used for equipment storage.

Room 202.

Function and Equipment. Room 202 is the nonradioactive pilot plant area and can be used for cold support for a wide variety of programs. The room contains one walk-in hood and two large countertop areas. Most of the room is or can be occupied by multiple pilot plants or process demonstrations. The 15 ft 9 in. ceiling allows projects to be considerably larger than in other PPSL rooms. Furnaces, hot plates, and rotary mixers are used in the open in this room whenever required by a project. Other types of heating are also used on rare occasion. Signs warning of hot surfaces are kept and used in this room to warn others of the potential thermal hazards. Rotary mixers are used only when submerged magnetic stir bars are inadequate. Equipment includes the following:

- Fume hood with a dedicated ventilation duct
- A mezzanine for additional floor space and use with tall equipment
- General laboratory work.

Functions for room 202 include chemical preparation and properties investigations; equipment testing, cleaning, and troubleshooting; materials testing; and flowsheet verification or improvement studies that include heating/cooling and the various unit operations of chemical engineering, which include fluid flow, heat transfer, extraction, distillation, calcination, precipitation, drying, diffusion, and phase separation.

Alarms and Protective Features. Room 202 contains a room sprinkler system, a safety shower, two eyewash stations, and a smoke detector.

Services. Room 202 is provided with compressed air, instrument air, 120- and 480- Vac, telephone/PAX, cold/hot water, and liquid waste drain (drains to the 241-Z Building) services.

Rooms 205, 250, and 251-A. These rooms are used as offices.

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Table 5-1. Plutonium Finishing Plant Buildings and Structures.
(3 sheets)

Building number	Contents/purpose
200-Z	Maps, outside and underground facilities
207-Z	Retention basin
216-Z-1[c]	Crib (isolated: pipe has been capped or removed)
216-Z-1A[c]	Tile field, sanitary tile field (isolated: pipe has been capped or removed)
215-Z-1AA[c]	Tile field (isolated: pipe has been capped or removed)
216-Z-1AB[c]	Tile field (isolated: pipe has been capped or removed)
216-Z-1AC[c]	Tile field (isolated: pipe has been capped or removed)
216-Z-7[c]	Crib (isolated: pipe has been capped or removed)
216-Z-8[c]	French drain (isolated: pipe has been capped or removed)
216-Z-9[b,c]	Crib (isolated: pipe has been capped or removed)
216-Z-9A[b,c]	Contaminated soil removal facility
216-Z-9B[b,c]	Industrial building; prefab building
216-Z-9C[b,c]	Industrial building; prefab building
216-Z-10[c]	Reverse wells (isolated: pipe has been capped or removed)
216-Z-11[c]	Ditch (isolated: pipe has been capped or removed)
216-Z-12[c]	Crib (isolated: pipe has been capped or removed)
216-Z-13	French drain
216-Z-14	French drain
216-Z-15	French drain
216-Z-16[c]	Crib (isolated: pipe has been capped or removed)
216-Z-18[c]	Crib (isolated: pipe has been capped or removed)
216-Z-19	Ditch (abandoned)
216-Z-20[c]	Crib (isolated: pipe has been grout-capped), Z8 manhole grouted
216-Z-21[c]	Pond (isolated: pipe has been grout-capped)
231-Z[b]	Materials Engineering Laboratory/Building (200 ADP facility - contains Plutonium Finishing Plant Plutonium material)
232-Z[a]	Waste Incinerator Facility (not used)
234-5Z[a]	Plutonium Finishing Plant; plutonium conversion facility
234-5ZA	Change room and MICON™ control station
234-ZB	Miscellaneous storage for construction forces (FFS-owned) acetylene, propane, oxygen, argon, nitrogen storage
234-ZC[a]	Loading dock for waste drums and special nuclear material containers (West End)
236-Z[a]	Plutonium Reclamation Facility (not used). Temporary storage of in-process material in access gloveboxes.
241-Z[a]	Liquid waste storage and treatment tanks in underground concrete cells
241-Z-RB	Waste water retention basin (not used)
241-ZA	Sample building: sample/loadout building
241-ZB	Curbed concrete pad housing the D-9 caustic tank
241-ZG	241-Z change room
241-Z-361	Underground liquid waste settling tank (no longer used)
242-Z[a]	Waste Treatment facility (not used)
242-ZA	Monitoring building (also known as TC-66)
243-Z[a]	Low-Level Waste Treatment Facility
243-ZA	Tank
243-ZB	Cooling towers and concrete pads for closed-loop cooling water system
252-Z-1	Electrical transformer (North of 234-5Z)
252-Z-2	Electrical transformer (in 291-Z Building)
2607-W-8	Septic tank
2607-WA	Septic tank
2607-WB	Septic tank

Table 5-1. Plutonium Finishing Plant Buildings and Structures. (3 sheets)

Building number	Contents/purpose
2607-Z	Septic tank
2607-Z-1	Septic tank
267-Z	Valve house for water supply to a 234-5Z sprinkler system (Riser #9 valve house)
270-Z	PFP support facility (office building) (houses emergency control center)
291-Z[a]	Ventilation exhaust fan house
291-Z-1[a]	Ventilation exhaust stack for 232-Z, 234-5Z, and 242-Z Buildings
296-Z-3[a]	Ventilation exhaust stack for 241 cells and tanks
296-Z-5[a]	Ventilation exhaust stack for 2736-ZB Building
296-Z-6[a]	Ventilation exhaust stack for 2736-Z Building
296-Z-14[a]	Ventilation exhaust stack for 232-Z Building
296-Z-15[a]	Ventilation exhaust stack for 243-Z Building
2503-Z	Electrical distribution system for PFP (switch yard)
2701-ZA	Central station alarm facility (criticality alarm portion)
2701-ZD	PFP badge house
2702-Z	Microwave tower
2704-Z	PFP support building (office building)
2705-Z	Operations control facility
2706-Z	Septic tank
2712-Z	291-Z-1 stack sampler and monitor shack
2715-Z	Paint shop (paint, oil, and solvent, and drum storage)
2721-Z[a]	Backup electric power generators (diesel driven)
2722-Z	Concrete pad for truck load-out station
2727-Z	Storage of miscellaneous operations and laboratory equipment
2729-Z	Storage of miscellaneous maintenance materials
2731-Z	Storage of empty flushed plutonium drums
2731-ZA	Laundry storage
2734-Z	Gas bottle storage (not used)
2734-ZA	Empty cylinder storage
2734-ZB	Breathing air (compressed gas) cylinder storage
2734-ZC	Oxygen and P-10 gas cylinders, P-10 gas supply
2734-ZD	Empty non-flammable gas cylinder storage
2734-ZF	Standby gas bottle storage (not used)
2734-ZG	Nitrogen storage
2734-ZH	Argon and nitrogen storage (not used)
2734-ZJ	Liquid nitrogen storage
2734-ZK	Argon, P-10, nitrogen, propane, acetylene, helium and miscellaneous flammable gas
2734-ZL	HF gas bottles and supply piping (not used)
2735-Z	Chemical storage of HNO_3, and ANN (not used)
2736-Z[a]	Plutonium material storage
2736-ZA[a]	2736-Z exhaust fans
2736-ZB[a]	Shipping and receiving plutonium material
2736-ZC[a]	Loading dock
2736-ZD[a]	Experimental Breeder Reactor II cask storage
2900-Z	Underground lines
2901-Z	Water tower
2902-Z	Elevated sanitary water tank and valvepit (not used)
2904-Z	Monitoring building
2904-ZA[b]	Sheet metal structure that housed 216-Z-20 crib stream effluent sampling, flow measurement, pH and alpha monitoring equipment (not used)

Table 5-1. Plutonium Finishing Plant Buildings and Structures.
(3 sheets)

Building number	Contents/purpose
2904-ZB[b]	Sheet metal structure that housed 216-Z-20 crib stream effluent sampling, flow measurement, pH and alpha monitoring equipment (not used)
225-WC[b]	Houses the sampling and monitoring equipment for the waste water discharge to Treated Effluent Disposal Facility
MO-011[b]	200 W Patrol headquarters trailer
MO-014[b]	Mobile office building; office trailer
MO-015[b]	Mobile office building; office trailer
MO-016[b]	Mobile office building; office trailer
MO-017[b]	Mobile office building; office trailer
MO-031[b]	Mobile office building; office trailer
MO-032[b]	Mobile office building; office trailer
MO-244[b]	Mobile office building; Patrol change trailer
MO-249[b]	Mobile office building; office trailer
MO-250[b]	Mobile office building; office trailer
MO-290[b]	Mobile office building; IRM computer hub trailer
MO-428	Mobile office building; office trailer
MO-429	Mobile office building; office trailer
MO-432	Mobile office building; office trailer
MO-544[b]	Mobile office building; field trailer at carbon tetrachloride site
MO-834	Mobile office building; FFS lunchroom/office trailer
MO-839	Mobile office building; FFS lunchroom/office trailer
MO-939	Mobile office building; office trailer
No #s	Hazardous waste staging areas (various locations)
No #s	Fenced material control areas
No #s	Storage shed (West of 234-Z8 Building)
No #s	Moveable storage structures
HS-045	Hazardous waste storage unit - No. 2 (West of MO-432)
HS-043	Hazardous waste storage unit - No. 3 (West of MO-432)
HS-047	Hazardous waste storage unit - No. 1 (East of 234-5Z Building); Recyclable oil and miscellaneous absorbents storage
HS-046	Hazardous waste storage unit - No. 4 (East of 234-5Z Building); Temperature controlled chemical storage unit
E Maintenance Conex	Miscellaneous maintenance supplies storage
G Maintenance Conex	Miscellaneous maintenance supplies storage
Material Control Conex #1	Filter storage
Material Control Conex #2	JCS job-related hardware and components
Maintenance D Conex	-
Maintenance F Conex	Oil storage
234-5Z-BA (Oil-fired packaged boiler)[b]	Dedicated boiler provides steam supply to the PFP buildings for various uses. (Boiler operated and maintained by separate DOE-RL contractor)

[a]Major PFP structures: Those structures that were identified as having a source term and/or containing major processing equipment or one of the confinement systems.
[b]These items are located outside of the PFP Exclusion Area.
[c]Under jurisdiction of River Protection Project.

Table 5-2. Construction Dates, Design Criteria, and Natural Phenomena Hazards Design Analyses of Plutonium Finishing Plant Facilities. (2 sheets)

Building	Designed	Constructed	Design criteria	Seismic		Wind[a]	Snow[b]	Conclusions
				Type	Reference	Reference	Reference	
234-5Z[d]	1947	1949	UBC 1946	Dynamic	URS 1987 Vollert 1987	Giller 1989a Giller 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g), extreme wind, missile, and snow.
236-Z	1960	1964	UBC 1961 SDC 4.1	Dynamic	URS 1987 URS 1988a Islam 1994 Vollert 1987	Giller 1989a Giller 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g), extreme wind, missile, and snow.
232-Z	1959	1961	UBC 1958 SDC 4.1	None	Ballinger 1993	None	None	Building failure assumed in Chapter 9.0. Qualified for 0.09 g but not 0.20 event.
241-Z	1947	1949	UBC 1946	None	Ocoma 1988	Giller 1990 WHC 1990	Giller 1990 WHC 1990	Cover blocks can withstand DBE (0.25 g). Abovegroundstructures are assumed to fail in Chapter 9.0.
242-Z	1960	1964	UBC 1958 SDC 4.1	Dynamic	URS 1980 Giller 1991a	Giller 1990 WHC 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g) in current status. Building as-is can withstand extreme wind, missile, and snowfall.
243-Z[c]	1989	1994	DOE 6430 SDC 4.1	None	None	None	None[e]	Building not required to meet high hazard SDC 4.1 requirements. Building failure assumed in FSAR.
291-Z	1947	1949	UBC 1946	Dynamic	URS 1987 URS 1980 Vollert 1987	Giller 1989a Giller 1990 WHC 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g), extreme wind, missile, and snow.
291-Z-1 stack	1947	1949	UBC 1946	Dynamic	URS 1980 URS 1987 URS 1988b	Giller 1989a Giller 1990	Giller 1990	Stack can withstand DBE (0.25 g), extreme wind, missile, and snow.
2721-Z	1977	1979	UBC 1976 SDC 4.1	Static	WHC 1990	Giller 1990 WHC 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g), extreme wind, missile, and snow.

Table 5-2. Construction Dates, Design Criteria, and Natural Phenomena Hazards Design Analyses of Plutonium Finishing Plant Facilities. (2 sheets)

Building	Designed	Constructed	Design criteria	Seismic		Wind[a]	Snow[b]	Conclusions
				Type	Reference	Reference	Reference	
2736-Z	1969	1971	UBC 1967 SDC 4.1	Dynamic	Anderson 1971 Lein 1972 Giller 1991b Giller 1994a	Giller 1990 WHC 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g), extreme wind, missile, and snow.
2736-ZA	1969	1971	UBC 1967 SDC 4.1	Static Dynamic	Giller 1991 Giller 1994b Orbeta 1994	WHC 1990 Giller 1990	Giller 1990 WHC 1990	Building can withstand DBE (0.25 g), extreme wind, missile, and snow. Tear in duct work between building.
2736-ZB	1979	1982	UBC 1976 SDC 4.1	Static Dynamic	Goakey 1980 Giller 1991 Weiner 1994	Goakey 1980 WHC 1990 Giller 1990	Giller 1990 Goakey 1980	Building can withstand DBE (0.25 g), extreme wind, and snow.

[a] Wind analysis included study of both extreme wind and wind-driven missile.
[b] Analyses for combined loading of snow plus ashfall and for ashfall only, were not performed since these natural phenomena hazards are required only for new safety class 1 (safety class) facilities as per SDC 4.1, Rev. 11 (DOE-RL 1989).
[c] This facility, though it is not a high hazard facility, is included in the list because the building serves as a focal point to which a significant portion of PFP liquid effluents is directed before release from the PFP.
[d] This facility was analyzed for combined load of snow plus ashfall and for ashfall.
[e] This facility was designed for ash loading, as required under SDC 4.1, Rev. 12 (DOE-RL 1993).

Table 5-3. Major Plutonium Finishing Plant Building Construction Summary.

Building	Structure	Roof	Roof cover	Exterior walls	Interior walls	Floors	Interior finish	Fire resistance
234-5Z	Braced steel frame	Metal deck	Built up	Corrugated metal	Metal, plaster, concrete	Concrete	Noncombustible	Unprotected noncombustible
236-Z	Reinforced concrete	Concrete slab over metal deck	Built up	Concrete	Concrete, concrete block	Concrete	Noncombustible	Fire resistive
232-Z	Concrete block	Concrete slab over metal deck	Built up	Concrete block	Concrete block and metal partition	Concrete	Noncombustible	Fire resistive
241-Z Tanks (below grade)	Reinforced concrete	Reinforced concrete	Reinforced concrete cover blocks	Reinforced concrete	Reinforced concrete	Reinforced concrete	Noncombustible	Noncombustible
241-Z Structure (above grade)	Corrugated steel	Corrugated steel	Paint	Corrugated steel	None	Reinforced concrete (cover blocks)	Noncombustible	Fire resistive
242-Z	Braced steel frame	Metal deck	Built up	Corrugated metal	Metal, plaster, concrete	Concrete	Noncombustible	Unprotected noncombustible
243-Z	Corrugated steel	Corrugated steel	Paint	Corrugated steel	None	Concrete	Noncombustible	Fire resistive
291-Z	Reinforced concrete	Concrete	Built up	Concrete	Concrete	Concrete	Noncombustible	Fire resistive
291-Z-1 Stack	Reinforced concrete	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2721-Z	Reinforced concrete	Concrete	Built up	Concrete	Concrete	Concrete	Noncombustible	Fire resistive
2736-Z	Reinforced concrete	Concrete	Built up	concrete	Concrete	Concrete	Noncombustible	Fire resistive
2736-ZA	Steel and concrete	Concrete	Built up	Concrete	Concrete	Concrete	Noncombustible	Fire resistive
2736-ZB	Steel and concrete	Concrete	Built up	Concrete	Concrete and gypsum board on metal studs	Concrete	Noncombustible	Fire resistive

Building	Seismic analysis performed		Design response spectra		Critical damping (%)	Soil structure	Conclusions
	Analysis type	Chapter 4.0 Reference	PHGA (g)	PVGA (g)			
234-5Z	Rigorous dynamic using 3D nonlinear model	URS, 1987	0.3	0.17	7	Considered	Building can withstand DBE without collapse. Four beam-to-column connections yield.
236-Z	Rigorous dynamic using 3D lumped-mass beam model	URS, 1988	0.3	0.17	5	Neglected	Building can withstand DBE and meets code.
232-Z	None	--	--	--	--	Neglected	Failure assumed.
241-Z	None	Ocoma et al., 1988	0.3	0.17	--	Neglected	Coverblock can withstand DBE.
242-Z	Dynamic, modal analysis	Giller, 1988	0.3	0.17	7	Neglected	Building can withstand DBE without collapse.
291-Z	Dynamic, rigorous finite element	URS, 1980	0.3	0.17	5	Considered	Building can withstand DBE.
291-Z-1 Stack	Dynamic, equivalent static	URS, 1988a	0.3	0.17	7	Considered	Stack can withstand DBE.
2736-Z	Dynamic, single degree-of-freedom	Anderson, 1971	0.3	0.17	--	Neglected	Building can withstand DBE.
2736-ZB	Static	Goakey, 1980	0.3	0.17	--	Neglected	Building can withstand DBE.
2721-Z	Static	WHC, 1990	0.3	0.17	--	Neglected	Building can withstand DBE.
2734-ZL	Static	WHC, 1990	0.3	0.17	--	Neglected	Building can withstand DBE.
2736-ZA	Static	WHC, 1990	0.3	0.17	--	Neglected	Building can withstand DBE.

PHGA = peak horizontal ground acceleration.
PVGA = peak vertical ground acceleration.

Table 5-5. Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets)

(see Table 9-25 for Criticality Prevention Specification Limits)

Glovebox/room	Room	Building	Seismic Qualification
Hood 1	148	234-5Z	no
Hood 2	148	234-5Z	no
Hood 1	149	234-5Z	no
Hood 2	149	234-5Z	no
Glovebox 522	152	234-5Z	no
Hood 521	152	234-5Z	no
Glovebox 5	153	234-5Z	no
Hood 1	153	234-5Z	no
Hood 2	153	234-5Z	no
Hood 3	153	234-5Z	no
Hood 4	153	234-5Z	no
Glovebox 1 (inactive)	154	234-5Z	no
Glovebox 2+3	154	234-5Z	no
Hood 1	155	234-5Z	no
Hood 2	155	234-5Z	no
Hood 3	155	234-5Z	no
Hood 4	155	234-5Z	no
Glovebox 1+2	156	234-5Z	no
Hood 3	156	234-5Z	no
Hood 4	156	234-5Z	no
Glovebox 1+2	157	234-5Z	no
Glovebox 3+4	157	234-5Z	no
Glovebox HC-4	166	234-5Z	YES
Glovebox HC-6 (inactive)	166	234-5Z	no
South hood	166	234-5Z	no
Glovebox HA-40F (inactive)	169	234-5Z	no
Glovebox HC-46F (inactive)	170	234-5Z	no
Hood (inactive)	170	234-5Z	no
Glovebox 1	179	234-5Z	no
Glovebox 10	179	234-5Z	no
Glovebox 12	179	234-5Z	no
Glovebox 4	179	234-5Z	no
Glovebox 6	179	234-5Z	no
Glovebox 9	179	234-5Z	no
Glovebox 11 (inactive)	179	234-5Z	no
Hood 2 (inactive)	179	234-5Z	no
Hood 3 (inactive)	179	234-5Z	no
Hood 1	180	234-5Z	no
Glovebox 5 (inactive)	183	234-5Z	no
Hood 1	187	234-5Z	no
Hood 2	187	234-5Z	no

Table 5-5. Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets)

(see Table 9-25 for Criticality Prevention Specification Limits)

Glovebox/room	Room	Building	Seismic Qualification
Hood 3	187	234-5Z	no
Hood 4	187	234-5Z	no
Hood 5	187	234-5Z	no
Glovebox 1	188	234-5Z	yes
Glovebox 3	221-C	234-5Z	no
Hood 1	221-C	234-5Z	no
Hood 2	221-C	234-5Z	no
Storage Cabinet SC-221C	221-C	234-5Z	no
Hood 1	221-D	234-5Z	no
Hood 2	221-D	234-5Z	no
Hood 3	221-D	234-5Z	no
Hood 4	221-D	234-5Z	no
Glovebox 5	221-D	234-5Z	no
Hood 1	221-E	234-5Z	no
Hood 2	221-E	234-5Z	no
Hood 3	221-E	234-5Z	no
Glovebox HC-227S	227	234-5Z	YES
Hood HC-227T	227	234-5Z	YES
Glovebox HC-1, conveyor	228-A, B,C	234-5Z	no
Glovebox HC-2, conveyor	228-A, B,C 230-A, B,C	234-5Z	no
Glovebox HC-7	228-A	234-5Z	YES
Glovebox HC-9B	228-A	234-5Z	YES
Glovebox HC-10 (inactive)	228-A	234-5Z	no
Glovebox HC-11	228-A	234-5Z	YES
Glovebox HC-12S (inactive)	228-A	234-5Z	no
Glovebox HC-13MD	228-B	234-5Z	no
Glovebox HC-15A,-B,-C (inactive)	228-B	234-5Z	YES
Glovebox HC-16CC (inactive)	228-B	234-5Z	no
Glovebox HC-17-SBB (inactive)	228-C	234-5Z	no
Glovebox HC-17DC (inactive)	228-C	234-5Z	no
Glovebox HC-17P (inactive)	228-C	234-5Z	no
Glovebox HC-18BS	228-C	234-5Z	YES
Glovebox HC-18M	228-C	234-5Z	no
Glovebox HC-21C	230-A	234-5Z	no
Glovebox HC-21A	230-B	234-5Z	no
Glovebox HC-3, conveyor	230-C	234-5Z	no
Glovebox HC-4, conveyor	230-C 235-B	234-5Z	no
Glovebox HC-5, conveyor	228-C	234-5Z	no

Table 5-5. Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets)

(see Table 9-25 for Criticality Prevention Specification Limits)

Glovebox/room	Room	Building	Seismic Qualification
Glovebox HC-60 (inactive)	230-C	234-5Z	no
Glovebox HA-46 (inactive)	232	234-5Z	no
Glovebox H-8, conveyor (inactive)	235-A	234-5Z	no
Glovebox H-9A conveyor (inactive)	235-A	234-5Z	no
Glovebox H-9D, conveyor (inactive)	235-A	234-5Z	YES
Glovebox H-9E, conveyor (inactive)	235-A	234-5Z	YES
Glovebox HA-7A (inactive)	235-A	234-5Z	YES
Glovebox HA-9C (inactive)	235-A	234-5Z	no
Glovebox HA-10, conveyor (inactive)	235-A	234-5Z	no
Glovebox HA-19	235-B	234-5Z	no
Glovebox HA-20MB	235-B	234-5Z	YES
Glovebox HA-21I	235-B	234-5Z	no
Glovebox HA-23S	235-B	234-5Z	YES
Glovebox HA-28, conveyor	235-B	234-5Z	no
Glovebox HC-1A (inactive)	235-B	234-5Z	no
Glovebox 235-B-2	235-C	234-5Z	no
Glovebox HA-16BS (inactive)	235-A1	234-5Z	no
Glovebox HA-16CS (inactive)	235-A1	234-5Z	no
Glovebox HA-22B	235-B	234-5Z	YES
Gloveboxes (1st floor) - east	East corridor	236-Z	YES
Gloveboxes (1st floor) - west	West corridor	236-Z	YES
Gloveboxes (2nd floor) - east	East corridor	236-Z	YES
Gloveboxes (2nd floor) - west	West corridor	236-Z	YES
Glovebox (2nd floor pH and maintenance room)	27	236-Z	no
Glovebox (MT-conveyor)	41	236-Z	no
Glovebox MT-1 (inactive)	41	236-Z	no
Glovebox MT-3 (inactive)	41	236-Z	no
Glovebox MT-4 (inactive)	41	236-Z	no
Glovebox MT-5 (inactive)	41	236-Z	no
Glovebox MT-6 (inactive)	41	236-Z	no
Glovebox (4th floor column)	42	236-Z	no
Glovebox (S&C canning and loading)	43	236-Z	no
Glovebox (S&C charging glovebox)	43	236-Z	yes

Table 5-5. Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets)

(see Table 9-25 for Criticality Prevention Specification Limits)

Glovebox/room	Room	Building	Seismic Qualification
Glovebox (5th floor column)	50	236-Z	no
Glovebox (6th floor column)	60	236-Z	no
Glovebox (repackaging glovebox)	636	2736-ZB	YES

Table 5-6. Inactive Glovebox Functions.

Glovebox	Functions
HC-4	Feed solution staging. This glovebox was used for the staging of plutonium solutions to be fed to the RMA and RMC Lines.
HC-6	Feed solution staging. This glovebox was used for the staging of plutonium solutions to be fed to the RMA and RMC Lines. Feed solutions were pumped through this glovebox, which served as a way station between HC-4 and tanks HA-7A and HC-7.
HA-7A	Solution treatment. This glovebox prepared plutonium nitrate feed for transfer to the reactor in H-9A.
HC-3 HC-4 HC-5 H-8A HC-10	Conveyors. These gloveboxes served as plenums that delivered air to all the adjoining gloveboxes, as well as transporting material in the RMA Line plutonium production processes.
H-9B	Plutonium metal production. (Not available)
H-9C	Product weighing. This glovebox was used to weight full powder pans of plutonium oxide.
H-9D	Plutonium metal production. (Not available)
H-9E	Product handling. This glovebox was used to blend plutonium oxide.
H-11	MgO Heater. This glovebox was used to heat the MgO sand that was used to fill the space between crucibles and pressure vessels..
H-12S	Pressure vessel sanding. This glovebox was used to dispense sand to pressure vessels.
HC-13MD	Crucible loading. The equipment in this glovebox was capable of receiving the PuF_4 powder and the reduction chemicals for mixing and transfer to a sanded crucible (now used for seal-in/seal-out for thermal stabilization processes).
H-13G	Gasket Installation. This glovebox was used to install gaskets to the charged pressure vessels.
H-13ABC	Reduction to metal. This glovebox holds the induction furnaces used to reduce PuF_4 to plutonium metal. This glovebox is divided into three vertical sections labeled A, B, and C. Each of the sections was provided with identical equipment and instrumentation to perform the reduction.
H-14CC	Crucible cutter. This glovebox was used to break MgO slag and crucibles to release the plutonium buttons.
H-14DC	Pressure vessel dumper. This glovebox was used to remove the contents of pressure vessels.
H-14P	Pickling. This glovebox was used to clean and pickle plutonium buttons.
H-14S	Sampling. This glovebox was used for sampling of the plutonium metal buttons.
H-15B	Weighing. A balance was used for weighing of RMA material.
H-15	Plutonium metal production. (Not available)
H-16CS	Conveyor storage.
H-16BS	Button storage. This glovebox was used for storage of plutonium buttons.
H-16L	Plutonium metal production. (Not available)
HA-19	Storage.

Table 5-7. Equipment Design Basis and Equipment for Interim Storage and Plutonium Material Handling Remote Mechanical C Line Gloveboxes.

Glovebox	Function	Equipment	Material	Design pressure lb/in^2 (gauge)	Design temperature °C
HC-7	Solution treatment	PRT	Pyrex™	15	Ambient
		THT	Pyrex™	15	Ambient
		FKT	Pyrex™	15	Ambient
		FCT	Pyrex™	15	Ambient
		FST	Pyrex™	15	Ambient
		ACT	Pyrex™	15	Ambient
		Process piping, valves, and pumps	304-L stainless steel	>100	Ambient
HC-9B	Powder production	RCTR tank	304-L stainless steel	>100	Ambient
		Vacuum drum filter	304-L stainless steel	N/A	Ambient
		CALC	304-L stainless steel	N/A	800 °C
		Recycle hopper	Hastelloy-C	N/A	Ambient
		BANJO Valve	Hastelloy-C base/stellite-21 overlay	N/A	800 °C
		FLUR	Hastelloy-C base/platinum/ iridium liner	N/A	600 °C
		CRT	Pyrex™	15	Ambient
		VRT	Pyrex™ glass (4-in.-dia)	25	Ambient
		OT	Pyrex™ glass (4-in.-dia)	25	Ambient
		HF Gas piping	Kynar™	--	Ambient
		Other process piping, valves, and pumps	304-L stainless steel	>100	Ambient
HC-11	Powder pan storage	Conveyor	304-L stainless steel	N/A	Ambient

Table 5-8. Miscellaneous Treatment Equipment. (2 sheets)

	Material	Diameter (in.)	Length (in.)	Volume (L)
Glovebox MT-1: inspection				
Funnel screen (cone of 1/8-in. wire cloth)	stainless steel	6.0	5	1.0
Glovebox MT-3: dissolution of bulk metallic plutonium				
Two dissolvers	Glass	6.0	6	2.7
Basket	Fluorocarbon	4.75	0.0625	
Electrodes	Tantalum	4.0	0.063 + 0.01	
Anode coated with	Platinum	4.0		
			36	
Two holding tanks	Glass	6.0		16.0
			18	
Two primary exchangers	stainless steel	6.4	~36	10.0
75 Double pass tubes	stainless steel	0.25		
			60	
Secondary exchanger	stainless steel	6.0	~60	
150 Tube exchanger	stainless steel	0.25	12	
Chemical addition	Glass	6.0		5.5
			8	
Gas sample exchanger	stainless steel	3.0	30	0.9
Coil exchanger	stainless steel	0.375		
			12	
Gas scrubber	Glass	4.0		2.5
			12	
With 1/2-in. saddles	stainless steel	4.0		2.5
			18	
Vacuum trap	Glass	6.0	3	8.2
Demister pad	Fluorocarbon	6.0		
Glovebox 4: decarbonization				
Cube still	Quartz tube	4.0	34	6.8
Cube furnace	Inconel™ tube	4.0	52	10.4
Receiver	Glass	6.0	6	2.7
Scrubber	Glass	3.0	18	2.0
Two coolers	stainless steel	0.5	25	
Exterior coil	Copper	0.25		
Boats	Nickel sheeting			
Styrene transfer	Glass	6.0	12	5.6
Vacuum trap	Glass	4.0	10	2.0
Cube crusher	stainless steel			
Glovebox 5: dissolution				
Five dissolver hot plates				
Five dissolver beakers	stainless steel	6.0	9	4.7
Five condensers	stainless steel	5.0	12	3.9
Double coils	stainless steel	0.375	~300	
Three pan filters	stainless steel	12.0	2	3.7
Chemical addition	PVC	6.0	25	11.5
Chemical addition	PVC	6.0	19	8.7
Sump receiver	Glass	4.0	18	3.6
Vacuum trap	Glass	4.0	10	2.0

Table 5-8. Miscellaneous Treatment Equipment. (2 sheets)

	Material	Diameter (in.)	Length (in.)	Volume (L)
Glovebox 6: separation and cementing of nonleachable solids				
Centrifuges (3)	stainless steel	10.5	6	8.0
Bowls (3)	stainless steel	3.8-ID	4	2.5
Two receivers	Glass	8.0D	30	14.4
Vacuum trap	Glass	6.0	12	2.5
Water reservoir	Glass	4.0	24	11.0
With cooler	stainless steel	6.0	8	3.7
Double coil	stainless steel	6.0	500	
Drying pan	stainless steel	0.375	1.88	1.5
Hot plate	--			
Vacuum pump	--	8.0		
236-Z Cell: clarified solution receiving				
Two holding tanks Tank 25, Tank 26	stainless steel	5.0 (4-barrel)	45	57.0
Glovebox HA-40F: dissolution of plutonium-bearing solids				
Furnace (2)	Ceramic	--	6.0	--
Glovebox HC-46F				
Four hot plates		6.0	9.0	4.0
Four dissolver beakers	stainless steel	6.0	9.0	4.0
Four reflux condensers (single pass)				
Inner tube	stainless steel	1.0	20.75	0.27
Shell	stainless steel	1.5	19.0	0.31
Four rotameters (0 to 5 gal/min)				
Three pan filters with Kynar™ 25-micron media	stainless steel	10.0	4.0	5.0
Two demister/scrubbers (with 1/2 Raschig rings)	stainless steel	6.0	30.0	13.9
One receiver	stainless steel	6.0	36.0	16.5
One vacuum trap	Glass	4.0	12.0	3.0
One cartridge filter housing (with 2-micron media)	stainless steel	3.0	10.0	1.0
Glovebox HC-60: hydroxide stabilization of organic residues				
Two hot plates (2 kW)				
Two dissolver beakers	stainless steel	6.0	9.0	4.0
Vacuum flask (2)	Glass			1.0
Vacuum trap	Glass	4.0	12.0	3.0
Two buchner funnels	Ceramic	--	--	0.5
Chemical addition funnels	stainless steel	3.0	6.0	

Table 5-9. Hanford Piping Standards (1960).

Standard	Application
H-6	N_2 Compressed air
H-9	Instrument air
H-12	Instrument air, dry air, and breathing air
H-22	Waste lines
H-33	Acid feed lines and process lines
H-34	Hydrogen fluoride gas

Table 5-10. American Society for Testing Materials Codes.

ASTM Code	Application
A 312-59T	Seamless and welded austenitic stainless steel
A 358-56T	Chrome-nickel high temperature steel
A 371-53T	Chrome-nickel welding rod
A 262-55T	Boiling HNO_3 test

Table 5-11. Major Plutonium Reclamation Facility Equipment.
(4 sheets)

Equipment number	Location	Function	Description* (diameter by length) (construction materials)	Working volume (L)	Overflow capacity (L)
TK-32	Process cell	CA Column--extracts plutonium from aqueous feed	4-in. by 50-ft stainless steel and Pyrex™[1]	144	--
TK-33	Process cell	CC Column--strips plutonium from organic solution	4-in. by 50-ft stainless steel and Pyrex™[1]	144	--
TK 34 (Failed)	Process cell	CO Column--plutonium scrubbing	6-in. by 19-ft 1-in. stainless steel, Teflon™-lined[1]	90	--
TK-WS-1 (Replaced TK-34)	Process cell	Replacement CO column--plutonium scrubbing	4-in. by 24-ft stainless steel, Teflon™-lined[1]	32	--
TK-123	Process cell	CU Column--uranium stripping	4-in. by 23-ft stainless steel[1]	65	--
TK-69	Process cell	CX Column--DBP scrubbing	6-in. by 11-ft 7-in. stainless steel, Teflon™-lined[1]	70	--
TK-48	Process cell	OA Column--organic reacidification	5-in. by 4-ft 6-in. stainless steel, Teflon™[1]-lined pipe and Pyrex™[1]	18	23
TK-15	Process cell	Feed storage tank	5-in. by 3-ft 9-in. stainless steel[4]	45	57
TK-16	Process cell	Feed storage tank	5-in. by 15-ft 4-in. stainless steel[4]	185	234
TK-17	Process cell	Feed makeup tank	5-in. by 15-ft 4-in. stainless steel[4]	185	234
TK-18	Process cell	Feed transfer to CA column	5-in. by 15-ft 4-in. stainless steel[4]	185	234
TK-19	Process cell	CAW Receiver tank	5-in. by 14-ft 4-in. stainless steel[4]	185	234
TK-20	Process cell	Feed tank to TK-21	5-in. by 45-in. stainless steel[4]	45	57
TK-21	Process cell	Filtrate evaporator	6-in. by 72-in. stainless steel with shell and tube heat exchanger[2]	25	34
TK-22	Process cell	Condenser for TK-21	5-in. by 45-in. stainless steel[1]	N/A	20
TK-23	Process cell	Evaporator receiver for TK-21	5-in. by 45-in. stainless steel[4]	45	57
TK-24	Process cell	Evaporator receiver for TK-21	5-in. by 45-in. stainless steel[4]	45	57
TK-25	Process cell	Receiver tank from MT	5-in. by 45-in. stainless steel[4]	45	57
TK-26	Process cell	Receiver tank from MT	5-in. by 45-in. stainless steel[4]	45	57
TK-27	Process cell	CAR Supply to CA column	5-in. by 45-in. stainless steel[4]	45	57
TK-29	Process cell	CAS Pump Tank to CA column	5-in. by 45-in. stainless steel[4]	45	57
TK-30	Process cell	CCX Pump tank to CC column	5-in. by 45-in. stainless steel[4]	45	57
TK-36	Process cell	CAIS Acid molarity adjustment and pump	5-in. by 45-in. stainless steel[4]	45	57
TK-37	Process cell	CAX Pump tank	5-in. by 13-ft 8-in. stainless steel[4]	185	234
TK-38	Process cell	CAX Pump tank	5-in. by 13-ft 8-in. stainless steel[4]	185	234
TK-39	Process cell	CAW Receiver tank (aqueous waste receiver tank)	5-in. by 13-ft 8-in. stainless steel[4]	185	234

Table 5-11. Major Plutonium Reclamation Facility Equipment. (4 sheets)

Equipment number	Location	Function	Description* (diameter by length) (construction materials)	Working volume (L)	Overflow capacity (L)
TK-40	Process cell	CAW Receiver tank (aqueous waste receiver tank)	5-in. by 13-ft 8-in. stainless steel[4]	185	234
TK-41	Process cell	CUU Receiver tank (aqueous waste receiver tank)	5-in. by 45-in. stainless steel[4]	45	57
TK-42	Process cell	Feed tank to TK-43	5-in. by 45-in. stainless steel[4]	45	57
TK-43	Process cell	Product concentration	4-in. by 10-ft 9-in. stainless steel with annular steam jacket[1]	5	27
TK-44	Process cell	Condenser for TK-43	6-in. by 3-ft 8-in. stainless steel[1]	15	20
TK-45	Process cell	PR for TK-43	5-in. by 45-in. stainless steel[4]	45	57
TK-46	Process cell	PR for TK-43	5-in. by 45-in. stainless steel[4]	45	57
TK-49	Process cell	Aqueous/organic separation and transfer	5-in. by 45-in. stainless steel[4]	45	57
TK-50	Process cell	Vacuum supply tank	6-in. by 5-ft stainless steel[1]	25	28
TK-52.1	East glovebox	Drain header receiver tank	6-in. by 2-ft 6-in. Glass pipe[1]	20	22
TK-52.2	East glovebox	Drain header receiver tank	6-in. by 2-ft 6-in. Glass pipe[1]	20	22
TK-52.3	West glovebox	Drain header receiver tank	6-in. by 2-ft 6-in. Glass pipe[1]	20	22
TK-52.4	West glovebox	Drain header receiver tank	6-in. by 2-ft 6-in. Glass pipe[1]	20	22
TK-54	East glovebox	Product LO (no longer in use)	6-in. 1-ft 9-in. Glass[1]	7	10
TK-55	Process cell	CA Column surge tank	6-in. by 18-in. 304-L stainless steel[4]	7	8.5
TK-56	Process cell	CC Column surge tank	6-in. by 18-in. 304-L stainless steel[4]	N/A	8.5
TK-57	West glovebox	Chemical addition	6-in. by 14-in. Glass pipe[1]	N/A	11
TK-58	Room 50 glovebox	Organic deentrainment	4-in. by 2-ft 6-in. Glass pipe[1]	N/A	6
TK-70	Process cell	CXX Pump tank	5-in. by 45-in. stainless steel[4]	45	57
TK-120	Process cell	CAP Pump tank	5-in. by 7-ft 5-in. stainless steel[4]	45	59
TK-126	Process cell	Miscellaneous storage	5-in. by 15-ft 4-in. stainless steel[4]	185	234
TK-127	Process cell	Miscellaneous storage	5-in. by 15-ft 4-in. stainless steel[4]	185	234
TK-128	Process cell	PR	5-in. by 45-in. stainless steel[4]	45	57
TK-WM-1	Process cell	CAW Receiver tank	6/5/32-in. by 14-ft 4-in. stainless steel[3]	185	234
D Centrifuge	West glovebox	Solids removal from product	stainless steel[1]	0.5	1
Filter 16.1	East glovebox	Solids removal	stainless steel	N/A	N/A
Filter 16.2	East glovebox	Solids removal	stainless steel	N/A	N/A
Filter 51	West glovebox	Solids removal	4-in. by 1-ft 6-in. 304-L stainless steel[1]	3	4
A-101, A-102	Room 40	Dissolver feed	4-ft by 5-ft stainless steel[1]	1570	--

Table 5-11. Major Plutonium Reclamation Facility Equipment.
(4 sheets)

Equipment number	Location	Function	Description* (diameter by length) (construction materials)	Working volume (L)	Overflow capacity (L)
A-103	Room 40	Pump Tank for NaOH	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-105	Room 40	Head tank for 12M HNO_3	3-ft 6-in. by 7-ft stainless steel[1]	1700	--
A-106	Room 40	Head tank for 1.8M Al $(NO_3)_3 \bullet 9H_2O$	3-ft 6-in. by 7-ft stainless steel[1]	1700	--
A-107	Room 40	Makeup of 4% Na_2CO_3	2-ft 6-in. by 2-ft 8-in. PVC	300	--
A-108	Room 40	Makeup of 1.5M HNO_3	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-109	Room 40	Makeup of 0.04M HN 0.2M HNO_3	4-ft by 5-ft stainless steel[1]	1500	--
A-109A	Room 40	NH_2NH_2 Storage	6-in. by 30-in. Glass	20	--
A-110	Room 40	Makeup of 2.0M HNO_3 0.2M HF or 3M HNO_3 1M ANN solution	2-ft 6-in. by 2-ft 6-in. PVC	300	--
A-112	Room 40	Dissolver flush solutions	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-113	Room 40	Makeup of 5,000 ppm Mistron™ 0.5M HNO_3	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-114	Room 40	Makeup of 20% TBP in CCl_4	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-115	Room 40	Head tank for CCl_4	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-116	Room 40	Makeup of 500 ppm antifoam 0.5M HNO_3	2-ft 6-in. by 2-ft 8-in. stainless steel[1]	280	--
A-117	Room 40	Makeup B-acid	2-ft 6-in. by 3-ft PVC	265	--
A-118	Room 40	Chemical addition	8-in. by 25-in. PVC	20	--
A-119	Room 40	Electrolytic dissolver acid	18-in. by 24-in. stainless steel[1]	85	--
TK-123A	Process cell	Air surge tank	6-in. by 12-ft Carbon steel	68	--
TK-131	Room 41 glovebox MT-5	Chemical tank for ANN	6-in. by 25-in. PVC	6	11
TK-132	Room 41 glovebox MT-5	Chemical addition tank for B-acid	6-in. by 19-in. stainless steel[1]	8	8
TK-C1	Room 41 glovebox MT-6	Overflow catch tank for TK-C2 an TK-C3	stainless steel	2.5	3
TK-C2	Room 41 glovebox MT-6	Receiver tank for MT solution	Glass[1]	14.4	--
TK-C3	Room 41 glovebox MT-6	Receiver tank for MT solution	Glass[1]	14.4	--
A Centrifuge	East glovebox	Solids removal from S&C dissolver product	3.8-in. ID, 8-in. OD x 4-in. stainless steel[1]	0.5	1
B-1 and B-2 Centrifuges	Room 41 glovebox MT-6	Solids removal	3.8-in. ID, 8-in. OD x 4-in. stainless steel[1]	0.5	1
C Centrifuge	Room 41 glovebox MT-6	Solids removal	3.8-in. ID, 8-in. OD x 4-in. stainless steel[1]	0.5	1
TK-01 and TK-02	3rd Floor east	S&C Dissolver preheaters	4-in. by 42-in. stainless steel	8	--

Table 5-11. Major Plutonium Reclamation Facility Equipment.
(4 sheets)

Equipment number	Location	Function	Description* (diameter by length) (construction materials)	Working volume (L)	Overflow capacity (L)
TK-08 and TK-124	Process cell	S&C Dissolvers	4-in. by 17-ft stainless steel	95	95
TK-09 and TK-125	Process cell	S&C Dissolver condensers	6-in. by 32-in. stainless steel	10	--
TK-10-A and TK-12-A	East glovebox	S&C Dissolver deentrainer	6-in. by 24-in. Glass	10	--
TK-10 and TK-12	Process cell	S&C Dissolver scrubbers	7-in. by 17-in. stainless steel	70	--
TK-11 and TK-13	East glovebox	S&C Scrubber coolers	2-in. by 32-in. stainless steel	1.5	--

*Numbers in parentheses indicate units in each tank.

Table 5-12. Pressure Vessel Design Description. (2 sheets)

Tank number	Drawing number (H-2-XXXXX)	Function	Design condition pressure (temperatures are ambient unless stated)	Corrosion severity ration (three being severe)	Material of construction
08/09	29709	S&C Dissolver	20 lb/in^2 (gauge)	NR	Kynar™-lined 304-L
08R/09F	93514	Spare S&C dissolver	20 lb/in^2 (gauge)	NR	304-L
124/125	26750	S&C Dissolver	20 lb/in^2 (gauge)	NR	304-L
27	29877	CAR Feed	-	2-	304-L
29	29889	CAS Pumping tank	-	1	304-L
30	29890	CCX Pumping	-	NR	304-L
32	29899	CA Column	-	2	304-L Body and bottoms disengaging, Pyrex™ top disengager
33	29890	CC Column	-	2	304-L Body and bottoms disengaging, Pyrex™ top disengager
34	29896	CO Column	-	3	Teflon™-lined SST
36	29877	CAIS Pumping	-	2	304-L
37	29901	CAX Pumping	-	1	304-L
38	29901	CAX Pumping	-	1	304-L
39	29901	CAW Aqueous waste	-	1	304-L
40	29901	CAW Aqueous waste	-	1	304-L
41	29893	CUU Aqueous waste receiver	-	2+	304-L
42	29877	Product concentrator feed	-	2	304-L
43	29903	Product concentrator	-	3+	Titanium
44	29903	Condenser for TK-43	-	2	304-L
45	29877	PR for TK-43	-	2	304-L
46	29877	PR for TK-43	-	2	304-L
48	26387	OA Column	-	2	304-L, Teflon™, and Pyrex™
49	29879	Aqueous/organic deentrainment	-	2	304-L
50	29911	Vacuum supply	-	1	304-L
52.1	29908	Drain header receiver	-	1	Pyrex™
52.2	29908	Drain header receiver	-	1	Pyrex™
52.3	29908	Drain header receiver	-	1	Pyrex™
52.4	29908	Drain header receiver	-	1	Pyrex™
55	29895	CA Column surge	-	1	304-L
56	29895	CC Column surge	-	2	304-L
57	29980	Chemical addition	-	2	Glass
58	29895	CCP Disengaging	-	2	Glass
69	29833	CX Column	-	3	Teflon™-lined 304-L
70	29833	CXX Pumping	-	3	304-L
A-101	29913	Dissolver feed	-	3	304-L

Table 5-12. Pressure Vessel Design Description. (2 sheets)

Tank number	Drawing number (H-2-XXXXX)	Function	Design condition pressure (temperatures are ambient unless stated)	Corrosion severity ration (three being severe)	Material of construction
A-103	29912	NaOH Pumping	-	2	304-L
A-105	29917	12M HNO_3 Head tank	-	3	304-L
A-106	29917	ANN Head tank	-	2	304-L
A-107	29919	Na_2CO_3 Makeup	-	2	PVC
A-108	29912	1.5M HNO_3 Makeup	-	2	304-L
A-109	29913	HN Makeup	-	2	304-L
A-109-A	29913	HN Storage	-	2	Glass
A-110	29919	HNO_3, HF, and ANN Makeup	-	3	PVC
A-122	29912	Dissolver flushing	-	3	304-L
A-114	29912	Organic makeup	-	--	304-L
A-115	29912	CCl_4 Head tank	-	--	304-L
A-116	29912	Antifoam makeup	-	--	304-L
A-117	24073	B-acid Makeup	-	3	PVC
A-118	Chemical	Chemical addition	-	3	PVC
A-119	16054	Dissolver acid	-	3	304-L
120	26731	CAP Pumping	-	3	304-L
123	26729	CU Column	-	2	304-L, Intalox™ saddles
123-A	26737	Air surge	-	--	Carbon steel
131	26202	ANN Storage	-	3	PVC
132	26202	B-acid Chemical addition	-	3	PVC

Table 5-13. Piping Design Description.

Service	Piping standard	Fitting standard	Material wall thickness	Design pressure [lb/in^2 (gauge)]	Test pressure [lb/in^2 (gauge)]
Instrument air	ASTM 53 or ASTM 120	ASA B16.3	Galvanized steel, schedule-40 pipe	150	225
Process water	ASTM 53 or ASTM 120	ASA B16.4	Malleable-iron 150-lb fittings	150	225
Steam	ASTM 53	ASA B16.3 ASA B16.9	Black steel, schedule-40 pipe, malleable 300-lb fittings Flanges (>1 to 1/2 d)	125	225
Contaminated wastes	HWS-8064-S	HWS-8066-S	304-L stainless steel, Schedule-40 (22-in.), schedule-10 (22-in.) 150-lb fittings flanges	Gravity	150
Chemical addition*	HWS-8064-S [HWS-8065-S] Tubing	HWS-8066-S	Seamless 304-L stainless steel, schedule-40, butt weld joints or 150-lb forged 304-L stainless steel flanges "Koncentrik" fittings, Teflon™ gaskets	100	150

*ANN, CAS, CCl_4, CCX, Dissolvers, water, $NaNO_2$, TBP, NaOH, and HNO_3.

Table 5-14. Major Components of the 241-Z Radioactive Liquid Waste Treatment System.

Component	Function	Size	Comments
TK-D8	Waste receiver tank	17,900 L at overflow	347 stainless steel, 3 m wide x 2.4 m high (see drawing H-2-16418)
TK-D5	Waste treatment and shipping tank	15,400 L at overflow	347 stainless steel, 3 m wide x 2.4 m high (see drawing H-2-16418)
TK-D4	Lag storage tank	15,400 L at overflow	347 stainless steel, 3 m wide x 2.4 m high (see drawing H-2-16418)
TK-D7	Lag storage tank	17,900 L at overflow	347 stainless steel, 3 m wide x 2.4 m high (see drawing H-2-16418)
Overflow Tank	Overflow receiver tank	700 L	304L Stainless Steel, 0.8 m wide x 1.8 m high (see drawing H-2-27584)
TK-D9	Sodium hydroxide supply tank	15,400 L at overflow	Inactive. Undergoing deactivation and removal (see drawing H-2-41341)
TK-D10	Sodium nitrite makeup tank	190 L	304 stainless steel (see drawing H-2-80234)
TK-D11	Ferric nitrate makeup tank	190 L	304 stainless steel (see drawing H-2-80234)
A-D8-1	TK-D8 agitator	7.5 hp	Vertical gear motor, 480V, 3-phase (see drawing H-2-97264)
A-D4-1 A D5 1 A-D7-1	TK-D4,D5 D7 agitators	1.5 hp	Vertical gear motor, 480V, 3-phase (see drawing H-2-43549)
A-D5-1	TK-D5 agitator	3 hp	Vertical gear motor, 480V, 3-phase (EMI Company)
P-D5-1	TK-D5 transfer pump	3 hp 4-stage	PUREX type. Vertical Turbine pump, 10-65 gal/min @ 51-58 ft head (see drawings H-2-37478 and H-9-1069)
P-D8-1	TK-D8 sample pump	19 L/min	Air operated diaphragm pump (see drawing H-2-80102)

Table 5-15. Description of Auxiliary Facilities.
(2 sheets)

Building	Roof	Exterior walls	Interior walls	Floors	Interior finish	Occupancy/uses
2736-ZA	Concrete with built-up tar and felt	Concrete	Concrete	Concrete	Noncombustible	Emergency generator for exhaust ventilation equipment, exhaust fans, and filters for 2736-Z Building
2736-ZD	--	--	--	--	--	Concrete cylindrical vault containing experimental breeder reactor II casks
2721-Z	Concrete with built-up tar and gravel	Concrete	Concrete	Concrete	Noncombustible	Backup power generators for 2736-ZB Building
2701-ZA/ZB	Concrete with built-up tar and gravel	Concrete block	Concrete block and gypsum board	Concrete	Gypsum board and acoustical sound boards	PFP security headquarters
234-ZB	Corrugated metal	Corrugated metal	Unfinished gypsum board	Concrete	--	Storage of construction materials
234-ZC	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Electric breaker box, storage of used HEPA filters
241-ZA	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Test and sampling equipment, annunciator panel
241-ZG	Corrugated metal	Corrugated metal	Unfinished gypsum board	Concrete	--	Changeroom
2704-Z	Wood with tar shingles	Transite shingles over wood	Finished gypsum board	Wood covered with tile	--	Office space, Halon system protects records storage vault
2715-Z	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Storage of paints and oils
2727-Z	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Storage of miscellaneous laboratory and operations equipment
2729-Z	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Storage of maintenance materials
2731-Z	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Storage of empty plutonium drums after flushing
2731-ZA	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Miscellaneous storage: laundry, boxes, lights
2734-Z	Wood	Wood	Wood and transite	Concrete	--	Open structure for storage of compressed gases
2734-ZA	Corrugated metal	Concrete block	Concrete block	Concrete	--	Empty cylinder storage
2734-ZB	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Breathing air cylinder storage
2734-ZD	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Empty nonflammable cylinder storage
2734-ZF	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Standby gas bottle storage (not used)
2734-ZG	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	No longer in service

Table 5-15. Description of Auxiliary Facilities.
(2 sheets)

Building	Roof	Exterior walls	Interior walls	Floors	Interior finish	Occupancy/uses
2734-ZH	Corrugated metal	Corrugated metal	Corrugated metal	Concrete	--	Out of service argon gas manifold
2734-ZL	Corrugated metal	Corrugated metal	Finished gypsum board	Concrete	--	HF Gas supply manifold for RMC Line operations
2735-Z	Transite	Transite	Transite	Concrete	--	Chemical storage of HNO_3 and ANN (not used)
2904-Z	Metal	Corrugated metal	Foiled backed insulation	Concrete	--	Monitoring building
2904-ZB	Metal	Corrugated metal	Insulated metal	Concrete	--	Inactive
270-Z	Wood with tar and gravel	Wood frame plywood simulated stucco finish	Wood stud sheet rock	Carpet over concrete	Noncombustible	Offices
234-5ZA	Corrugated metal with 2-hr-rated roof assembly	Concrete	Concrete	Concrete	Acoustical	Men's changeroom

Table 5-16. Support System Configuration Compared with Regulatory Guide 3.39 Requirements.*

Plant system/process	Operating condition	Maximum hypothetical occurrence shutdown mode
The Plant (PFP complex)	5.3.1 Load	5.3.1 Load
Ventilation	Reduced	---
Environmental surveillance and alarms	Reduced	Emergency
Fire protection and alarms	Reduced	Emergency
Balance of plant	Reduced	---
Process lines	5.3.1 Load	5.3.1 Load
PRF (236-Z)	Line normal process	---
RMC Line (234-5Z)	normal process	---
Product handling (2736-Z) (ventilation)	normal process	Emergency

*NRC 1976

Table 5-17. Analysis of System Loads for the Plutonium Finishing Plant.

System/location	Loads		
	Normal process	Reduced	Emergency
Electrical			
Ventilation	1,787 kW	1,787 kW	150 kW
Environmental surveillance	66 kW	66 kW	66 kW
Fire protection	15 kW	15 kW	15 kW
Balance of plant	390 kw	390 kW	0 kw
Subtotal	2,258 kW	2,258 kW	231 kW
PRF	0 kW	0 kW	0 kW
RMC Line	0 Kw	0 kW	0 kW
Product handling	10 kW	10 kW	10 kW
Total	2,268 kW	2,258 kW	241 kW
Steam			
Plant	50,000 lb/h	50,000 lb/h	0.00
PRF	0.00	0.00	0.00
RMC Line	0.00	0.00	0.00
Product handling	0.00	0.00	0.00
Sanitary water			
Not metered, assumed daily release to TEDF equivalent to or less than requirements	10,000 gal/day	10,000 gal/day	0.00
PRF*	0.00	0.00	0.00
RMC Line*	0.00	0.00	0.00
Product handling	0.00	0.00	0.00
Process air			
Total plant	250 ft^3/min	250 ft^3/min	0.00
Instrument air			
Total plant	200 ft^3/min	200 ft^3/min	0.00
Dry air			
Total plant, mainly for RMC Line whether operating or not	0 ft^3/min	0 ft^3/min	0.00

*Engineering estimate of intermittent process water requirement.

Table 5-18. Ventilation Zones and Associated Differential Pressures.

Zone	Ventilation system	Damper	Set pressure (in. w.g.)
1	S-1	A	+0.14 to +0.16
3*	S-3*	B	-0.14 to -0.17
3	S-3	C	-0.14 to -0.17
3A	S-3A	D	-0.11 to -0.14
3B	S-3B	E	-0.03 to -0.10
4	-	-	-1.1

*Note that zone 3 includes those rooms formerly balanced as zone 2.

Table 5-19. Typical Plutonium Finishing Plant Ventilation System Air Supply Flowrates.

Supply system	Damper	Airflow (ft^3/min)	Areas supplied
S-1	A	91,000	Zone 1
S-3	B	28,000	Zone 3
S-3	C	38,000	Zone 3
S-3A	D	72,000	Zone 3A
S-3B	E	10,000	Zone 3B
S-3B	F	49,000	236-Z Building
Total	-	288,000	-

Table 5-20. Plutonium Finishing Plant Compressed Gas Storage Facilities.

Facility	Compressed
2734-Z	Gas bottle storage (not used)
2734-ZA	Empty cylinder storage
2734-ZB	Breathing air (compressed gas) cylinder storage
2734-ZC	Oxygen and P-10 gas cylinders, P-10 gas supply
2734-ZD	Empty non-flammable gas cylinders
2734-ZF	Standby gas bottle storage (not used)
2734-ZG	Nitrogen storage
2734-ZH	Argon bottle supply (not used)
2734-ZJ	Liquid nitrogen storage tank
2734-ZK	Argon, propane, acetylene, and gas bottle storage
2734-ZL	HF gas bottles and supply piping (not used)

Table 5-21. Sanitary Water Service Connections. (2 sheets)

	Location	Size	Service
1.	234-5Z Building under north wall at column 5-1/4	4-in. dia	Riser 1 to sprinklers. Deluge for 252-Z-1 substation.
2.	234-5Z Building under north wall at column 9-1/2	6-in. dia	Building sanitary water. Building process water through backflow preventers. Serves building water loops in duct level.
3.	234-5Z Building under north wall at column 13-1/2	8-in. dia	Riser 2 to second floor sprinklers. (Originally for filter room sprinklers, but not installed.)
4.	234-5Z Building under north wall at column 16-1/3	8-in. dia	Riser 3 for east roof sprinklers (under roof). Also first floor sprinklers.
5.	234-5Z Building under north wall at column 16-1/2	6-in. dia	Riser 4 for ventilation, supply, plenum chamber, deluge sprinklers.
6.	234-5Z Building under west wall at 5 ft north of column E	8-in. dia	Riser 5. Roof sprinklers west end.
7.	234-5Z Building under west wall at 3 ft 1-1/8 in. south of column E	8-in. dia	Riser 6. West end sprinklers including office addition sprinklers.
8.	234-5Z Building office addition at southwest corner; 14 ft south of 234-5Z Building south wall	1-1/2-in. dia 1.5-in.	Sanitary water only to office addition.
9.	Line comes from elevated tank valve pit, runs south to north side of 234-5Z Building, west side of 234-5Z, south to about 40 ft south of 234-5Z, and slants east by slightly north to northwest corner of 291-Z Building	2-1/2-in. dia 2.5-in.	Provides 291-Z Building service water if water loop service pressure decreases below a set pressure.
10.	Southwest side of 2736-ZA Building 2736-ZA plutonium storage	6-in. dia	Fire protection.
11.	South side of 232-Z Building incinerator building	3-in. dia	Sanitary water service (line has been capped).
12.	South side of 232-Z incinerator building through a special valve house	4-in. dia	Provides fire protection water for sprinklers (water is provided to riser in building, but riser has been capped).
13.	Southeast corner of 291-Z Building to machinery room	3-in. dia	Used only for sanitary water and for machinery. Seal water, inter and after coolers on compressors, etc.
14.	Northeast corner of 291-Z Building into 252-Z-2 substation	4-in. dia	Used only for deluge system for 252-Z-2 substation.
15.	Southeast corridor of 236-Z Facility	3-in. dia	Both sanitary and fire water risers.
16.	Southeast corridor 236-Z Facility	3-in. dia	Sanitary water and safety showers.
17.	Northeast corner of 236-Z Facility at 6 in. north of south wall of stair 1	3-in. dia	Sanitary water.
18.	Northeast corner of 236-Z Facility at 6 in. south of north wall of stair 1	6-in. dia	Riser 7. Fire protection for 236-Z Building sprinklers for all floors.

Table 5-21. Sanitary Water Service Connections. (2 sheets)

Location	Size	Service
19. 242-Z Building at east side of control room	2-in. dia	Sanitary water for safety showers.
20. 234-5Z Building on east side at 12 ft south of column G	8-in. dia	Riser 8. Serves sprinklers for entire engineering laboratory plus additional spaces in southeast area of building. Also branch into 242-Z.
21. 234-5Z Building under north wall at column	6-in. dia	Fire protection water for east end duct level sprinklers.
22. East side of 270-Z Building	6-in. dia	Fire protection water for the 270-Z Building.
23. East side of 270-Z Building	2-in. dia	Sanitary water supply for the 270-Z Building.
24. West side of 2736-ZB Building	6-in. dia	Fire protection water for the 2736-Z and 2736-ZB Buildings.
25. West side of 2736-ZB Building	4-in. dia	Sanitary water supply for the 2736-ZB Building.
26. South end of 2721-Z Building	4-in. dia	Riser. Fire protection water for the 2721-Z backup power generation building.
27. Under north wall at column 19 of 234-5Z Building	8-in. dia	Fire protection riser for the duct level, west end.
28. South east corner of 234-5ZA Building	6-in. dia	Riser 10. Fire protection for the 234-5ZA Building.
29. 234-5ZA	2-in. dia	Sanitary water supply for the 234-5ZA Building and safety showers for the 2735-Z Building.
30. 243-Z east side	6-in dia	Fire protection water for the 243-Z Building.
31. West isle of 243-Z Building	2-in dia	Sanitary water safety shower and process water for tank cleaning in 243-Z Building.

Table 5-22. Building 234-5Z Low-Level Waste Treatment Facility/ Treated Effluent Disposal Facility Streams. (2 sheets)

Stream description	Drain header number[1,2,3]	Manhole number
Roof drain, east end[4]	D-1	Z-3
Duct level safety shower drains[4]	D-1	Z-3
Protected precess water overflow drain[4]	D-1	Z-3
Hydraulic unit cooling water drain in rooms 145 and 146[4]	D-1	Z-3
Room 306 floor drain[4]	D-1	Z-3
Corridor 10 development laboratory drinking fountain drain[4]	D-2	Z-3
Analytical Lab:		
Corridor 4C drinking fountain drain[4]	D-2	Z-3
Room 132 air conditioner drain, duct level	D-2	Z-4
Room 141 open-face hood drain[4]	D-3	Z-4
Room 141 sink drain	D-3	Z-4
Room 152 glovebox condenser cooling water drain[4]	D-3	Z-4
Corridor 4D eyewash	D-2	Z-3
Room 150 air conditioner return water and condensate[4]	D-2	Z-3
Room 192:		
Refrigerate unit H1-73E drain riser[4]	D-2	Z-3
Drinking fountain drain[4]	D-2	Z-3
Room 192-D air conditioner drain riser (located in pipe tunnel)[4]	D-2	Z-3
Room 199 maintenance shop:		
Sink drain	D-2	Z-3
Floor drain[4]	D-2	Z-3
Room 202 ceramic shop:		
Two drain risers[4]	D-2	Z-3
Two floor drains[4]	D-2	Z-3
Room 228-B, gloveboxes HC-15A, -15B, and -15C induction coils cooling water drains[4]	D-3	Z-4
Room 229:		
TOCCO™ unit cooling water drain[4]	D-3	Z-4
Drinking fountain drain[4]	D-2	Z-3
Room 235:		
Drinking fountain drain located in corridor 13	D-2	Z-3
Drinking fountain drain riser located in duct level[4]	D-2	Z-3
Room 236, glovebox HC-41 chuck cooling water drain riser[4]	D-2	
Development Laboratory:		
Room 179-B drains[4]	D-3	Z-4
Rooms 182-A drain[4]	D-3	Z-4
Room 183-A sink drain[4]	D-3	Z-4
Room 184 floor drain[4]	D-3	Z-4
Rooms 186 and 187 glovebox cooling water drain[4]	D-3	Z-4
Room 189 floor drain[4]	D-3	Z-4
Room 191 floor drain[4]	D-3	Z-4
Room 202 ceramic shop sink drains (3)	D-3	Z-4
Room 227 floor drain[4]	D-3	Z-4
Room 228 compressed air condensate drip trap drains[4]	D-3	Z-4
Room 230 cooling water from hood drains[4]	D-3	Z-4

Table 5-22. Building 234-5Z Low-Level Waste Treatment Facility/ Treated Effluent Disposal Facility Streams. (2 sheets)

Stream description	Drain header number[1,2,3]	Manhole number
Room 235 RMA Line hoods cooling water drains	D-3	Z-4
Room 236 floor drain[4]	D-3	Z-4
Room 262 Duct level funnel drains (2)	D-3	Z-4
Column D-16 drain[4]	D-3	Z-4
Column D-18 sink drain[4]	D-3	Z-4
Rooms 306, 336, 337, and 338 floor drains	--	Z-1
Roof drains, west end	--	Z-1

[1]The 234-5Z D-1 header is made of 3 in. diameter stainless steel pipe.
[2]The 234-5Z D-2 header is made of 4 in. diameter stainless steel pipe.
[3]The 234-5Z D-3 header is made of 8 in. diameter stainless steel pipe.
[4]Drain is not in use or has been plugged.

Table 5-23. Building 236-Z Low-Level Waste Treatment Facility/ Treated Effluent Disposal Facility Streams. (2 sheets)

Stream description	Drain header number[1,2]	Manhole number
Room 16 maintenance shop sink drain[4]	D-1	Z-4
Room 16 drinking fountain drain[4]	D-1	Z-4
Corridor 10 wound flushing station drain[4]	D-1	Z-4
Corridor 11 fire water drain to exhaust duct sump	D-3	Z-4
Corridor 11 process hood drain	D-3	Z-4
Corridor 14 fire water drain to exhaust duct sump	D-3	Z-4
Corridor 14 process hood drain	D-3	Z-4
CAW-WM-1 jacket cooling water drain[4]	D-3	Z-4
S&C Condenser cooling water drain: Tank 125 flush condensate drain[4] Tank 9 flush condensate drain[4]	D-3 D-3 D-3	Z-4 Z-4 Z-4
Corridor 20 wound flushing station drain[4]	D-1	Z-4
EC and ED heaters condensate drains[4]	D-1	Z-4
Steam condensate header drain (3rd floor)[4]	D-1	Z-4
Tank 57 overflow drain[4]	D-1	Z-4
Corridor 30 wound flushing station drain[4]	D-1	Z-4
Corridor 33 protected process water drain from the hydropneumatic system[4]	D-1	Z-4
Room 35 (equipment room): Instrument air "condensifilter" drains Process water supply backflow preventer drain Steam condensate headers drain[4] Floor drain	 D-1 D-1 D-1 D-1	 Z-4 Z-4 Z-4 Z-4
BFP-1 backflow preventer drain	D-1	Z-4
BFP-2 backflow preventer drain	D-1	Z-4
BFP-3 backflow preventer drain	D-1	Z-4
BFP-4 backflow preventer drain	D-1	Z-4
Ventilation reheat coil 1 steam condensate drain	3	Z-4
Ventilation reheat coil 2 steam condensate drain	3	Z-4
Ventilation reheat coil 3 steam condensate drain	3	Z-4
Ventilation reheat coil 4 steam condensate drain	3	Z-4
Ventilation reheat coil 5 steam condensate drain	3	4
Ventilation reheat coil 6 steam condensate drain	3	4
Ventilation reheat coil 7 steam condensate drain	3	4
Chemical preparation room steam supply trap drain (3rd floor)	3	4
Processing steam supply trap drain (3rd floor)	3	4
Room 40 chemical preparation: Eyewash drain Sink drain Floor drains (2) Overflows drains from tanks 107, 108, 109, 110, 111, 112, 113, 114, and 117 Routed to overflow 2735-Z tank (next to changeroom)	-	-
Room 41 MT: Glovebox 3: Tank 73 steam condensate drain[4] Electric dissolver cooling water drain[4] Floor drain[4] Glovebox 4: Still condenser cooling water drain[4] Furnace condenser cooling water drain[4]	 D-1 D-1 D-1 D-1	 Z-4 Z-4 Z-4 Z-4
Room 44 drinking fountain drain[4]	D-1	Z-4

Table 5-23. Building 236-Z Low-Level Waste Treatment Facility/ Treated Effluent Disposal Facility Streams. (2 sheets)

Stream description	Drain header number[1,2]	Manhole number
Room 45 office drinking fountain drain[4]	D-1	Z-4
Corridor 47 wound flushing station drain[4]	D-1	Z-4
Corridor 47 eye wash drain[4]	D-1	Z-4
BFP-5 backflow preventer drain[4]	D-1	Z-4

[1]The 236-Z D-1 header is made of 6 in. diameter stainless steel.
[2]The 236-Z D-3 header is made of 3 in. diameter stainless steel.
[3]The header does not have a number and is referred to as "STEAM CONDENSATE DRAIN" on all reference drawings for the facility. This 3 in. diameter line is constructed of black wrought iron.
[4]Drain not in use or plugged.

Table 5-24. Building 291-Z Low-Level Waste Treatment Facility/ Treated Effluent Disposal Facility Streams.

Stream description	Manhole number
17-in. Mercury air sampling vacuum pump 1 seal water drain	Z-3
17-in. Mercury air sampling vacuum pump 2 seal water drain	Z-3
90 lb/in^2 air compressor 1 (90 hp) cooling water drain	Z-3
90 lb/in^2 air compressor 1 (60 hp) water separator drain	Z-3
90 lb/in^2 air compressor 2 (60 hp) cooling water drain	Z-3
90 lb/in^2 air compressor 2 (60 hp) water separator drain	Z-3
Evaporative air conditioner S-11 drain	Z-3
Evaporative air conditioner S-12 drain	Z-3
Evaporative air conditioner S-13 drain	Z-3
Evaporative air conditioner S-14 drain	Z-3
Evaporative air conditioner S-15 drain	Z-3
Transformer room floor drain	Z-3
291-Z Steam condensate	Z-3
Instrument air compressor prefilter 1 and 2	Z-13, Z-14
Instrument air compressor condensate blowdown drains 1 and 2	Z-13, Z-14
Instrument air receiver drain	Z-13, Z-14
Process air receiver drain	Z-13, Z-14

NOTE: Waste waters from the 291-Z Building are collected in a sump and pumped to manhole Z-3 via a 6-in. vitreous clay pipe.

Table 5-25. Other Building Streams.

Building	Stream description	Manhole number
243-Z	2 cooling towers (spray pans) 2 BFP drains	TK-101 LLWTF

Table 5-26. Continuous Air Monitors and Other Signals Alarmed at Panel ANN-714.

CAM High Rad 291-Z Stack
CAM Low Flow 291-Z Stack
CAM Fail 291-Z Stack
Record Low Flow 291-Z Stack
CAM High Rad 241-Z Stack
CAM/Record Low Flow 241-Z Stack
CAM Fail 241-Z-Stack
PWR Fail ANN-714
Back-up PWR Fail ANN-714
CAM Fail 2736-ZB Stack
CAM High Rad 2736-Z Stack
Loss of Vacuum 2736-ZB Stack
East CAM High Rad 2736-ZA Stack
Loss of Vacuum 2736-ZA Stack
West CAM Fail 2736-ZA Stack
East CAM Fail 2736-ZA Stack
West CAM High Rad 2736-A Stack
General Trouble 232-Z Stack
Moisture Liq. Detector 26" VAC No. 1
Moisture Liq. Detector 26" VAC No. 2
Trouble Liq. Detector 26" VAC No. 1
Trouble Liq. Detector 26" VAC No. 2
Disabled Seismic Fan Shutdown

Table 5-27. Fire-Alarm Control Panels and Remote Fire Alarm Reporters Associated with Plutonium Finishing Plant Buildings.

Building	FACP	RFAR
2716-Z, 2736-ZA, 2731-Z	FCP-1414	2810
243-Z	FCP-243Z-1	2787
232-Z	FCP-1413	2830
270-Z	FCP-270Z	2775
2701-ZA	FCP-2701ZA	2760
2701-ZD	FCP-2701ZD	2762
2704-Z	FCP-2704Z	2850
2721-Z, 2731-ZA, 2736-ZC, 2736-ZB	FCP-1421	2820

Table 5-28. Auxiliary Facilities Fire Protection Systems.
(2 sheets)

Building	Suppression and extinguishing systems	Fire detection systems	Pull box	Hose line	Alarms to fire department
2736-ZA	Wet pipe automatic sprinklers	Smoke detectors	Y	N	Y
2721-Z	Dry pipe automatic sprinklers	Heat detectors	Y	N	Y
2701-ZA/ZB	Total flooding Halon	Smoke detectors	Y	N	Y
234-ZB	None	None	N	N	N
234-ZC	None	Heat detectors	N	N	Y
241-ZA	None	None	N	N	N
241-ZG	None	None	N	N	N
2701-Z	None	None	N	N	N
2704-Z	Halon	Heat detectors	Y	N	Y
2715-Z	None	None	N	N	N
2727-Z	None	Heat detectors	Y	N	Y
2729-Z	None	Heat detectors	Y	N	Y
2731-Z	None	Heat detectors	N	N	Y
2731-ZA	None	Heat detectors	Y	N	Y
2734-Z	None	None	N	N	N
2734-ZA	None	Heat detectors	N	N	Y
2734-ZB	None	None	N	N	N
2734-ZC	None	Heat detectors	N	N	Y
2734-ZD	None	None	N	N	N
2734-ZF	None	None	N	N	N
2734-ZG	None	None	N	N	N
2734-ZH	None	None	N	N	N
2734-ZL	None	None	N	N	N
2735-Z	None	None	N	N	N

Table 5-28. Auxiliary Facilities Fire Protection Systems.
(2 sheets)

225-WC	None	None	N	N	N
270-Z	Wet pipe automatic sprinklers	None	Y	N	Y
2705	None	None	N	N	N
216-Z-9A/B	Wet pipe automatic sprinklers	Smoke and heat detectors	Y	N	Y
2701-ZD	Wet pipe automatic sprinklers	Smoke detectors	Y	N	Y
242-ZA (TC-66)	Wet pipe automatic sprinklers	None	N	N	Y
243-Z	Wet pipe automatic sprinklers	None	Y	N	Y
234-5ZA	Wet pipe automatic sprinklers	Duct smoke detectors	Y	N	Y

Table 5-29. Auxiliary Facility Compliance for Fire Protection.
(2 sheets)

Building	Occupancy/uses	Life safety NFPA	Exposure NFPA 80A	Liquid runoff	Improved risk DOE 5480.7	Probable loss DOE 5480.7	Maximum loss DOE 5480.7	Probable program delay DOE 5480.7	Maximum program delay DOE 5480.7
2736-ZA	Backup generator for exhaust ventilation equipment, exhaust fans, and filters for 2736-Z Building	Y	Y	Y	Y	Y	Y	Y	Y
2721-Z	Backup power generators for 234-5Z, 232-Z, 2736-Z, and 2736-ZB	Y	Y	Y	Y	Y	Y	Y	Y
2701-ZA/ZB	PFP security headquarters	Y	Y	Y	Y	Y	Y	Y	Y
234-ZB	Storage of construction materials	Y	Y	Y	Y	Y	Y	Y	Y
234-ZC	Electric breaker box, storage of used HEPA filters	Y	Y	Y	Y	Y	Y	Y	Y
241-Z	Houses five radioactive waste tanks	Y	Y	Y	Y	Y	Y	Y	Y
241-ZA	Test and sampling equipment, annunciator panel	Y	Y	Y	Y	Y	Y	Y	Y
241-ZG	Changeroom	Y	Y	Y	Y	Y	Y	Y	Y
2704-Z	Office space, Halon system protects records storage vault	Y	Y	Y	Y	Y	Y	Y	Y
2715-Z	Storage of paints and oils	Y	Y	Y	Y	Y	Y	Y	Y
2727-Z	Storage of miscellaneous laboratory and operations equipment	Y	Y	Y	Y	Y	Y	Y	Y
2729-Z	Storage of maintenance materials	Y	Y	Y	Y	Y	Y	Y	Y
2731-Z	Storage of empty plutonium drums after flushing	Y	Y	Y	Y	Y	Y	Y	Y
2731-ZA	Miscellaneous storage: laundry, boxes, lights	Y	Y	Y	Y	Y	Y	Y	Y
270-Z	Office building	Y	Y	Y	Y	Y	Y	Y	Y

Table 5-29. Auxiliary Facility Compliance for Fire Protection.
(2 sheets)

Building	Occupancy/uses	Life safety NFPA	Exposure NFPA 80A	Liquid runoff	Improved risk DOE 5480.7	Probable loss DOE 5480.7	Maximum loss DOE 5480.7	Probable program delay DOE 5480.7	Maximum program delay DOE 5480.7
2734-Z	Gas bottle storage (not used)	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZA	Empty flammable gas cylinders	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZB	Breathing air (compressed gas) cylinders	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZC	Oxygen and P-10 gas cylinders	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZD	Empty non-flammable gas cylinders	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZF	Argon cylinders	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZG	Nitrogen storage	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZH	Argon and nitrogen storage (not used)	Y	Y	Y	Y	Y	Y	Y	Y
2734-ZL	HF gas bottles and supply piping (not used)	Y	Y	Y	Y	Y	Y	Y	Y
2735-Z	Two pumps: one for HNO_3 to support PRF and RMC Line, and one ANN for PRF	Y	Y	Y	Y	Y	Y	Y	Y
225-WC	PFP liquid effluent sampling	Y	Y	Y	Y	Y	Y	Y	Y

Table 5-30. Process Chemicals Hazards Ratings.
(2 sheets)

Chemical			Rating org[a]	Hazards level[b]			
Name	Formula	Form		Health	Fire	Reactivity	Persistence
Aluminum nitrate nonahydrate (ANN)	$Al(NO_3)_3 \cdot 9H_2O$	Solid/solution	C N H	3 U 3	1	2	1
Calcium	Ca	Solid	C N H	U 1 --	3 1 --	2 2 --	0.00
Carbon tetrachloride	CCl_4	Liquid	C N H	333	0.00	0.00	3
Ferric nitrate	$Fe(NO_3)_3 \cdot 9H_2O$		C N H	2 U 3	0.00	0.00	3
Hydrogen peroxide	H_2O_2	Solution	C N H	323	0.00	111	0.00
Hydroxylamine nitrate (HN)	NH_2OHHNO_3	Solution	C N H	-- -- 3	-- -- 0	-- -- 0	
Iodine	I_2	Solid	C N H	114	0.00	111	0.00
Magnesium oxide	MgO	Solid	C N H	3 U --	0 0 --	0 0 --	0.00
Nitric acid	HNO_3	Solution	C N H	333	0.00	111	0.00
Oxalic acid	$H_2C_2O_4$	Solid/solution	C N H	313	111	0.00	0.00
Oxygen	O_2	Gas	C N H	330	0.00	0.00	0.00
Potassium hydroxide	KOH	Solution	C N H	333	0.00	111	0.00
Potassium permanganate	$KMnO_4$	Solid/solution	C N H	333	0.00	0.00	3

Table 5-30. Process Chemicals Hazards Ratings.
(2 sheets)

Chemical			Rating org[a]	Hazards level[b]			
Name	Formula	Form		Health	Fire	Reactivity	Persistence
Sodium carbonate	Na_2CO_3	Solid/solution	C N H	222	0.00	111	0.00
Sodium fluoride	NaF	Solid	C N H	343	0.00	0.00	0.00
Sodium hydroxide	NaOH	Solution	C N H	333	0.00	111	0.00
Sodium nitrite	$NaNO_2$	Solid	C N H	332	0.00	0.00	0.00
Sodium nitrate	$NaNO_3$	Solid	C N H	301	0.00	0.00	0.00
Tributyl phosphate	$(n\text{-}C_4H_9O)_3PO$	Liquid	C N H	324	111	0.00	0.00

[a]Rating organization: C = CERCLA, N = NFPA, H = HEHF.
[b]Rating description: CERCLA: 0 = no hazard, 1 = modest hazard, 3 = severe hazard
NFPA and HEHF: 0 = no hazard, 1 = slight hazard, 2 = modest hazard, 3 = serious hazard, 4 = extreme hazard
All: U = unknown.

Table 5-31. Other Large Quantity Chemical Hazards Ratings.

Chemical			Rating org[a]	Hazards level[b]			
Name	Formula	Form		Health	Fire	Reactivity	Persistence
Acetylene	C_2H_2	Gas	C N H	1 1 --	344	333	0.00
Argon	Ar	Gas	C N H	U U --	0.00	0.00	0.00
Methane	CH_4	Gas/liquid	C N H	1 1 --	344	0.00	0.00
Nitrogen	N_2	Liquid	C N H	U 3 0	0.00	0.00	0.00
Propane	H_8C_3	Gas/liquid	C N H	1 1 --	344	0.00	0.00

[a]Rating organization: C = CERCLA, N = NFPA, H = HEHF.
[b]Rating description: CERCLA: 0 = no hazard, 1 = modest hazard, 3 = severe hazard
NFPA and HEHF: 0 = no hazard, 1 = slight hazard, 2 = modest hazard,
3 = serious hazard, 4 = extreme hazard
All: U = unknown.

Table 5-32. Process Line Gloveboxes - Recommended Fire Protection

Status	Plastic Windows (polycarbonate or acrylic)	Glass Windows
Inactive	• Automatic suppression or inerting system or • Separation; and remove all combustibles; and provide automatic detection or • Separation; and remove all combustibles; and remove ignition sources; and cap gloves	• Automatic suppression or inerting system or • Separation; and contents limited to ordinary combustibles; and provide automatic detection or • Remove all combustible contents; and remove ignition sources; and provide automatic detection or • Separation; and remove all combustibles; and remove ignition sources; and cap gloves
Active	• Automatic suppression or inerting system	• Automatic suppression or inerting system or • No flammable liquids; storage of combustible materials less than that required to activate suppression system; and combustible materials transported during supervised operation only; and provide automatic detection
Containing combustible or pyrophoric metals	• Gas inerting system or • Apply inactive/active glovebox criteria for oxidation processes	• Gas inerting system or • Apply inactive/active glovebox criteria for oxidation processes

Table 5-33. MICON System Response to Loss of Power Upsets (See Figure 5-70)

Building/System	Function	Condition	Power Restoration
2738-ZB	Monitors both voltage and frequency of the normal power feed to 2736-ZB	Voltage or Frequency outside of normal limits for more than five seconds	Alarm Sounded Breaker NP-VF-1-3 opened Two generators started Demand Mode after 5 minutes
2701-ZA	Monitors Signal from ATS-3 or ATS-4	Under-voltage detected by either Automatic Transfer Switch ATS-3 or ATS-4	Alarm Sounded Startup of one generator SGS Bus powered Breaker F8X-702 closed Demand Mode after 5 minutes
291-Z	Monitors Signal from ATS-2	Under-voltage detected by Automatic Transfer Switch ATS-2	Alarm Sounded Startup of three generators SGS Bus powered Breaker F8X-703 closed Demand Mode after 5 minutes
400 Bus	Monitors both voltage and frequency of the bus via hardwired connection	Voltage or Frequency outside of normal limits for more than ten seconds Start Call from switches on the 400 Bus	Open F8X-340 via hardwired interlocks Startup of one generator Power detected on the SGS Bus Breaker F8X-704 closed Breaker F8X-309 closed Demand Mode after 5 minutes

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Figure 5-1. Plutonium Finishing Plant Site.

(Ref. Dwg. H-2-80249, Sheet 1)

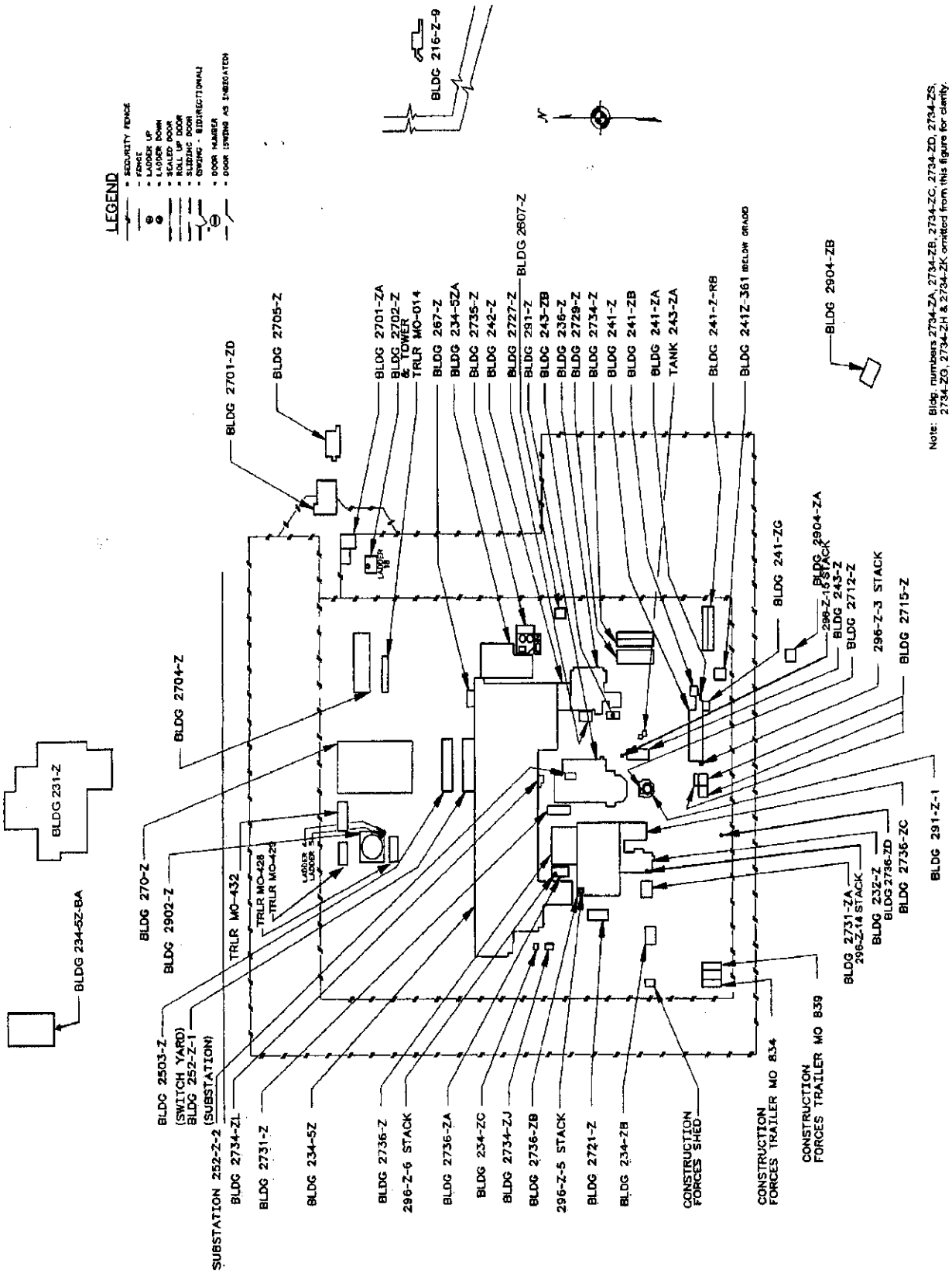


Figure 5-2. Location of the Hanford Site.

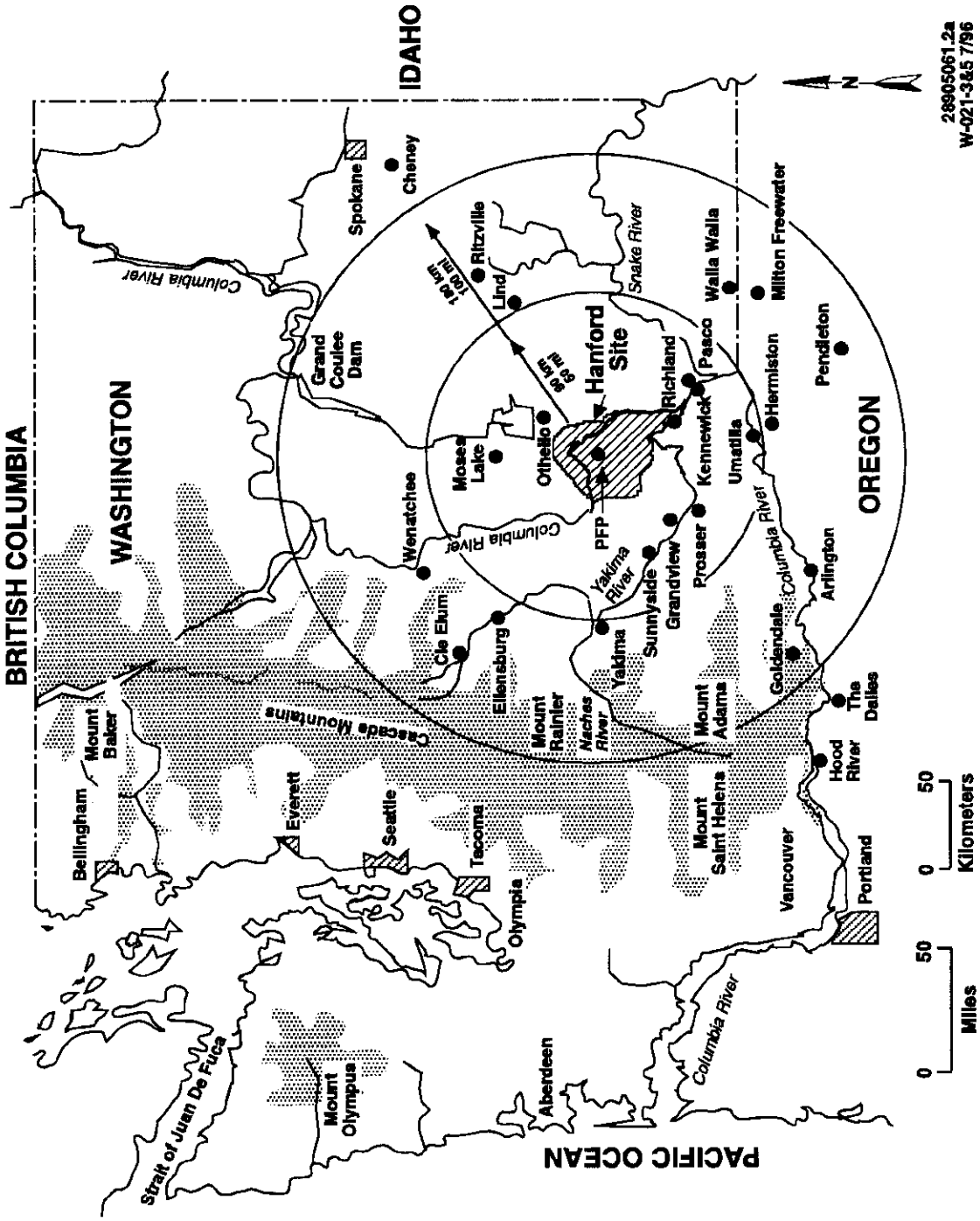
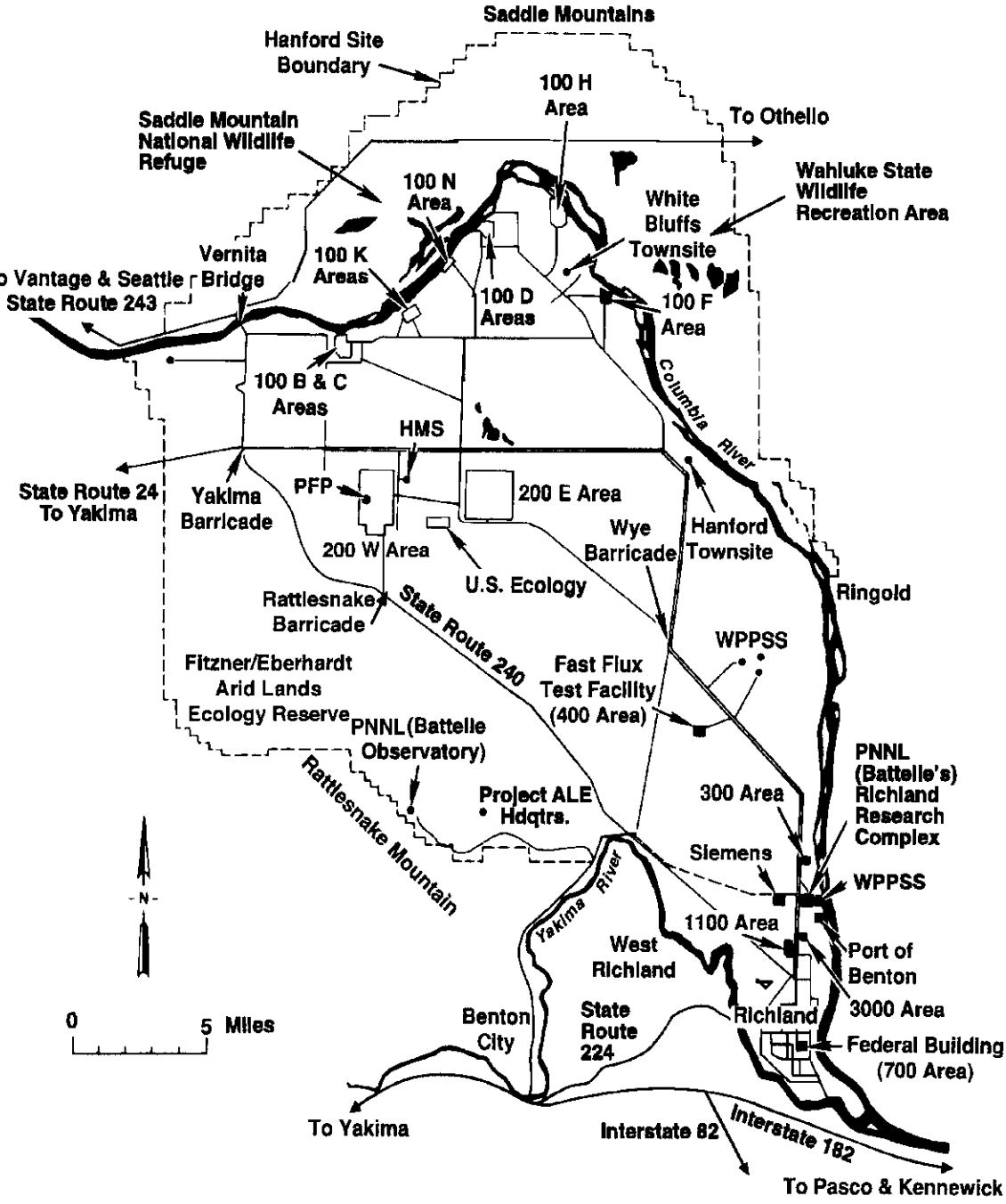
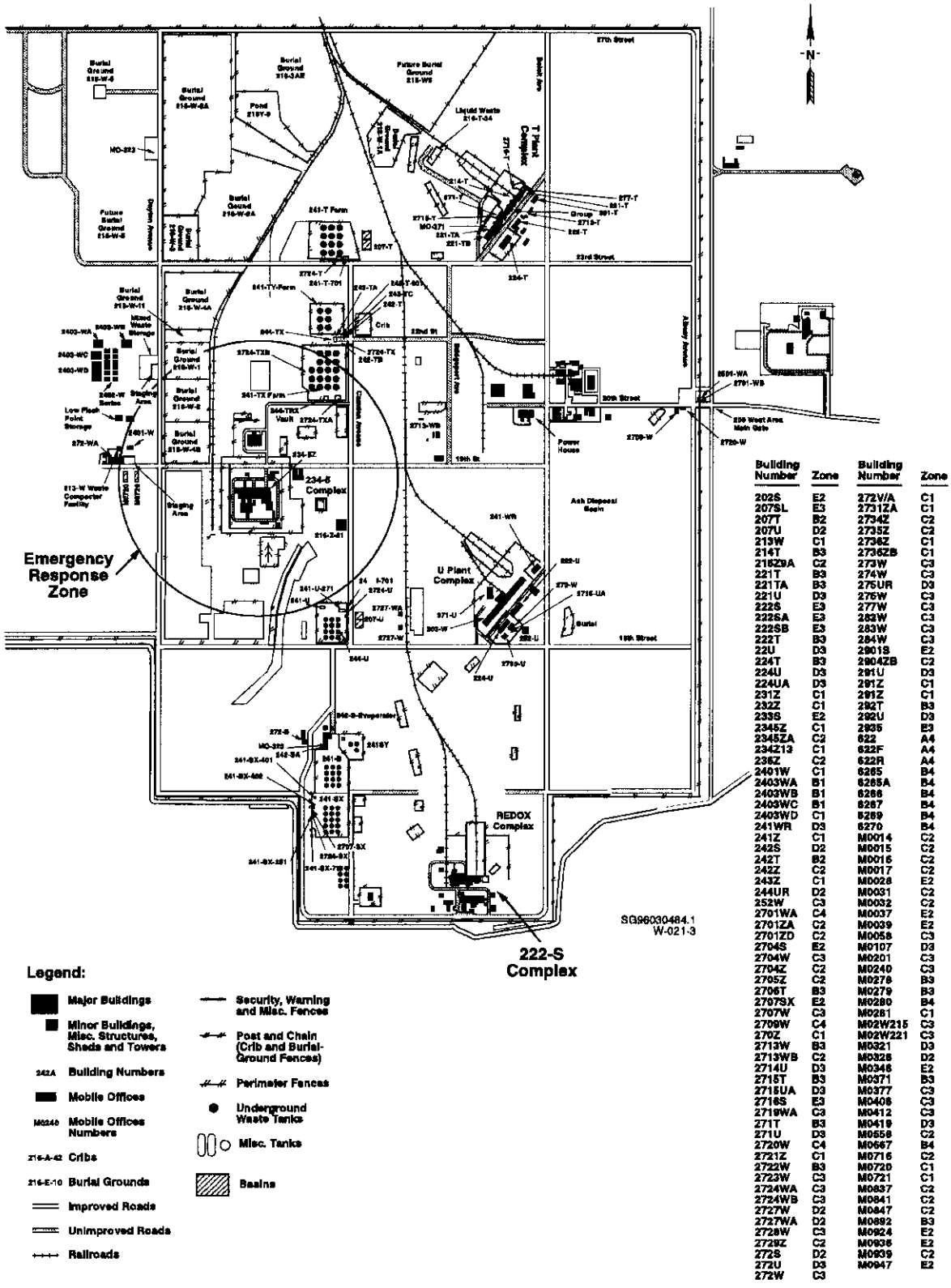


Figure 5-3. Hanford Site.



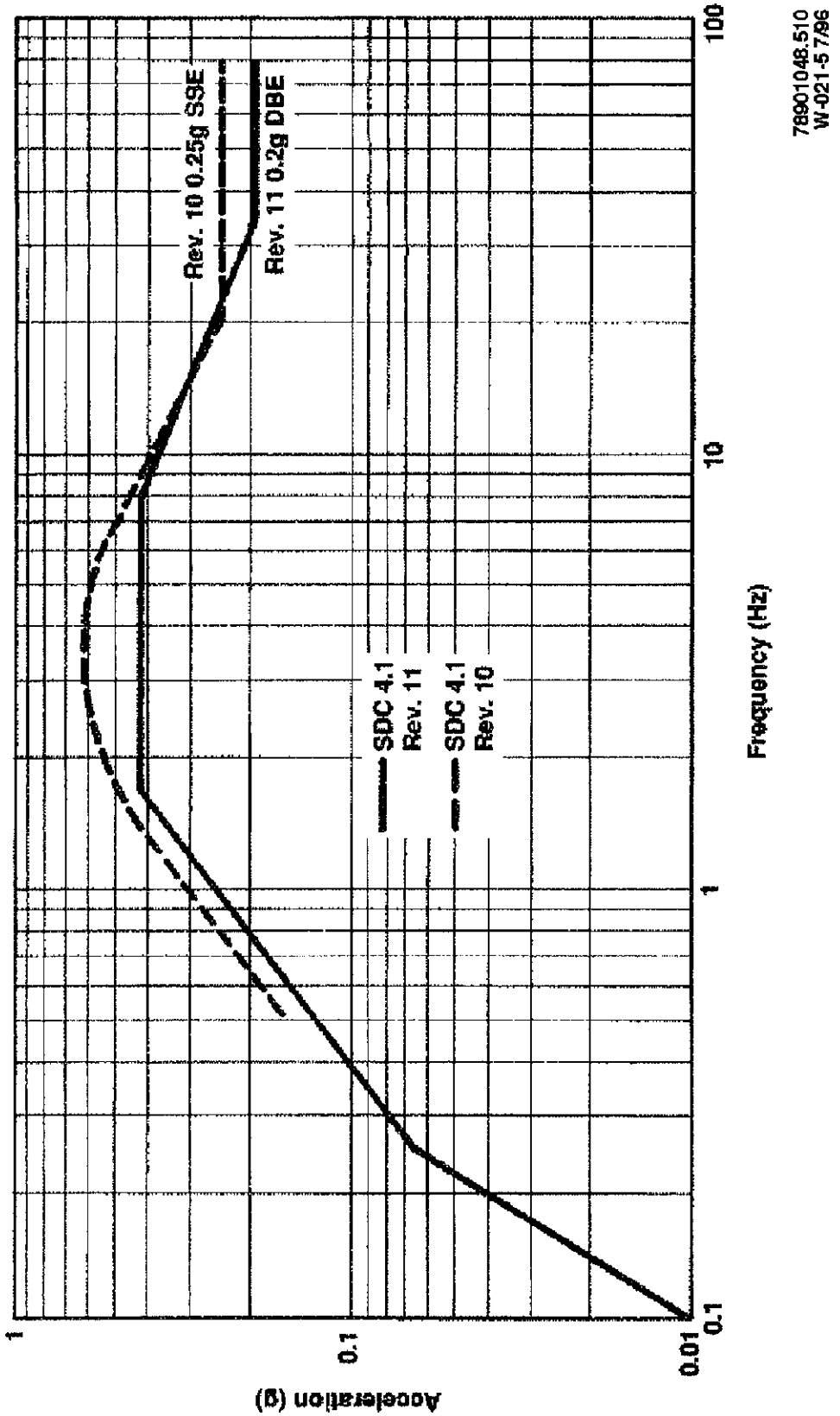
HMS - Hanford Meteorological Station
PNNL - Pacific Northwest National Laboratory
PFP - Plutonium Finishing Plant
WPPSS - Washington Public Power Supply System

Figure 5-4. 200 West Area.



Building Number	Zone
202S	E2
207SL	E3
207T	B2
207U	D2
213W	C1
214T	B3
216Z9A	C2
221T	B3
221TA	B3
221U	D3
222S	E3
222SA	E3
222SB	E3
222T	B3
22U	D3
224T	B3
224U	D3
224UA	D3
231Z	C1
232Z	C1
233S	E2
2345Z	C1
2345ZA	C2
234Z13	C1
236Z	C2
2401W	C1
2403WA	B1
2403WB	B1
2403WC	B1
2403WD	C1
241WR	D3
241Z	C1
242S	D2
242T	B2
242Z	C2
243Z	C1
244UR	D2
252W	C3
2701WA	C4
2701ZA	C2
2701ZD	C2
2704S	E2
2704W	C3
2704Z	C2
2705Z	C2
2706T	B3
2707SX	E2
2707W	C3
2709W	C4
270Z	C1
2713W	B3
2713WB	C2
2714U	D3
2715T	B3
2715UA	D3
2716S	E3
2719WA	C3
271T	B3
271U	D3
2720W	C4
2721Z	C1
2722W	B3
2723W	C3
2724WA	C3
2724WB	C3
2727W	D2
2727WA	D2
2728W	C3
2729Z	C2
272S	D2
272U	D3
272W	C3
272W/A	C1
27231ZA	C1
2734Z	C2
2735Z	C2
2736Z	C2
2736ZB	C1
273W	C3
274W	C3
275UR	D3
276W	C3
277W	C3
282W	C3
283W	C3
284W	C3
2901S	E2
2904ZB	C2
291U	D3
291Z	C1
291Z	C1
292T	B3
292U	D3
2935	E3
622	A4
622F	A4
622R	A4
6285	B4
6285A	B4
6286	B4
6287	B4
6289	B4
6270	B4
M0014	C2
M0015	C2
M0016	C2
M0017	C2
M0026	E2
M0031	C2
M0032	C2
M0037	E2
M0039	E2
M0058	C3
M0107	D3
M0201	C3
M0240	C3
M0276	B3
M0279	B3
M0280	B4
M0281	C1
M02W215	C3
M02W221	C3
M0321	D3
M0328	D2
M0346	E2
M0371	B3
M0377	C3
M0408	C3
M0412	C3
M0419	D3
M0558	C2
M0567	B4
M0716	C2
M0720	C1
M0721	C1
M0837	C2
M0841	C2
M0847	C2
M0892	B3
M0924	E2
M0936	E2
M0939	C2
M0947	E2

Figure 5-5. Newmark-Hall Median Response Spectra (5% Critical Damping).



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Figure 5-6. Plutonium Finishing Plant Buildings Floor Plan.
(Sheet 1 of 5)
(Ref. Dwg. H-2-80249, Sheets 2-5)

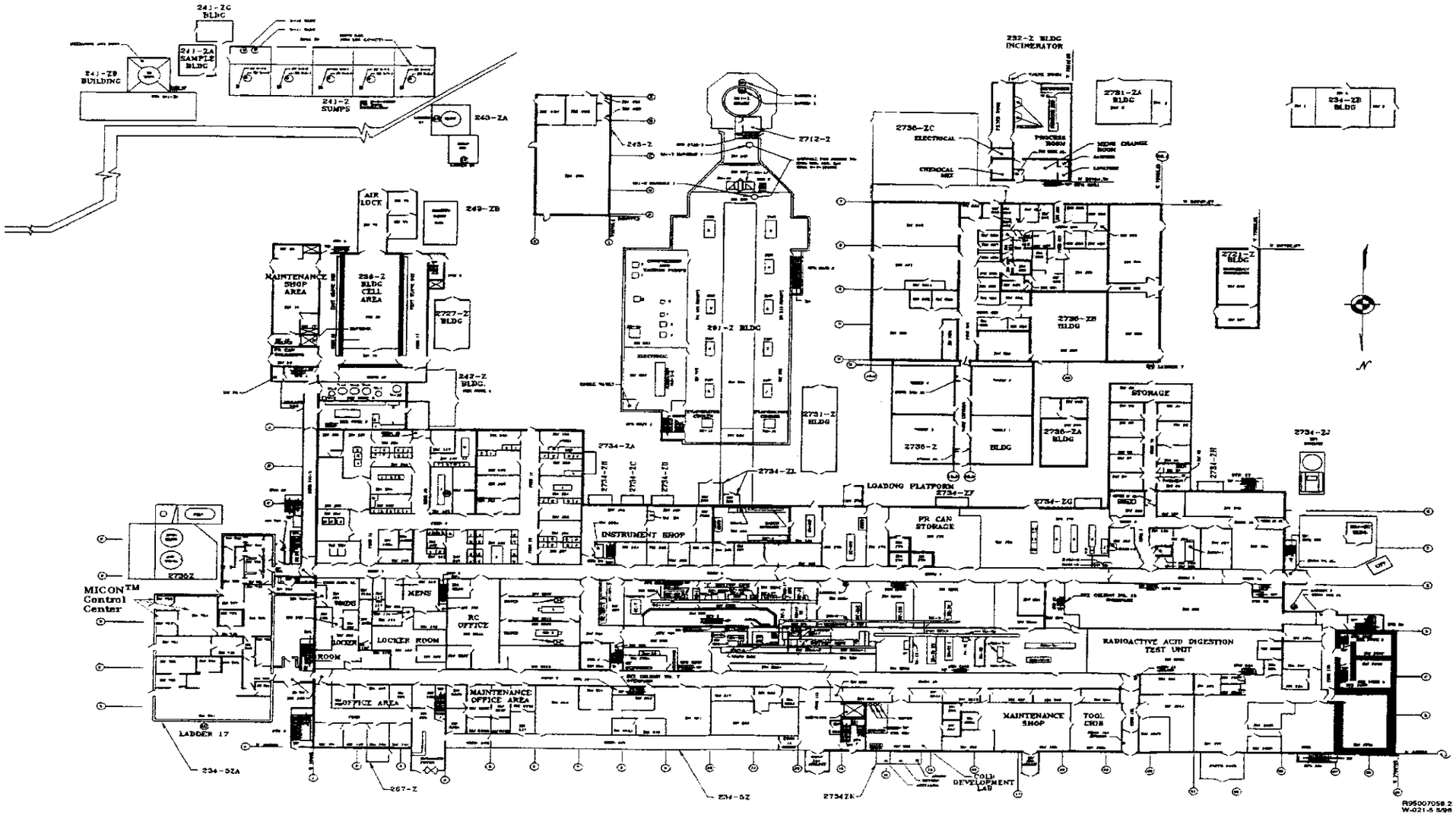


Figure 5-6. Plutonium Finishing Plant Buildings Floor Plan. (Sheet 2 of 5)

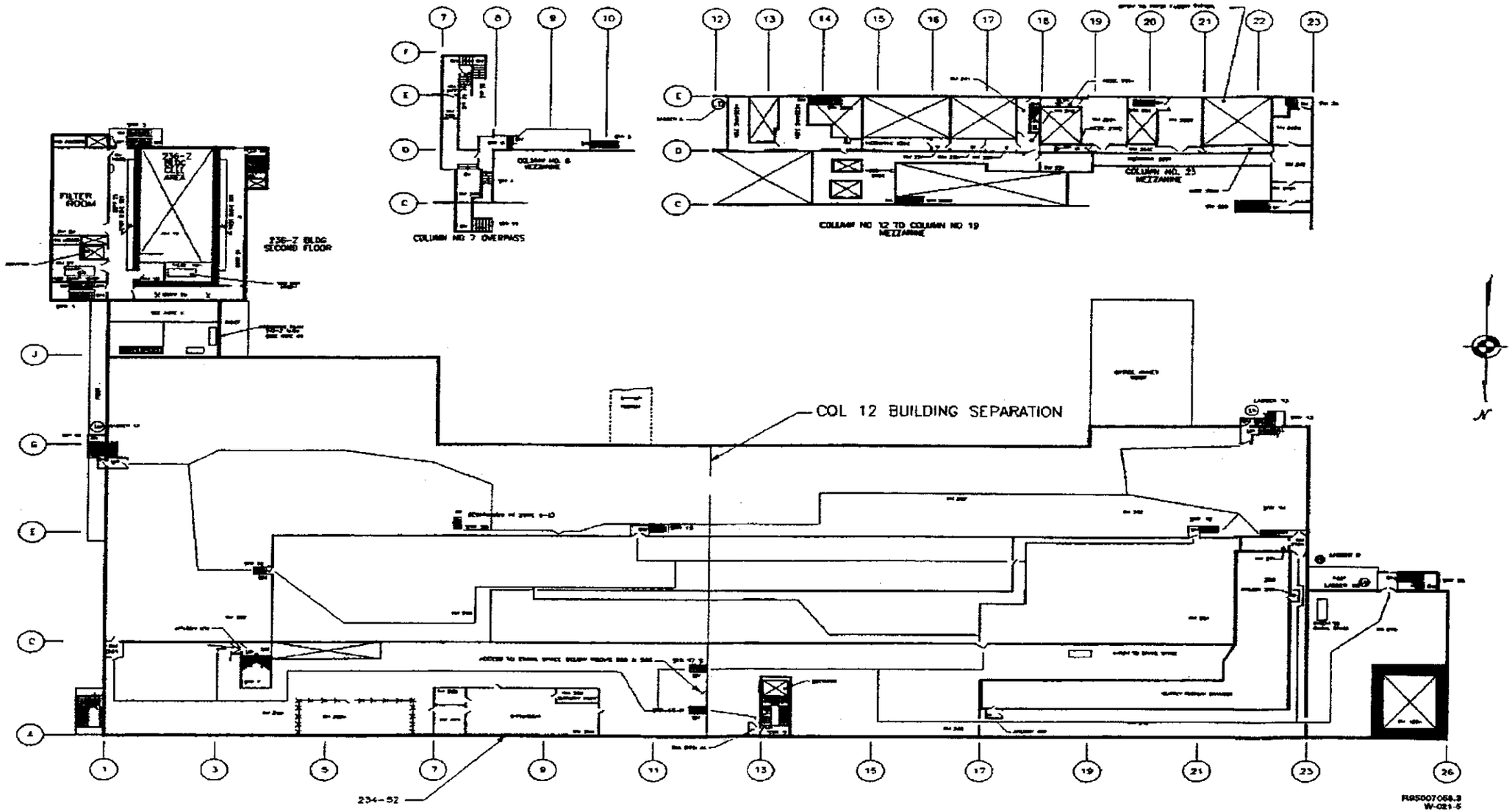


Figure 5-6. Plutonium Finishing Plant Buildings Floor Plan. (Sheet 3 of 5)

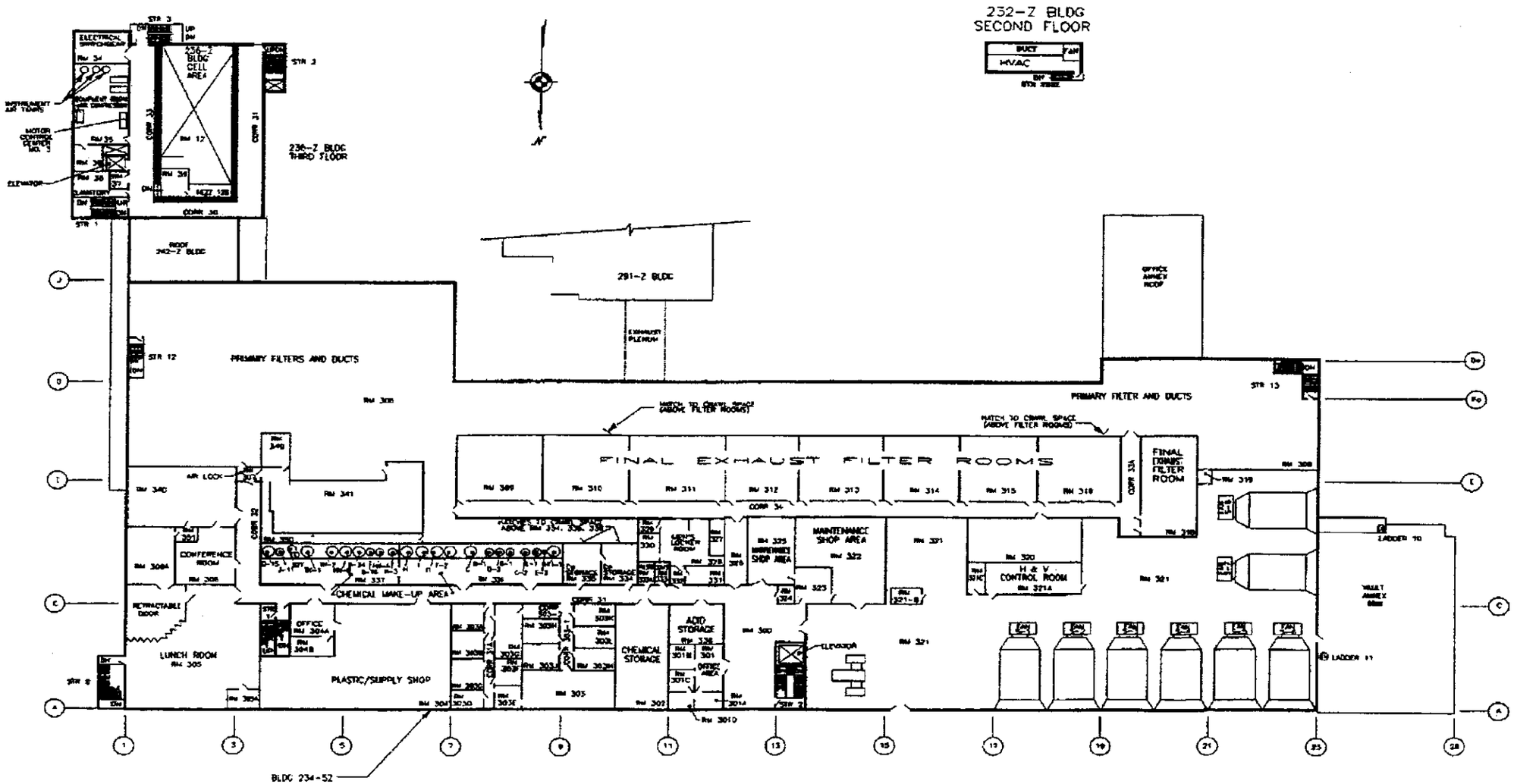


Figure 5-6. Plutonium Finishing Plant
Buildings Floor Plan.
(Sheet 4 of 5)

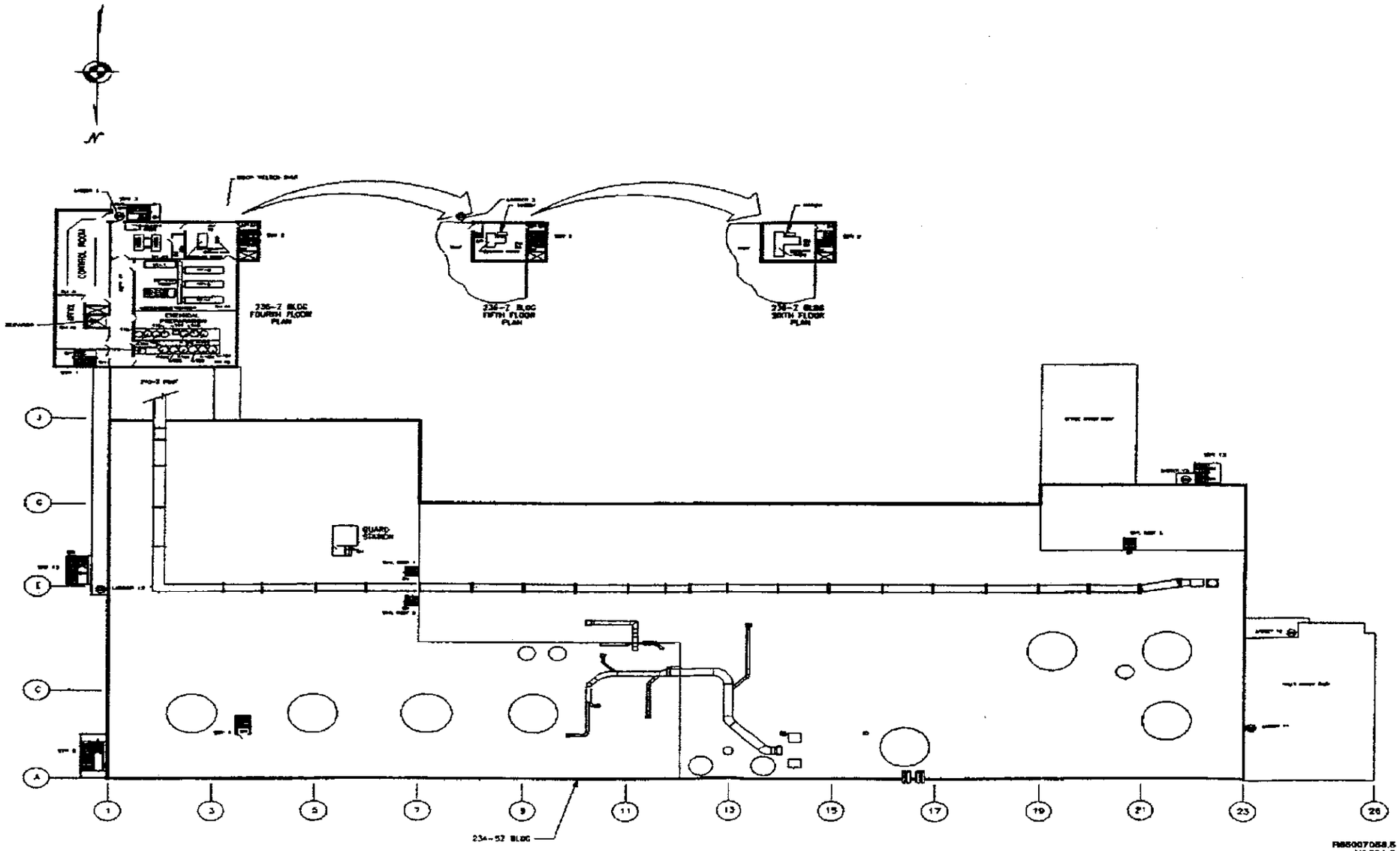
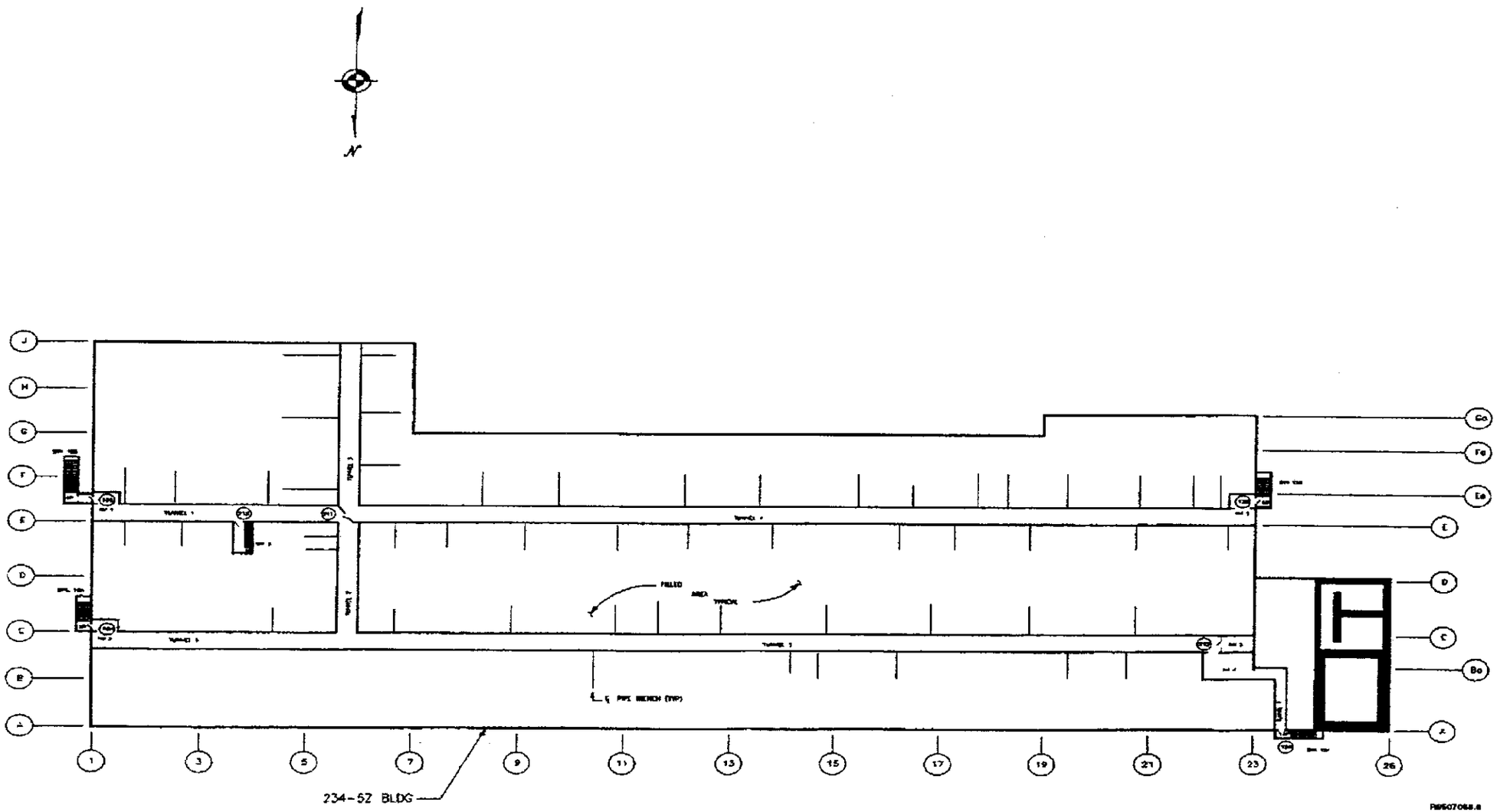
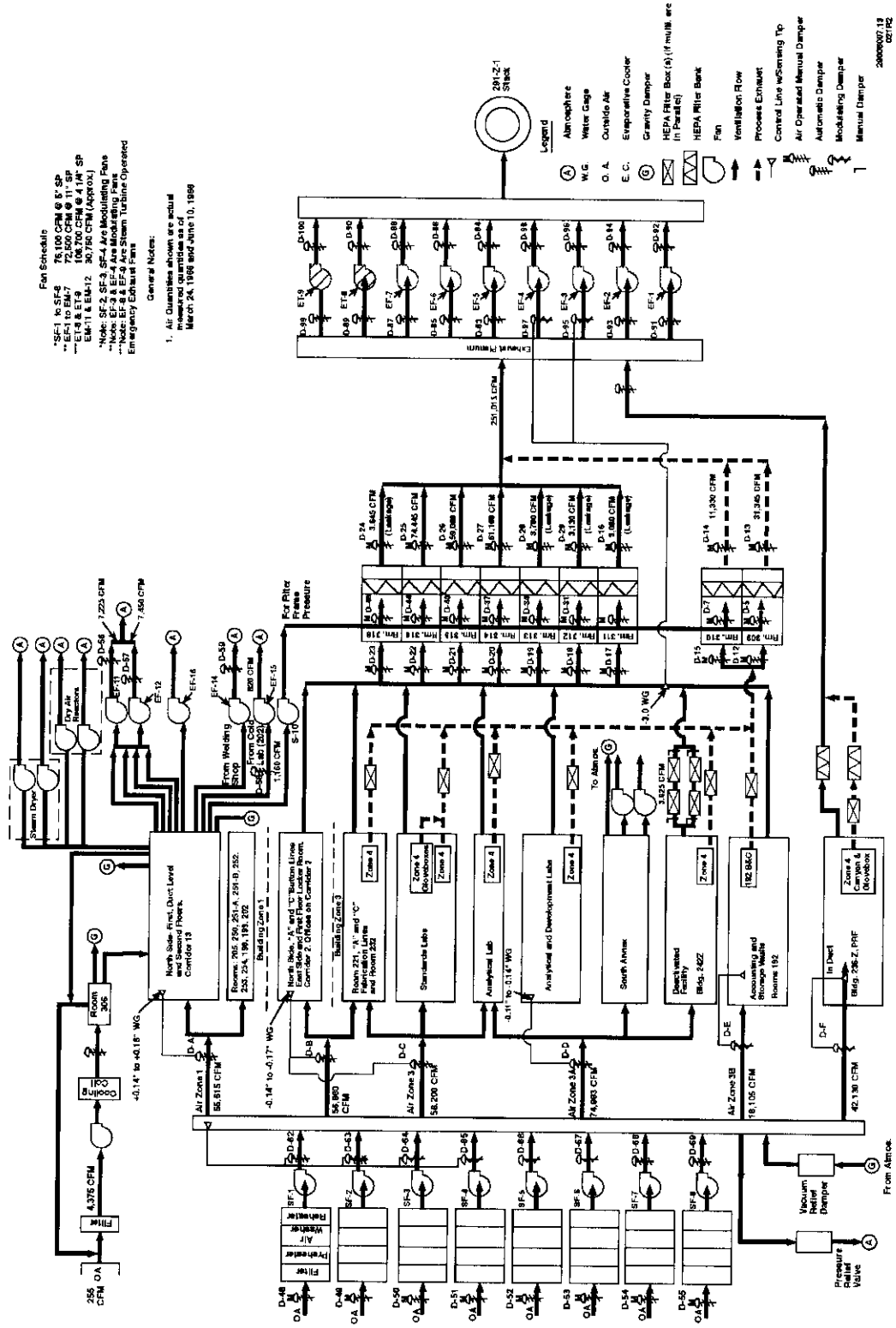


Figure 5-6. Plutonium Finishing Plant
Buildings Floor Plan.
(Sheet 5 of 5)



FOUNDATION AND TUNNEL PLAN

Figure 5-7. Heating, Ventilating, and Air Conditioning Airflow Diagram, Plutonium Processing Buildings.*



* Steam-driven turbine exhaust fans ET-8 and ET-9 are no longer in service and have been isolated from the steam supply system and the remainder of the facility exhaust system. Figure requires general updating.

Figure 5-8. Aerial View of the Plutonium Finishing Plant with Cutaway View of the 234-5Z Building.

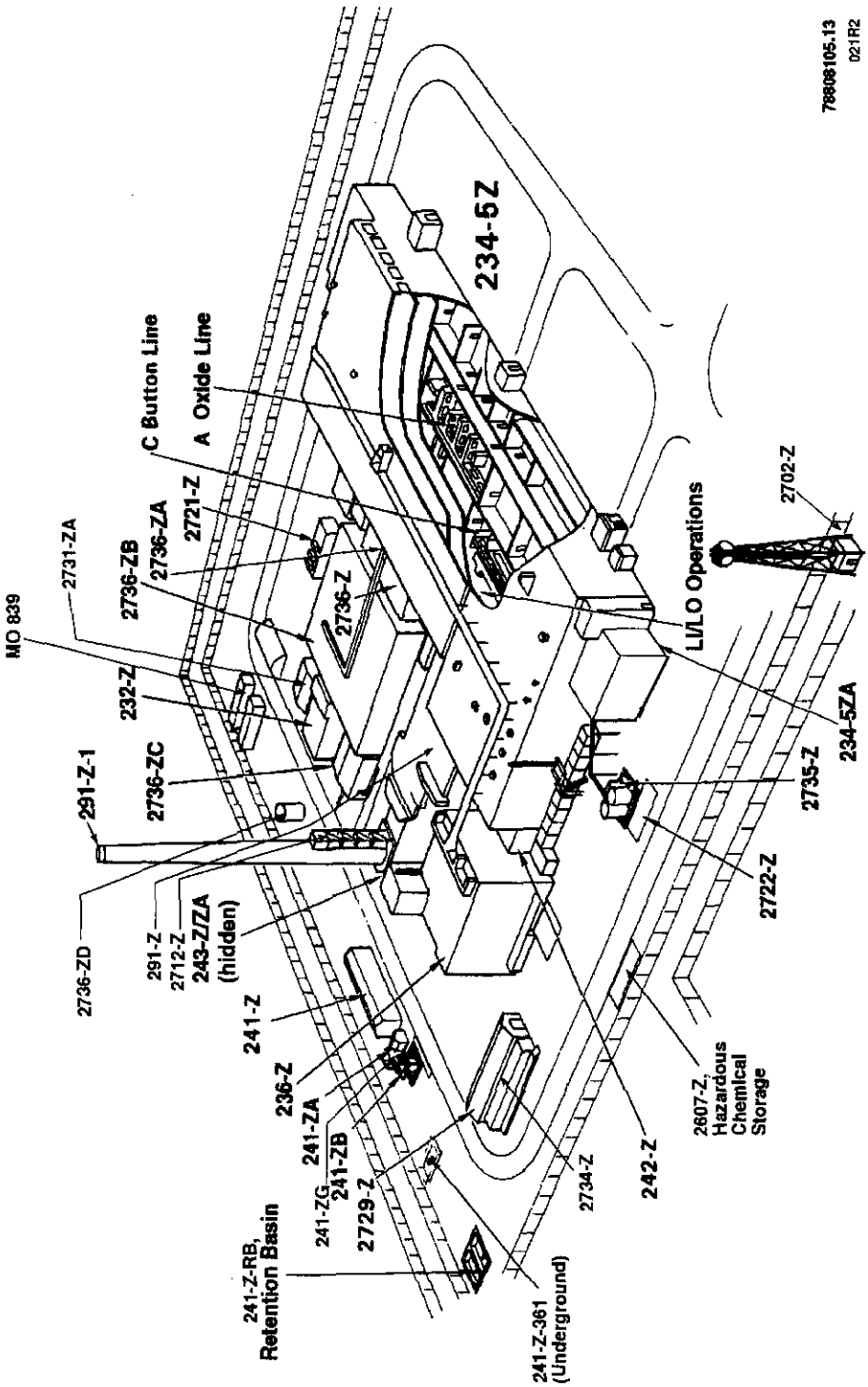


Figure 5-9. Remote Mechanical A and C Line Location.
(Glovebox & control station details incomplete - also see Figure 5-10)

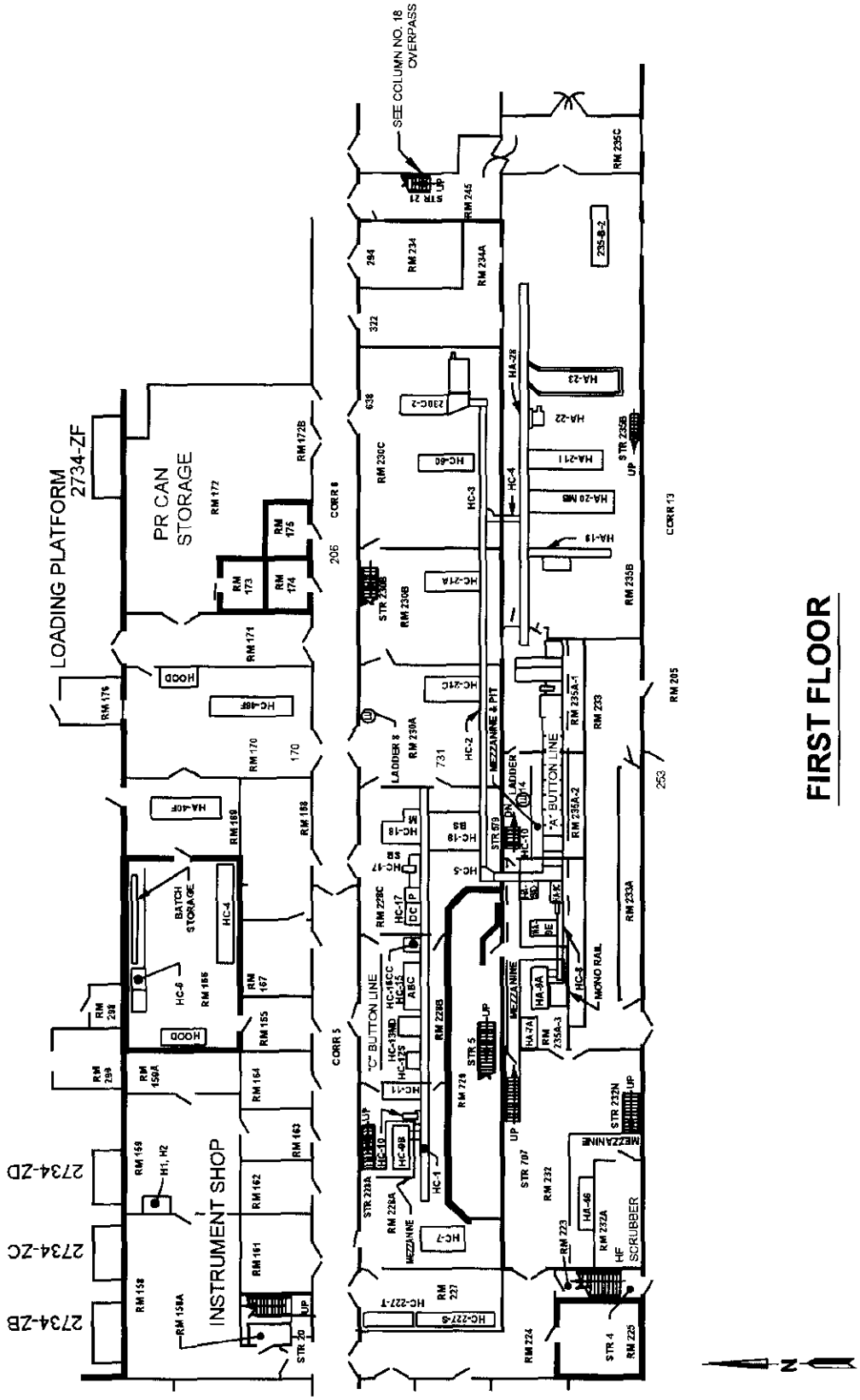
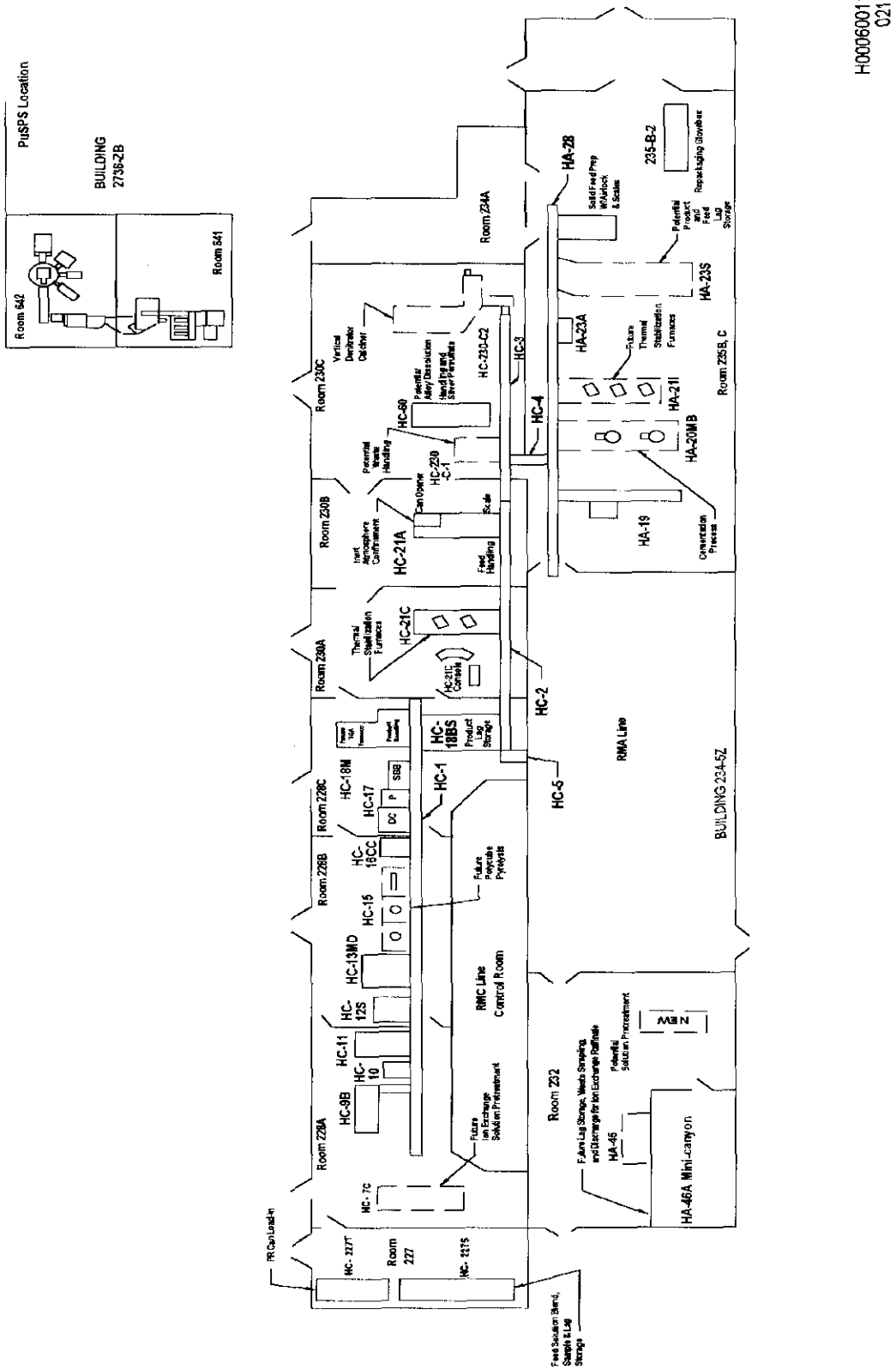


Figure 5-10. Reactive Material Stabilization and Plutonium-Bearing Solution Stabilization Gloveboxes.



H000600116 021R2

Figure 5-11. Not Used

Figure 5-12. Glovebox HA-23S.
(Ref. Dwg. H-2-29010, Sheet 1)

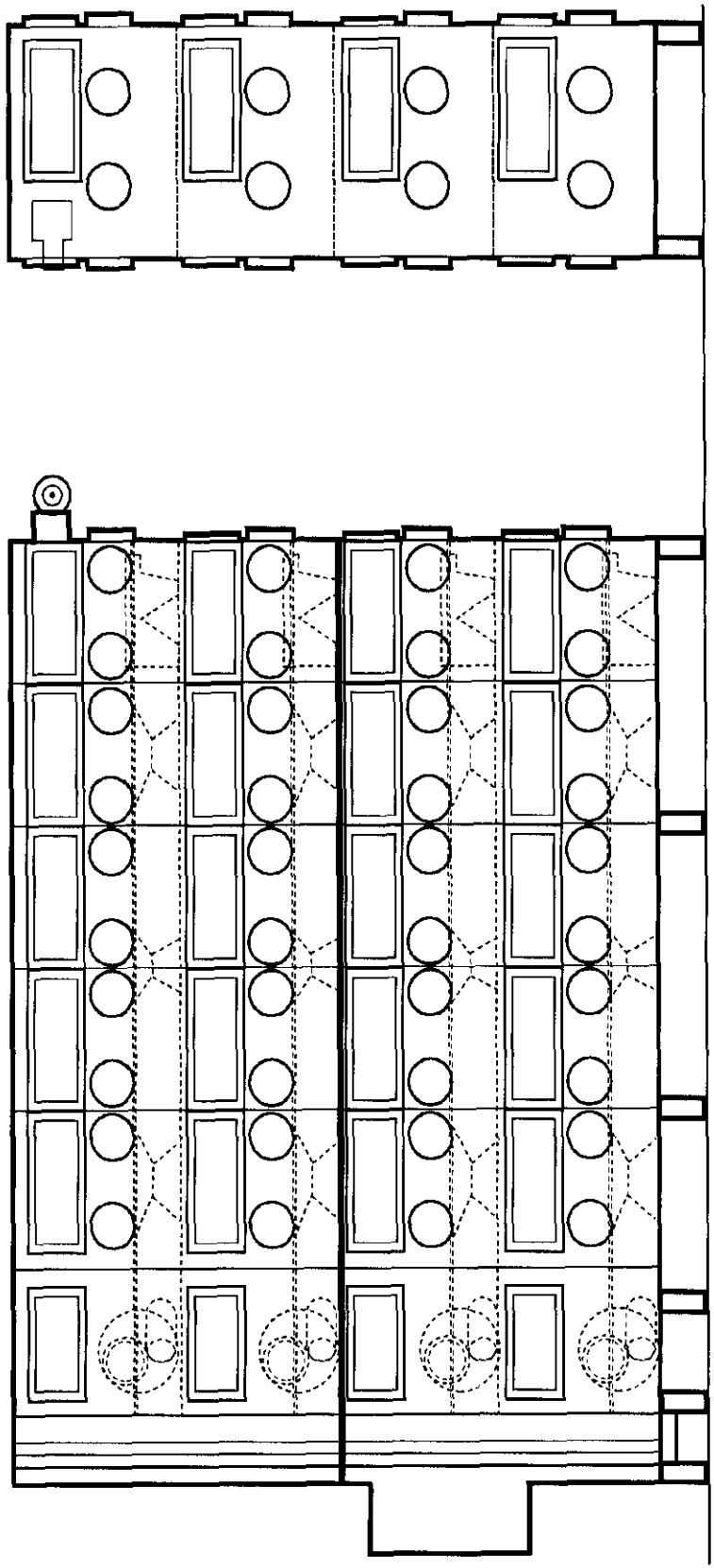
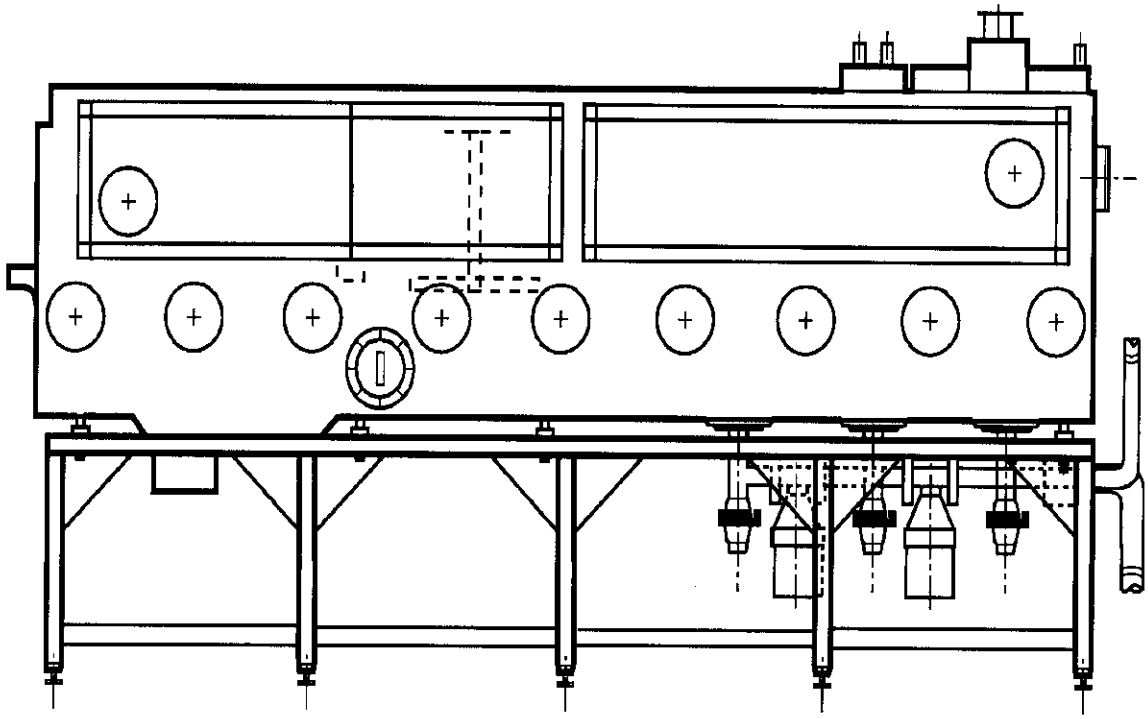


Figure 5-13. Glovebox HA-21I.
(Ref. Dwg. H-2-29109, Sheet 1)



SG96030484.9
021R2

Figure 5-14. Remote Mechanical "C" Line Ventilation.
(needs updating re: FB-9A, FB-9B and FB-9AB)

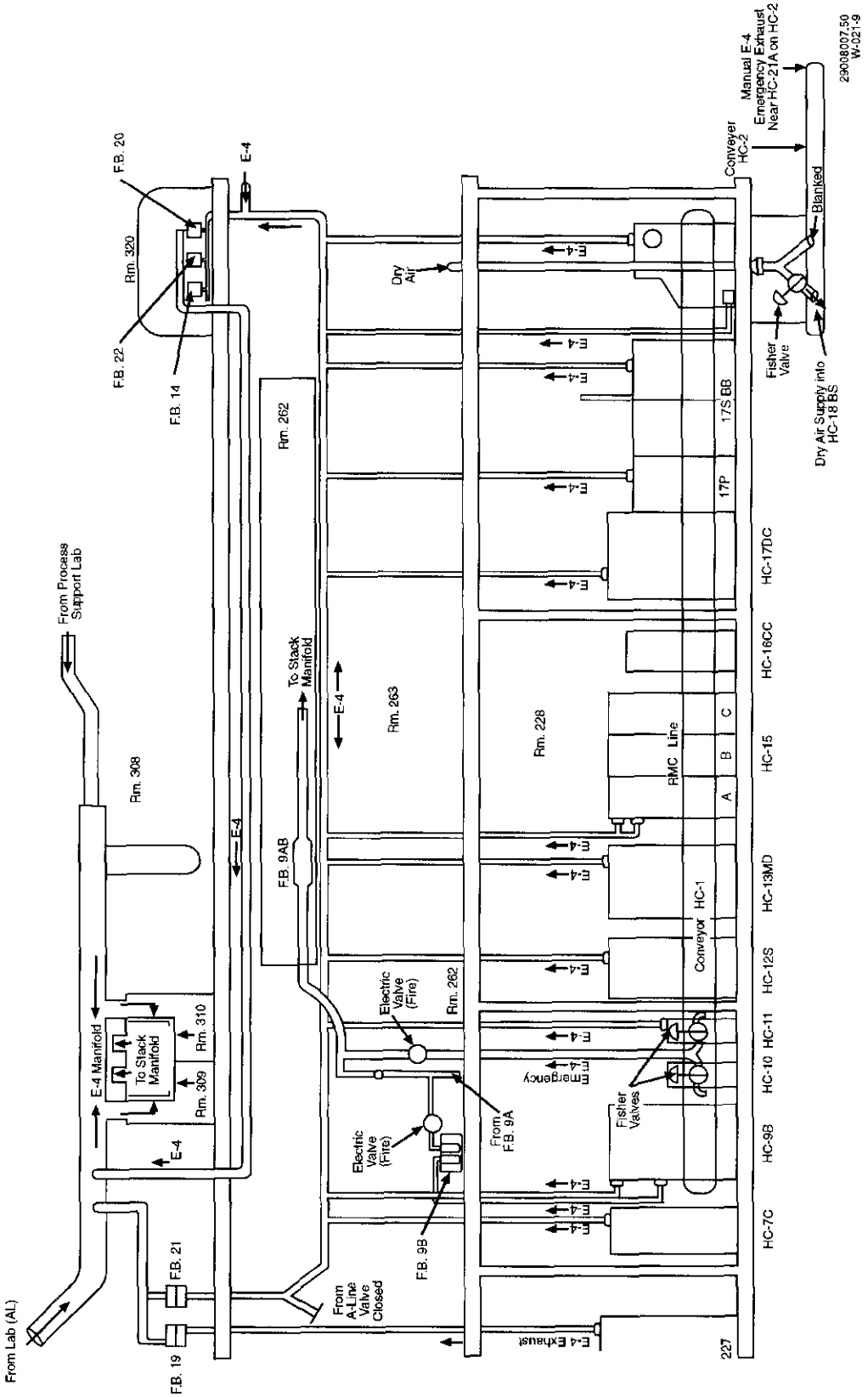


Figure 5-15. Gloveboxes HC-21A & HC-21C.
(Ref. Dwg. H-2-19669, Sheet 3)

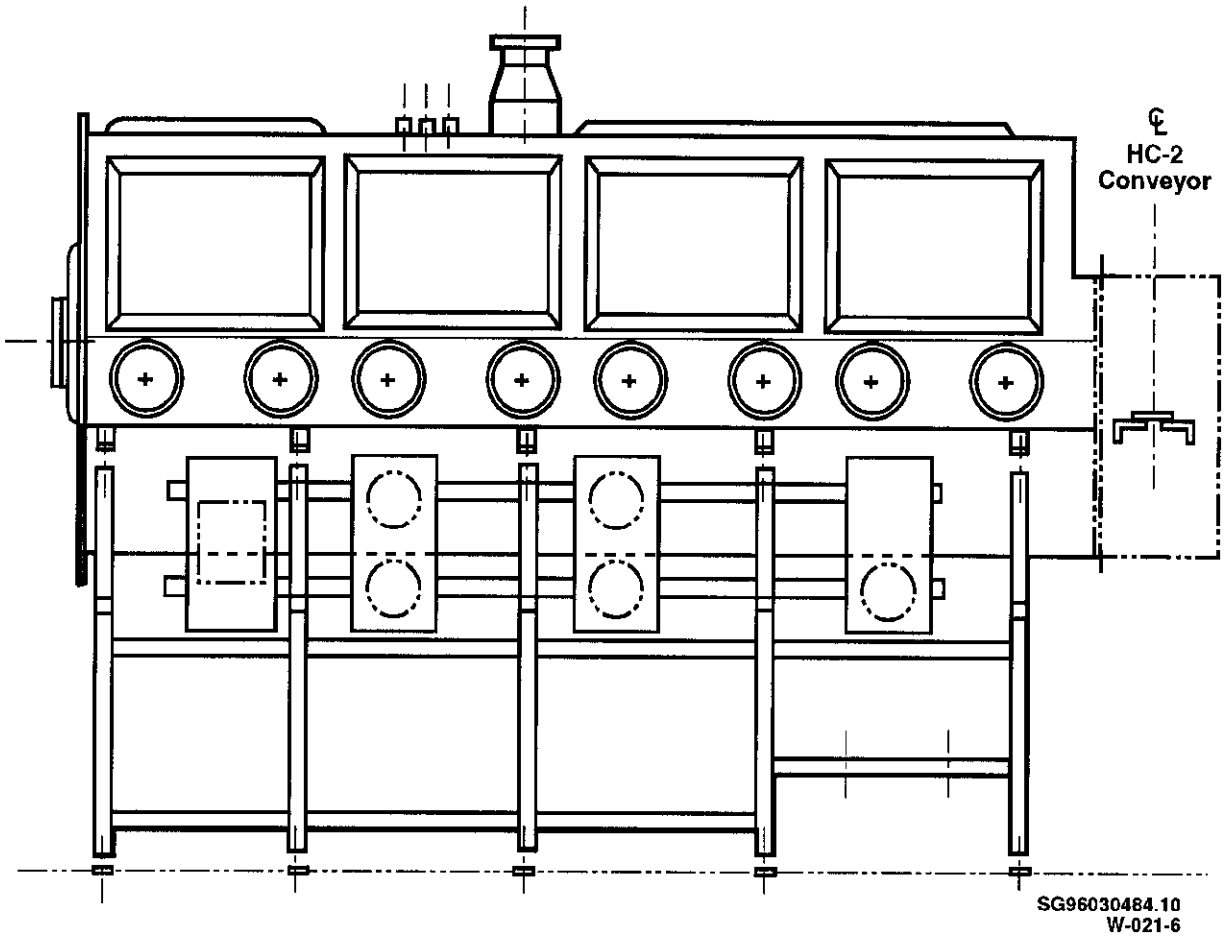


Figure 5-16. Glovebox HC-4 Piping Schematic.
(Sheet 1 of 11)

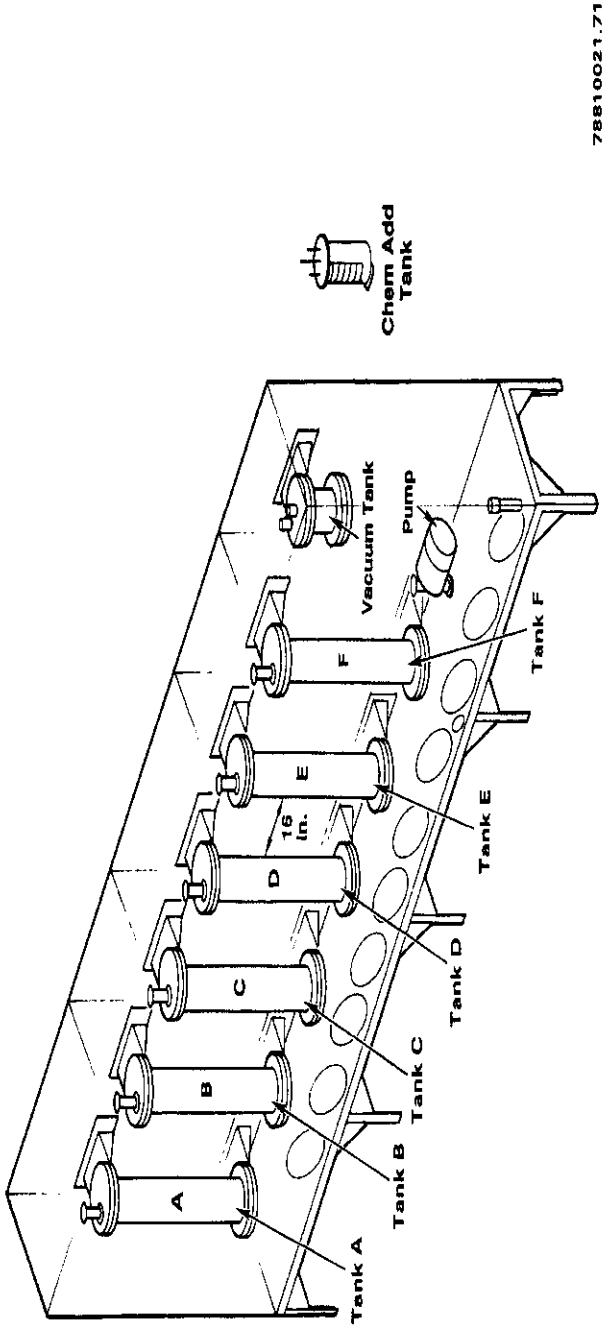


Figure 5-16. Glovebox HC-7 Piping Schematic.
(Sheet 2 of 11)

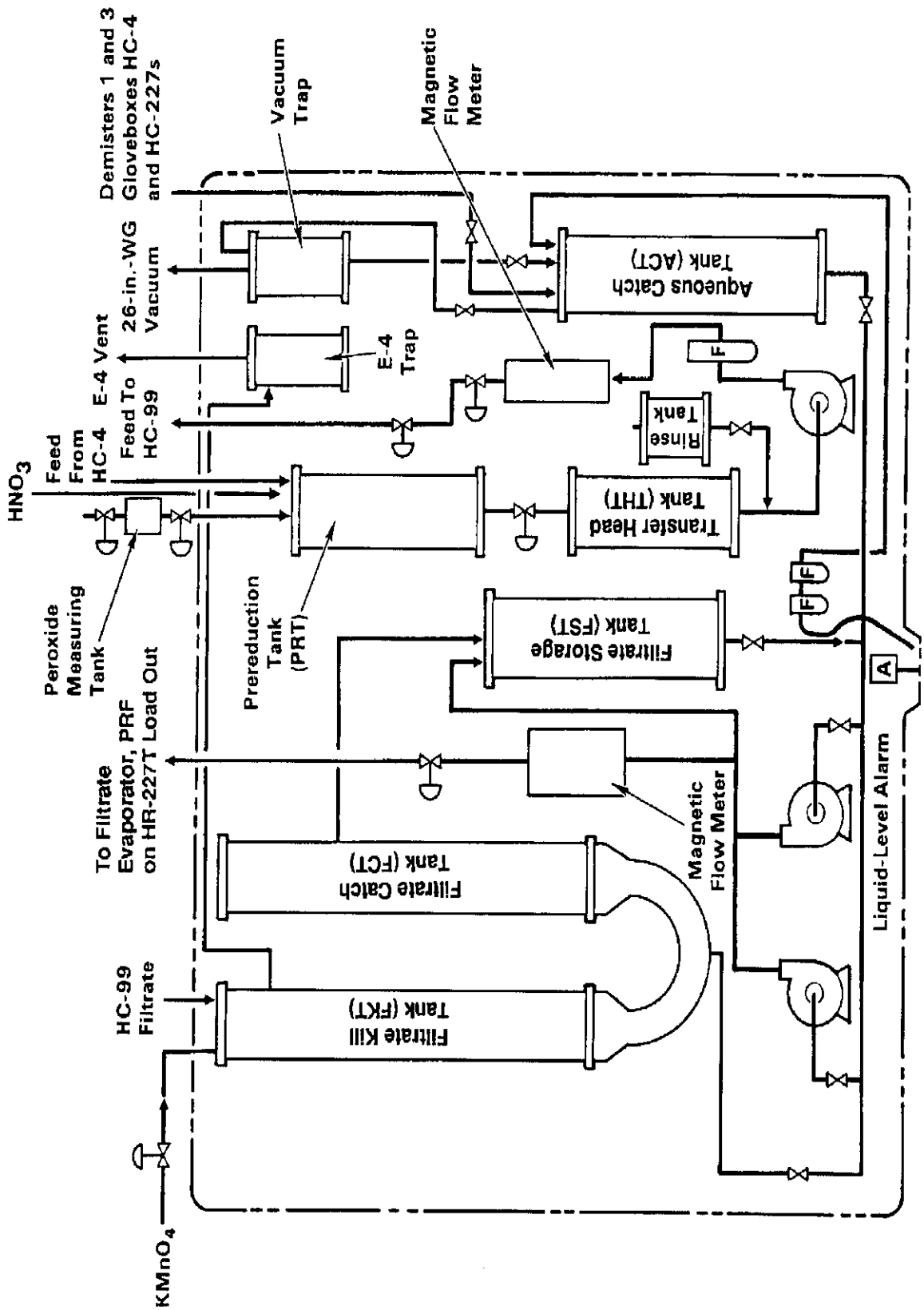


Figure 5-16. Glovebox HC-9B Schematic.
(Sheet 3 of 11)

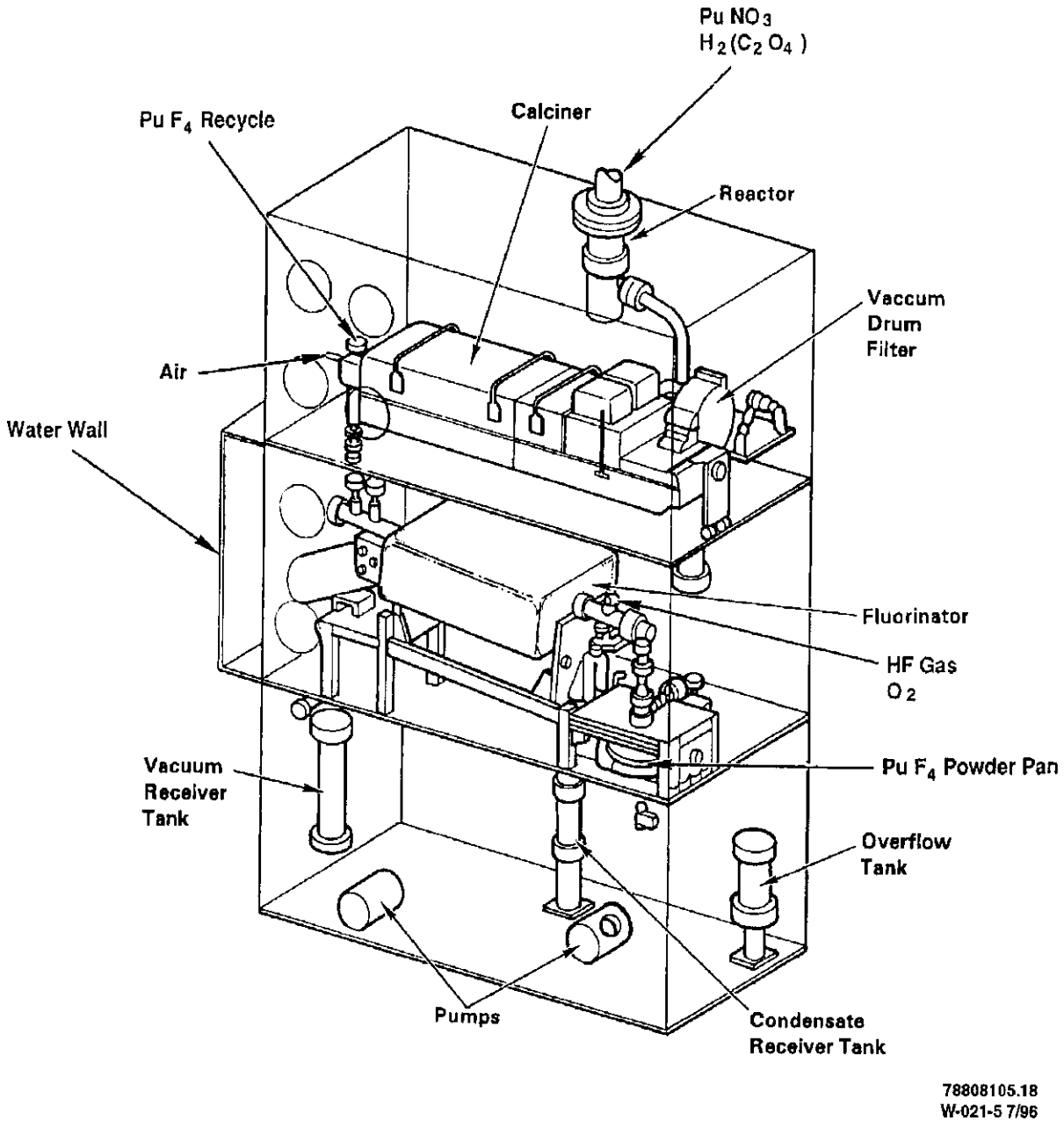


Figure 5-16. HA-46/Cell 46 Piping Schematic.
(Sheet 4 of 11)

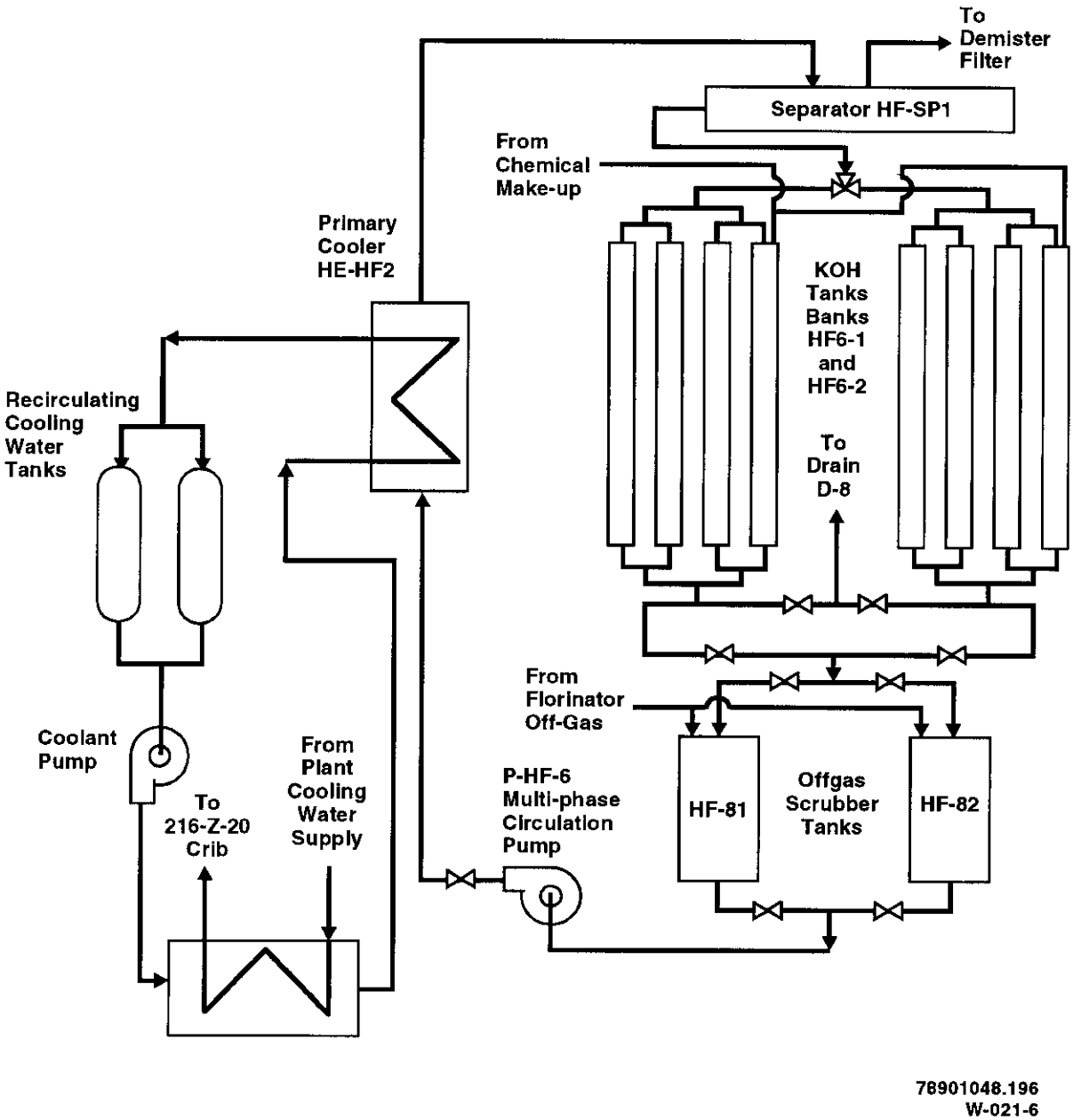


Figure 5-16. Glovebox HC-12S.
(Sheet 5 of 11)

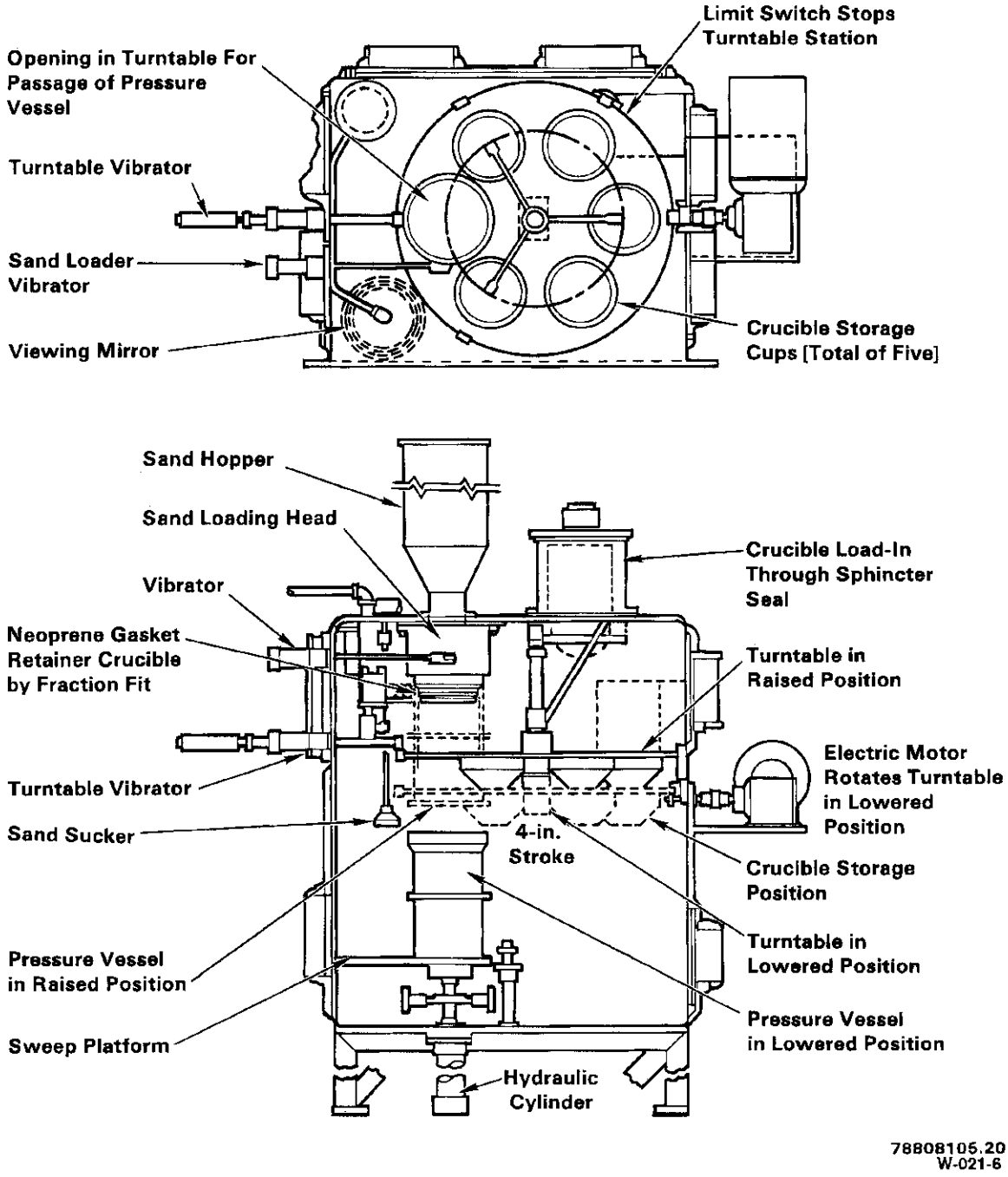


Figure 5-16. Glovebox HC-13MD.
(Sheet 6 of 11)

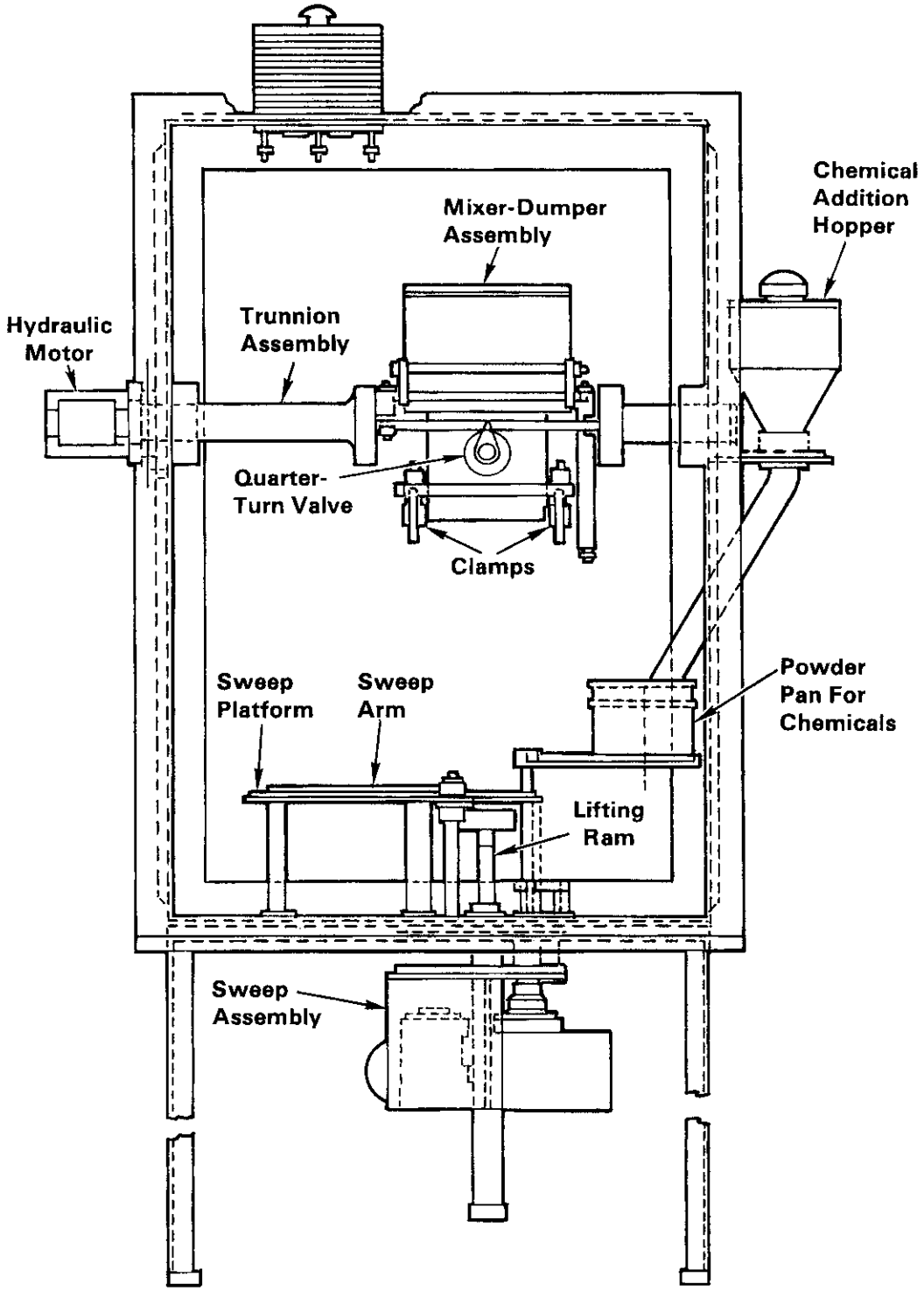


Figure 5-16. Glovebox HC-15.
(Sheet 7 of 11)

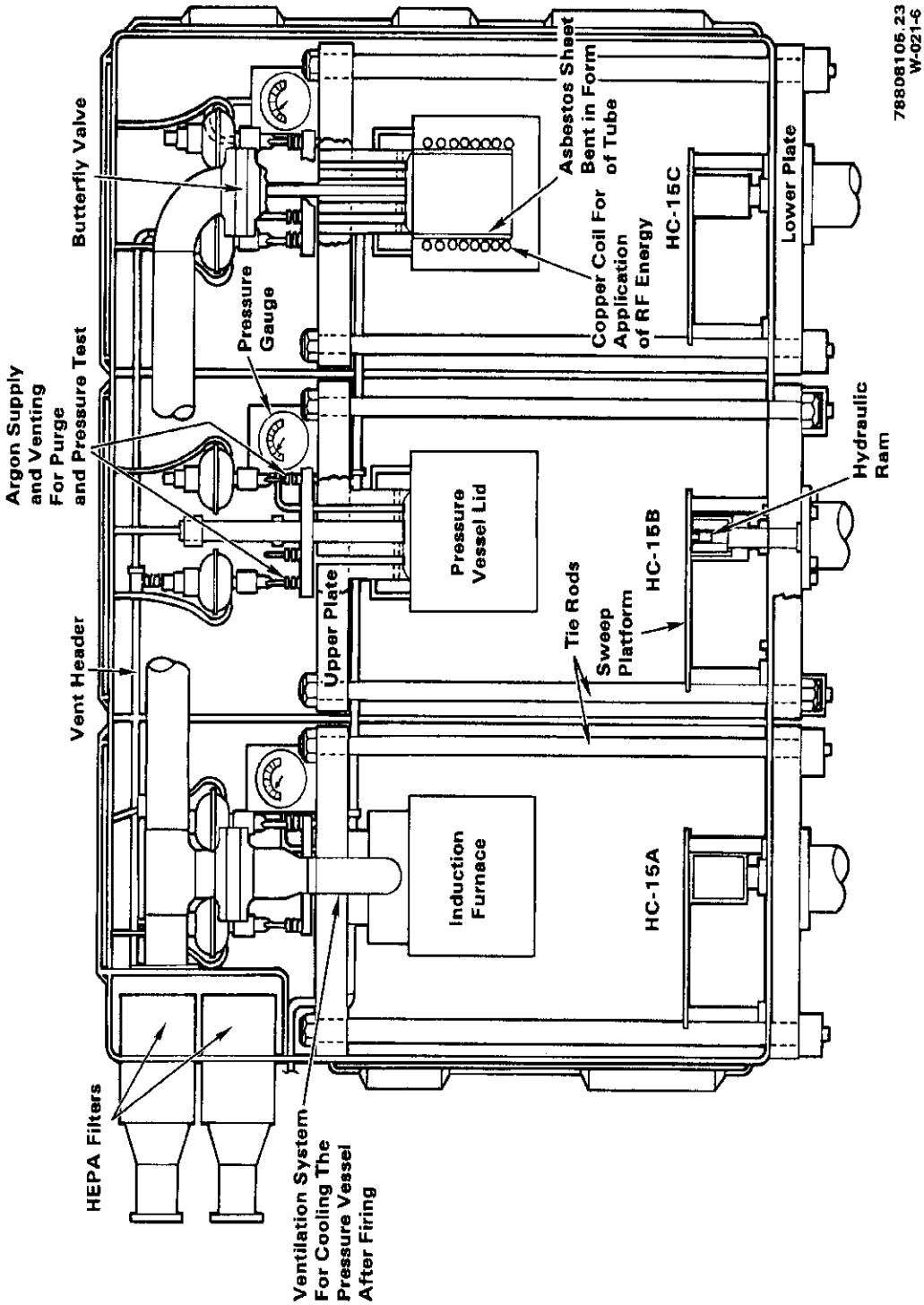


Figure 5-16. Glovebox HC-16CC.
(Sheet 8 of 11)

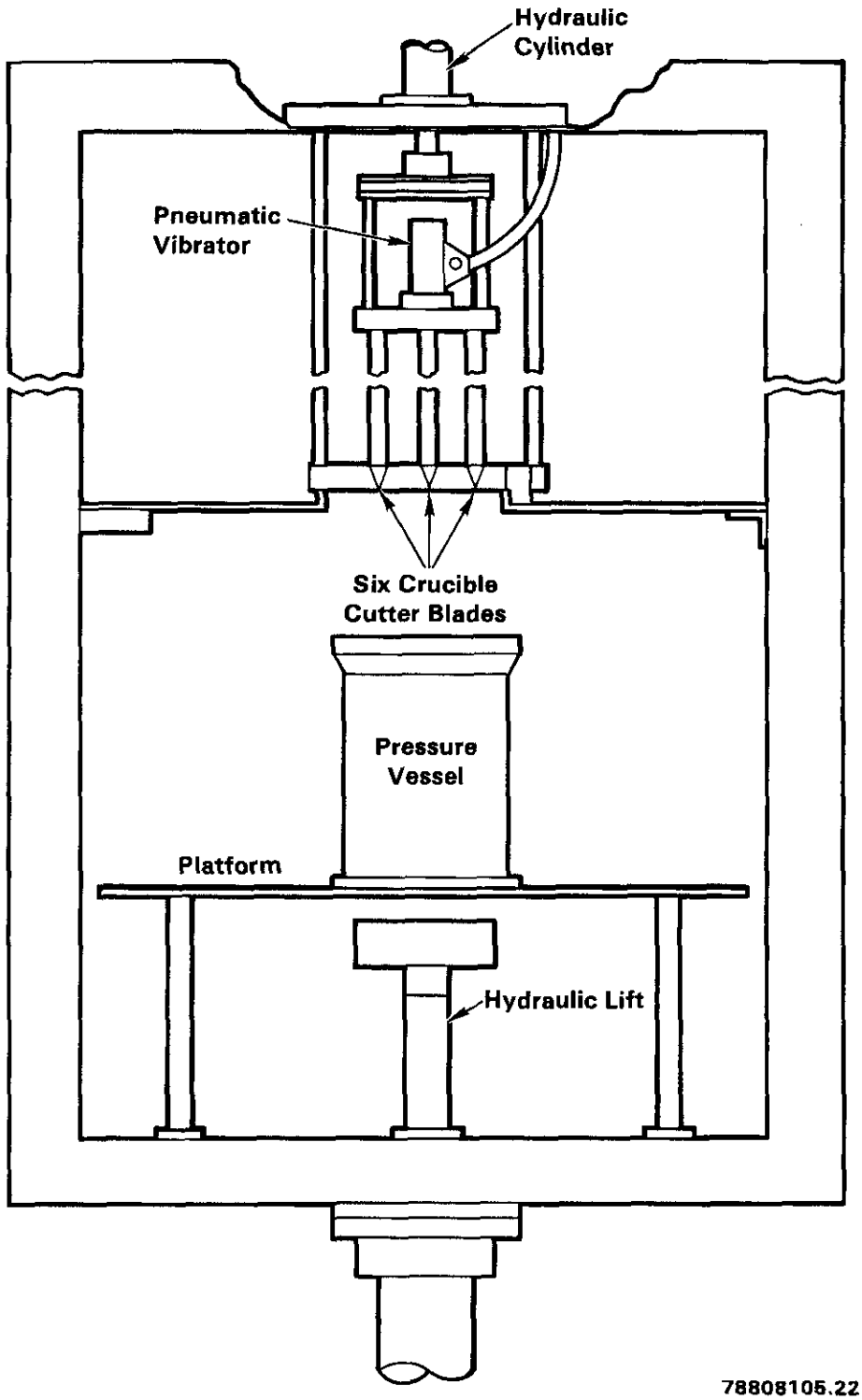


Figure 5-16. Glovebox HC-17DC.
(Sheet 9 of 11)

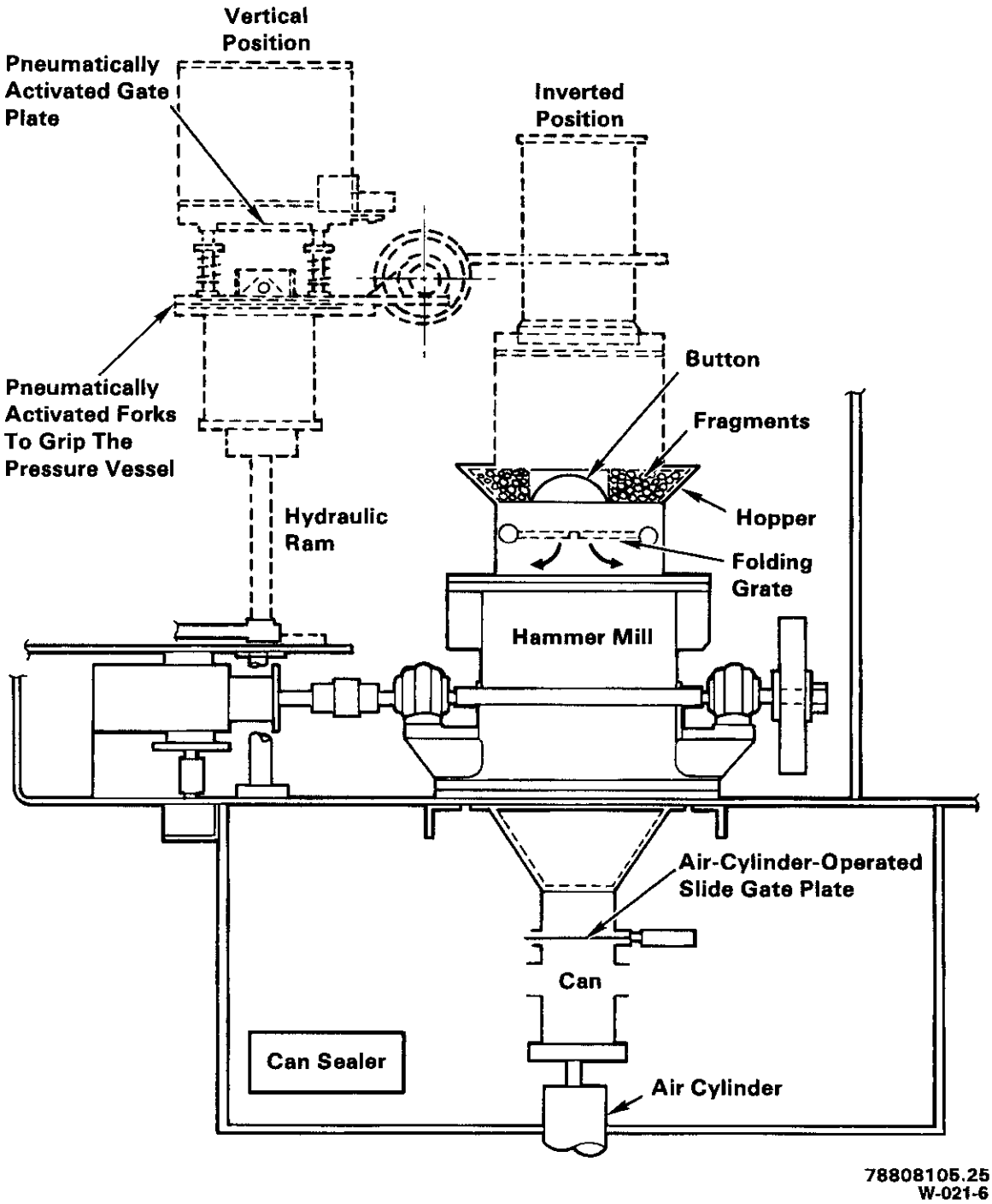


Figure 5-16. Glovebox HC-17P.
(Sheet 10 of 11)

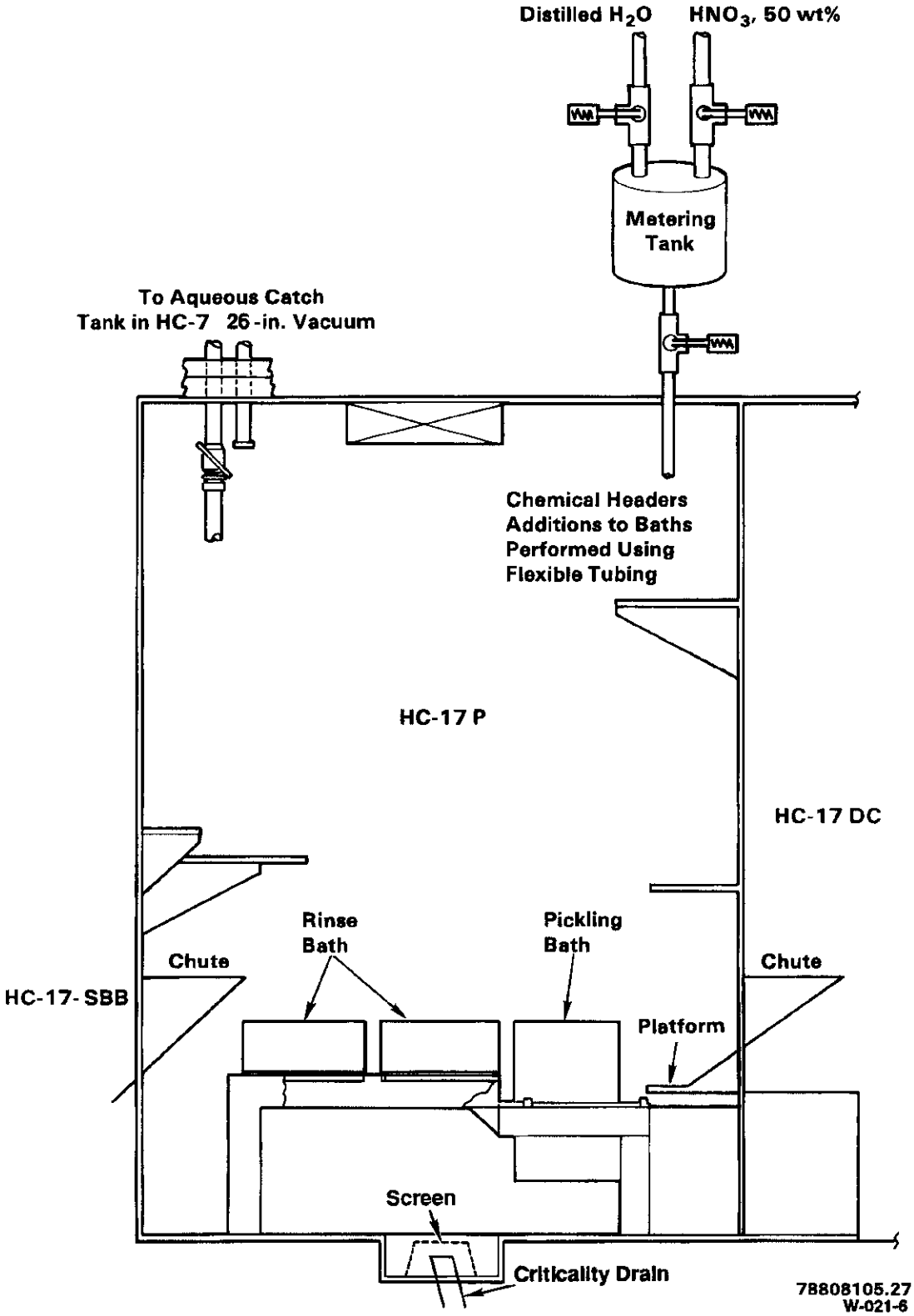


Figure 5-16. Glovebox HC-17SBB.
(Sheet 11 of 11)

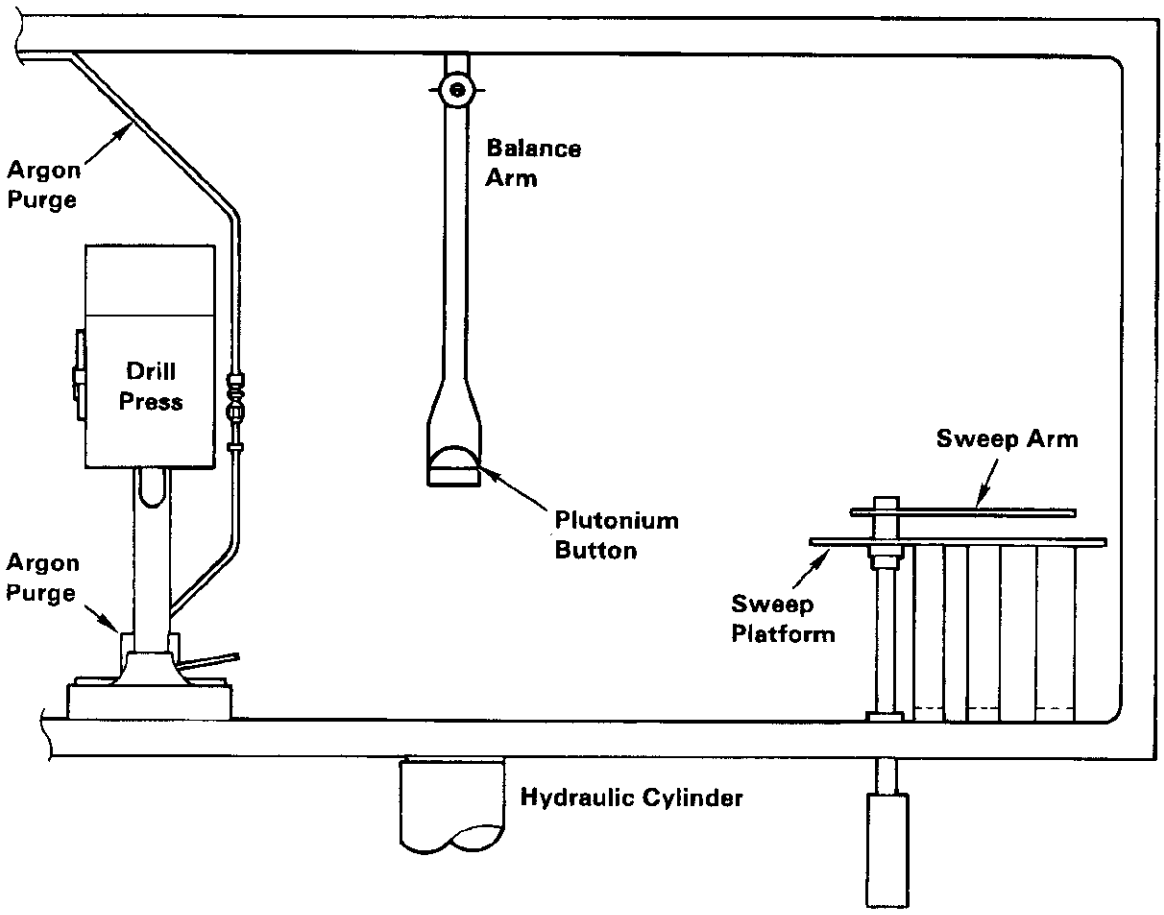


Figure 5-17. Glovebox HC-227S & Hood HC-227T.
(Ref. Dwg. H-2-26100, Sheet 1)

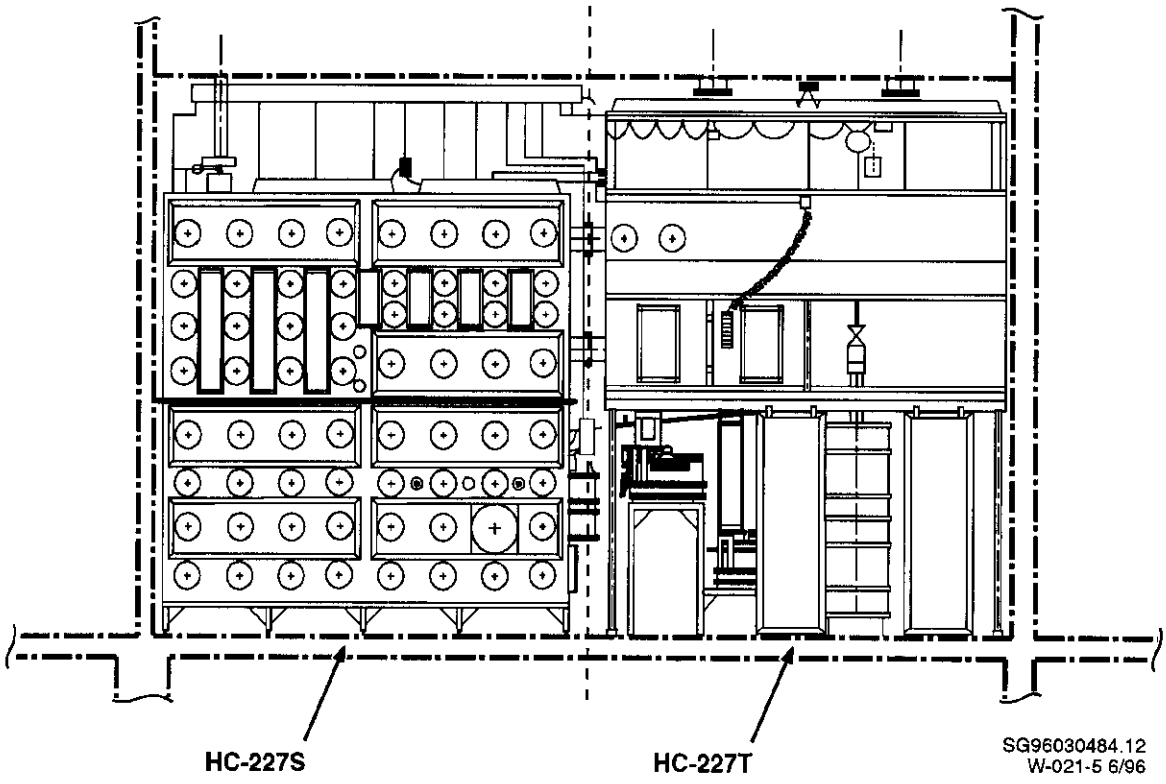


Figure 5-18. Not Used

Figure 5-19. Cross-Sectional Diagram of the Plutonium Finishing Plant Laboratory Prototype Calciner.

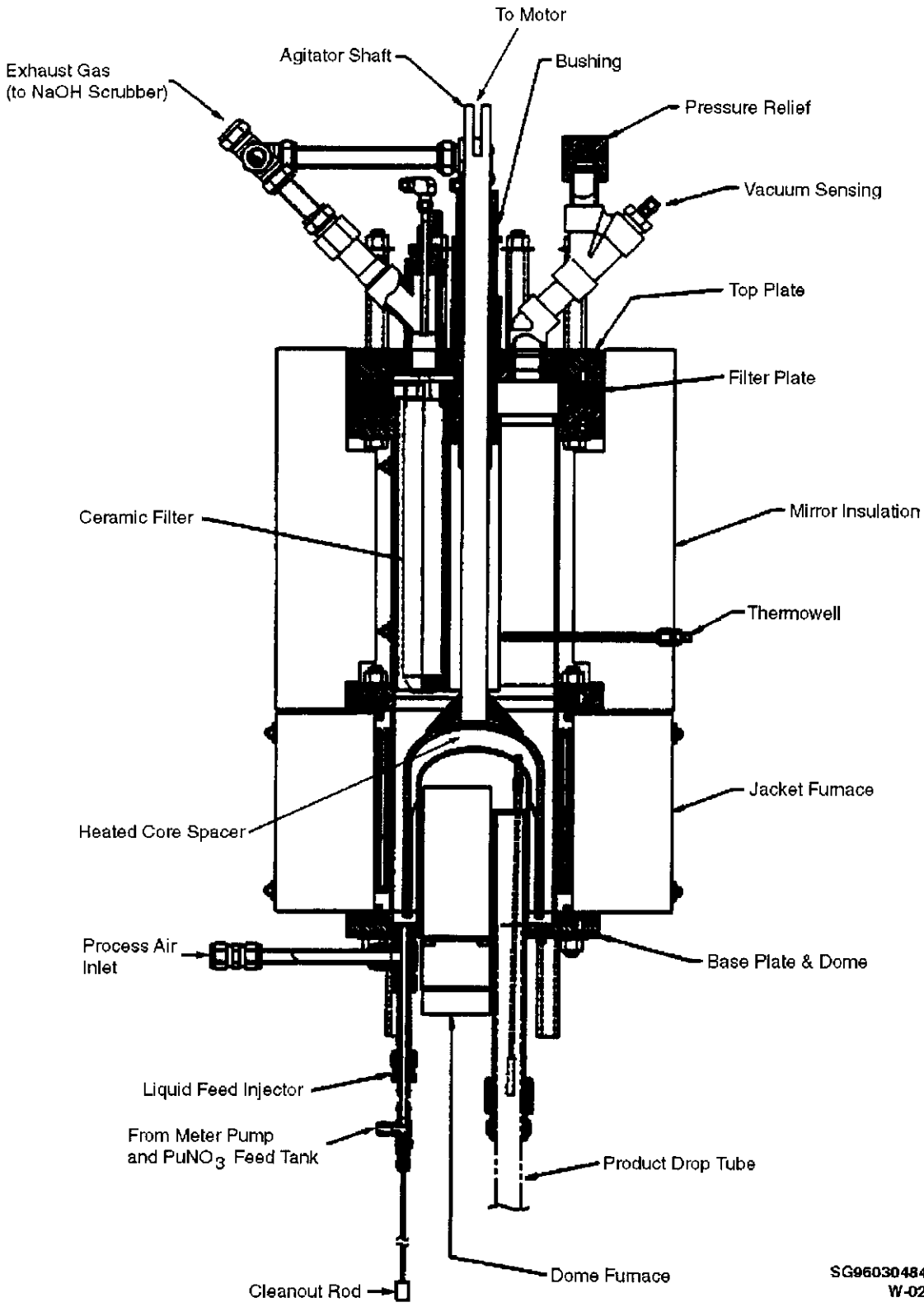


Figure 5-20. Building 234-5Z Chemical Makeup and Chemical Storage Rooms.
(Ref. Dwg. H-2-80249, Sheet 4)

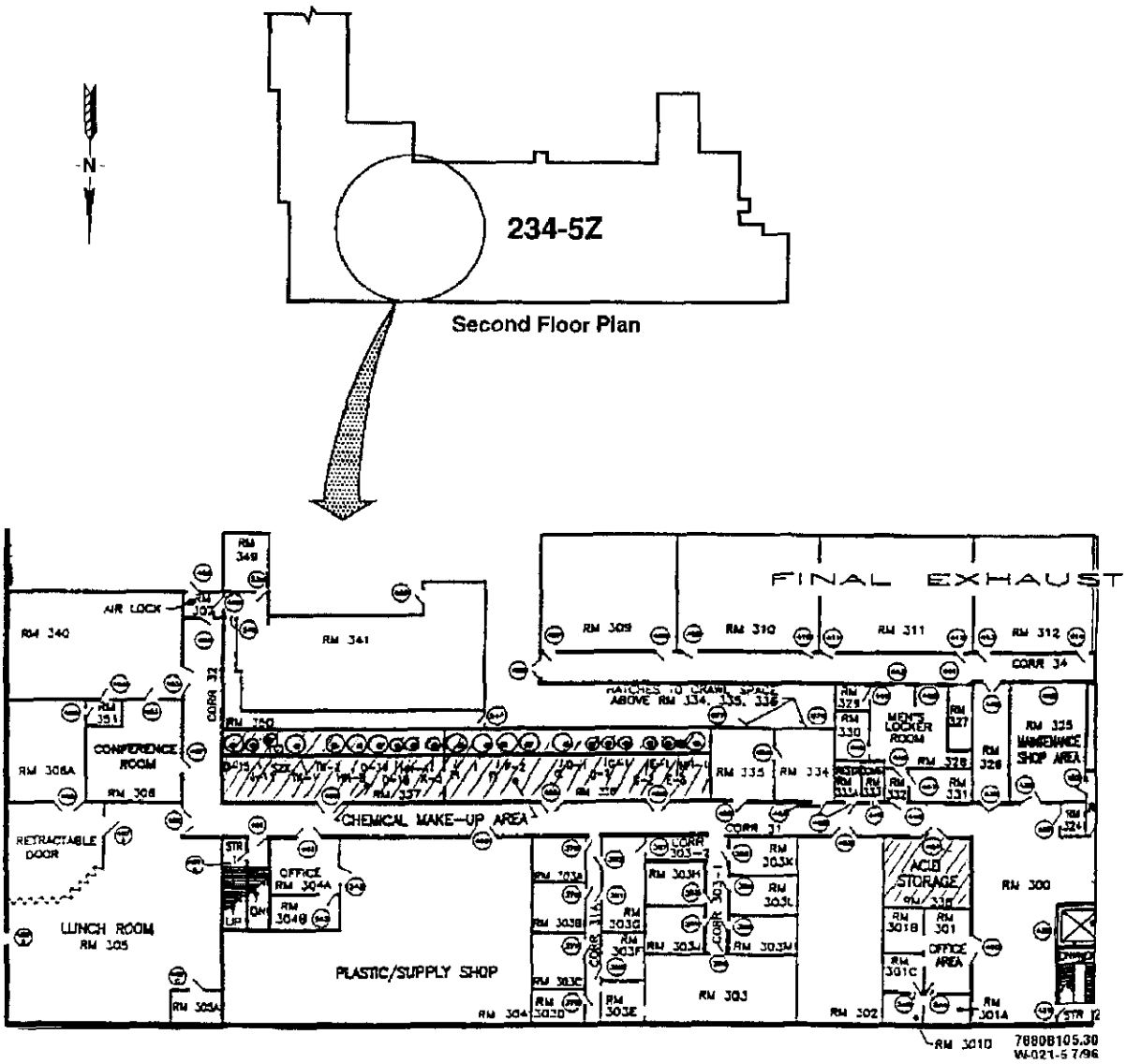


Figure 5-21. Cutaway View of the 236-Z Building.

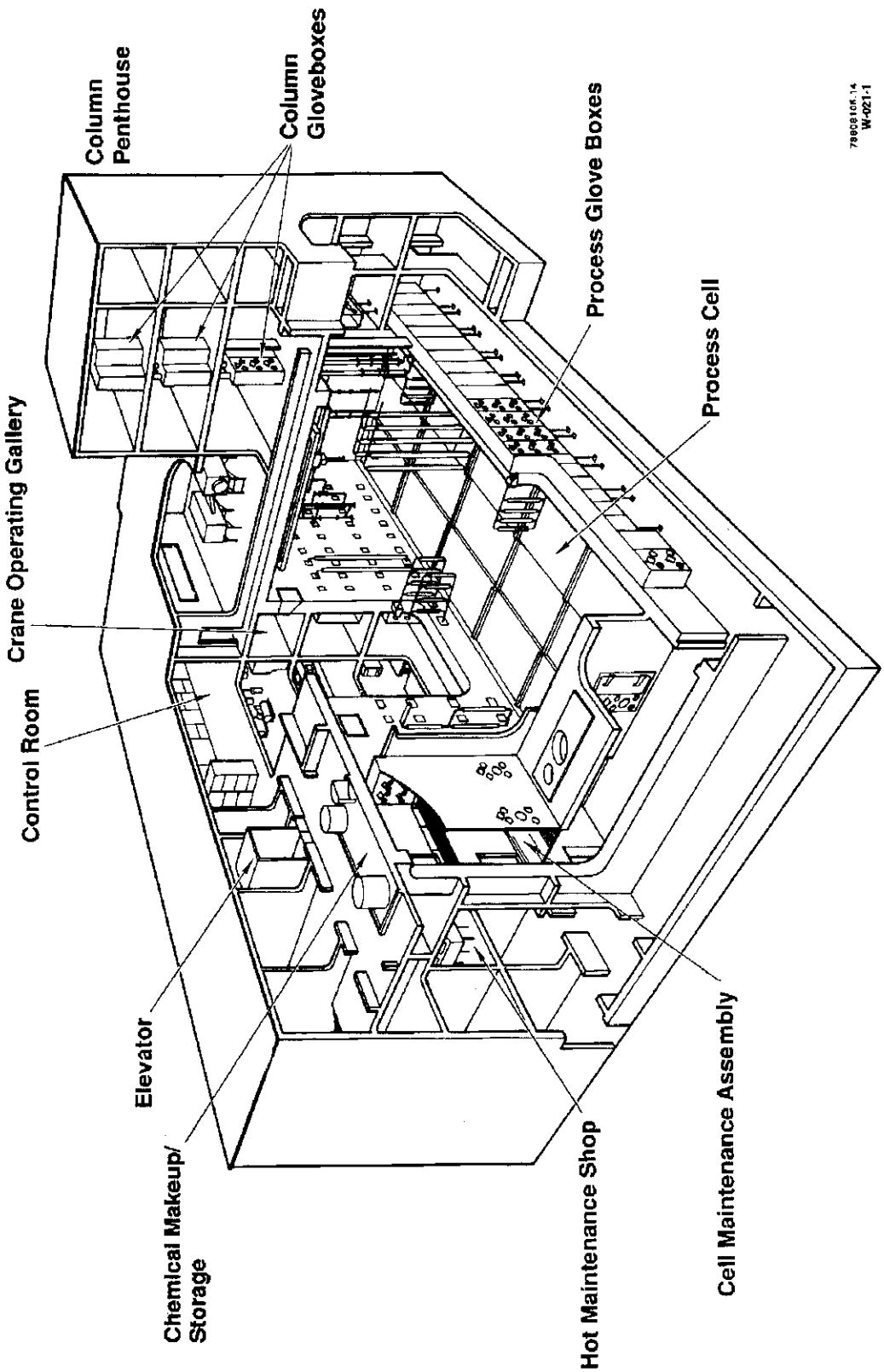
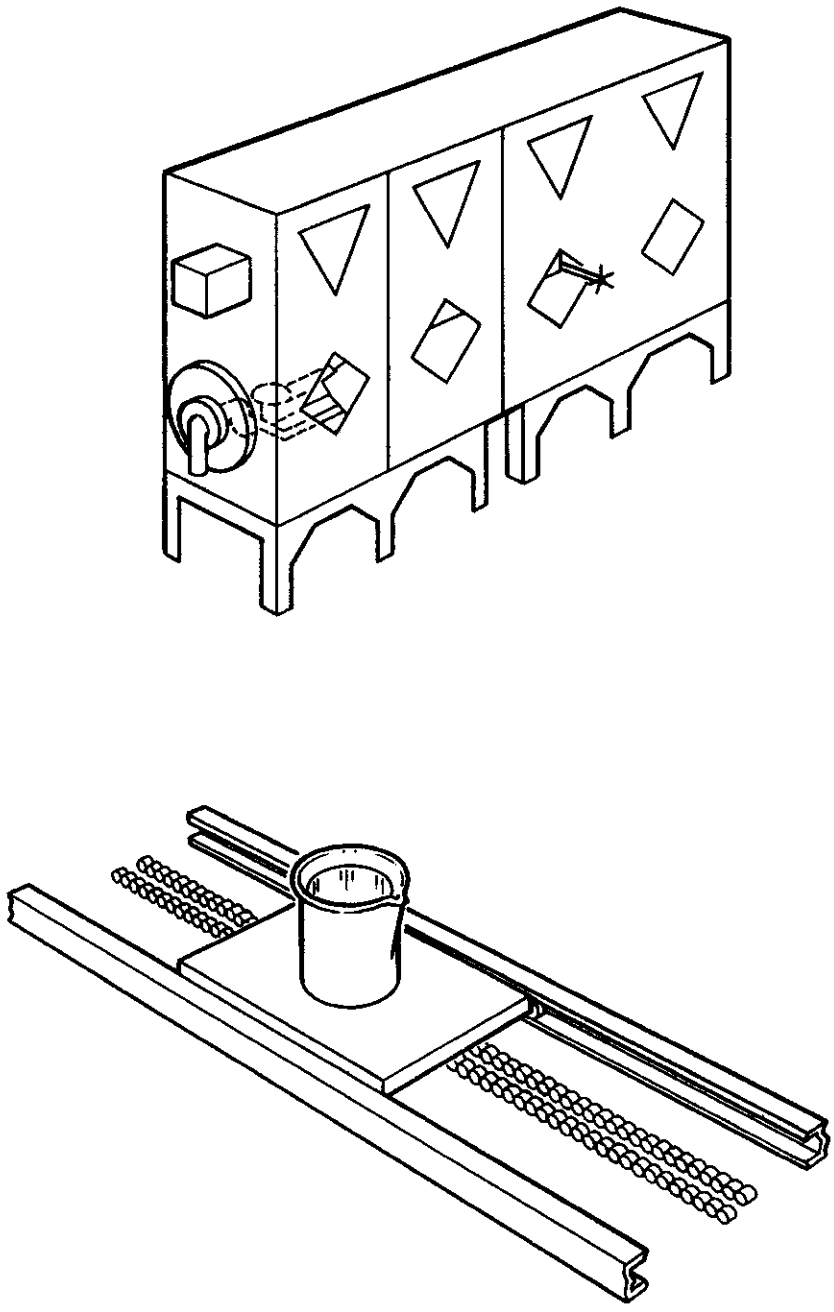


Figure 5-22. Miscellaneous Treatment Glovebox 1 and Hood Conveyor.



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Figure 5-23. Glovebox MT-5 and Process Equipment.
(Sheet 1 of 2)

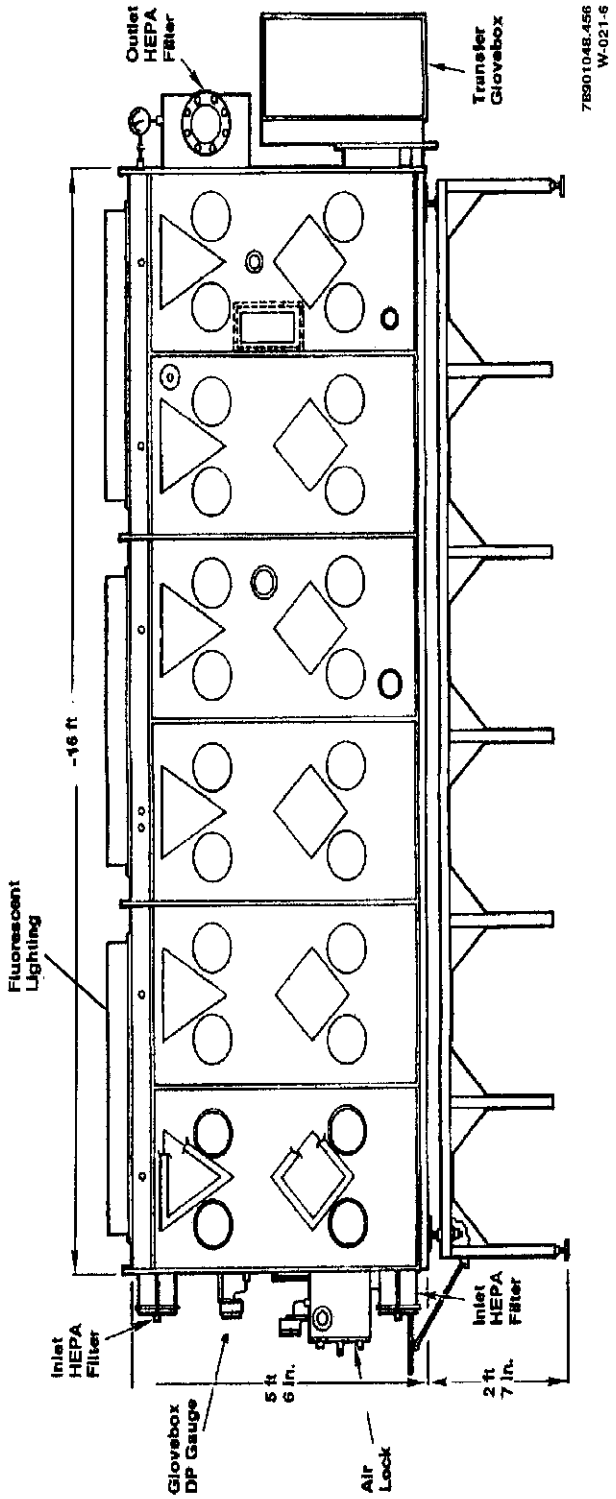
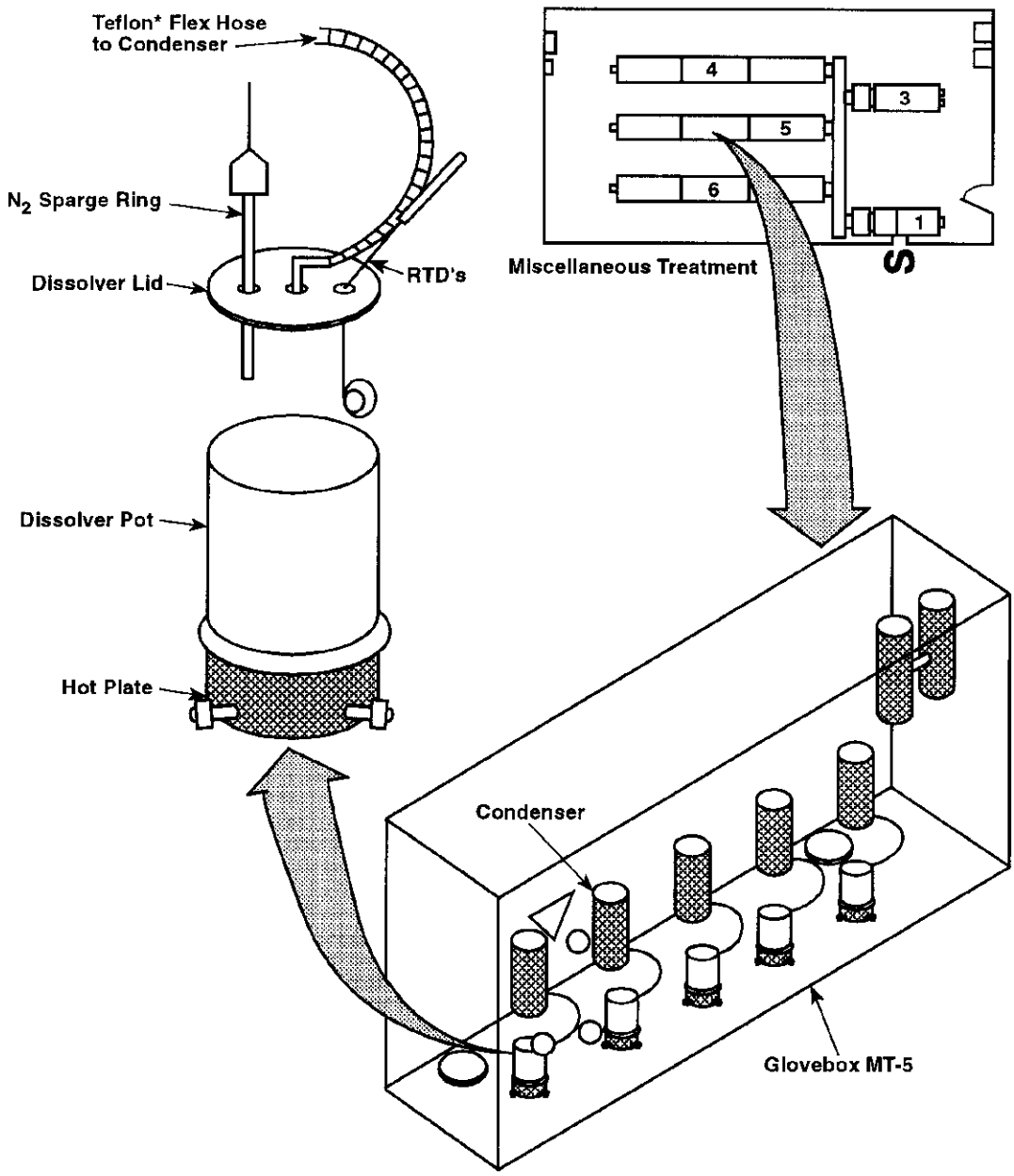


Figure 5-23. Glovebox MT-5 and Process Equipment.
(Sheet 2 of 2)



* Teflon is a trademark of E.I. du Pont de Nemours and Company

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Figure 5-24. Miscellaneous Treatment Glovebox MT-6.

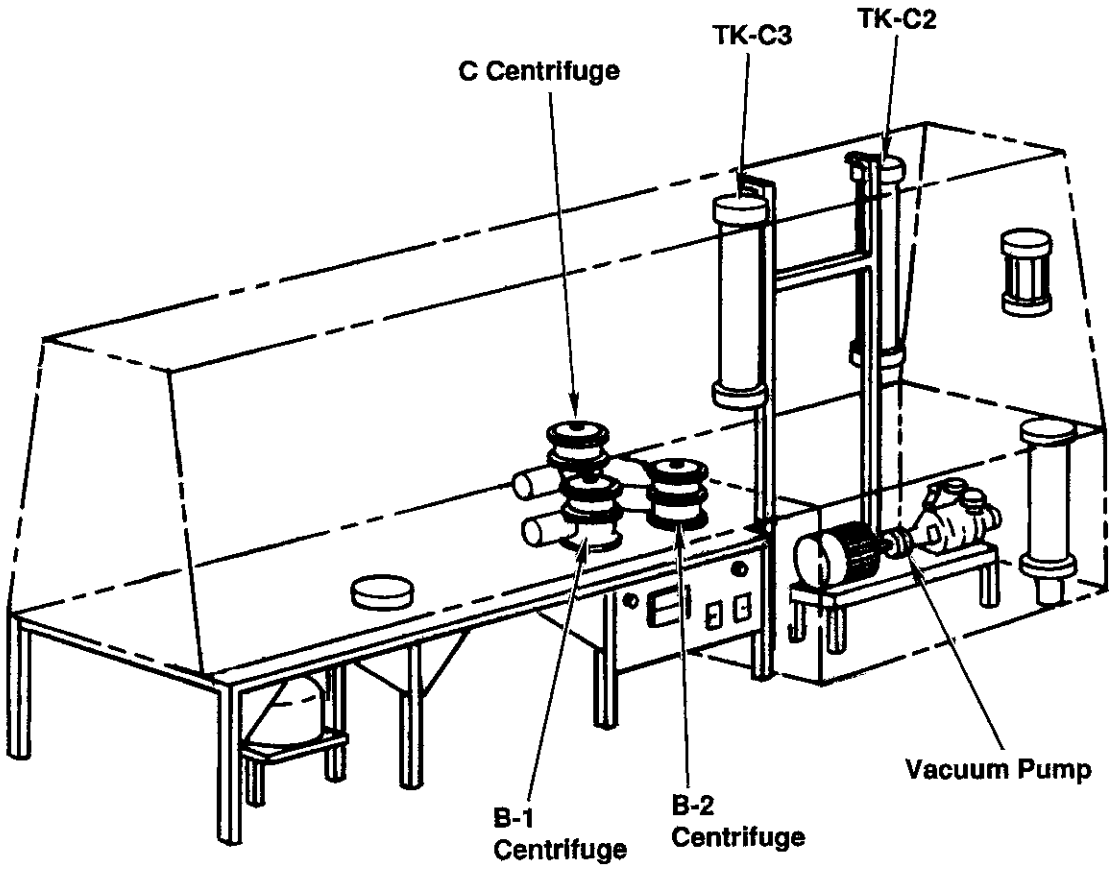


Figure 5-25. Building 236-Z Process Canyon. (Inactive)

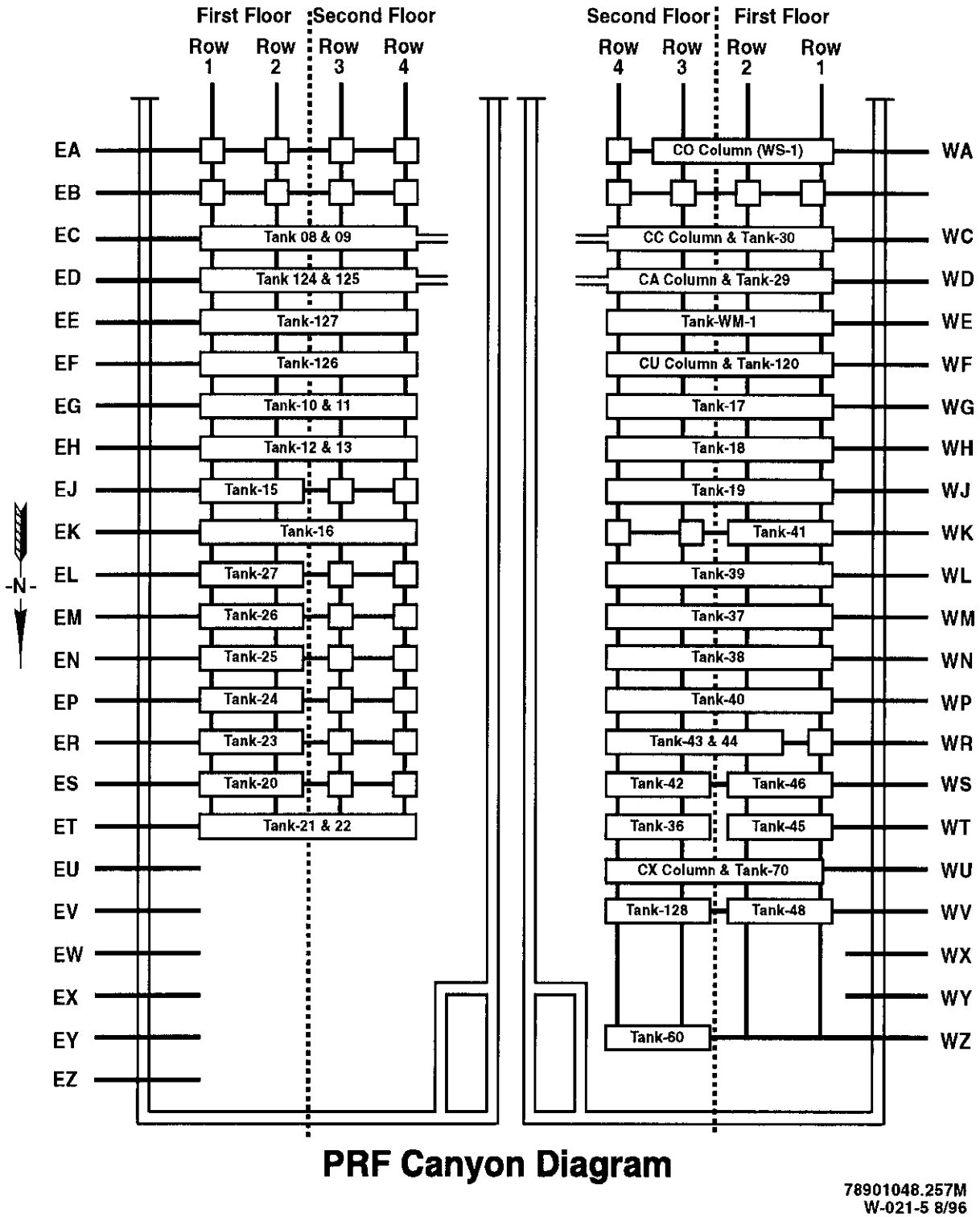


Figure 5-26. Schematic Diagram of the Solvent Extraction and Organic Treatment Sections. (Inactive)

(For schematic purposes - component designations not verified)

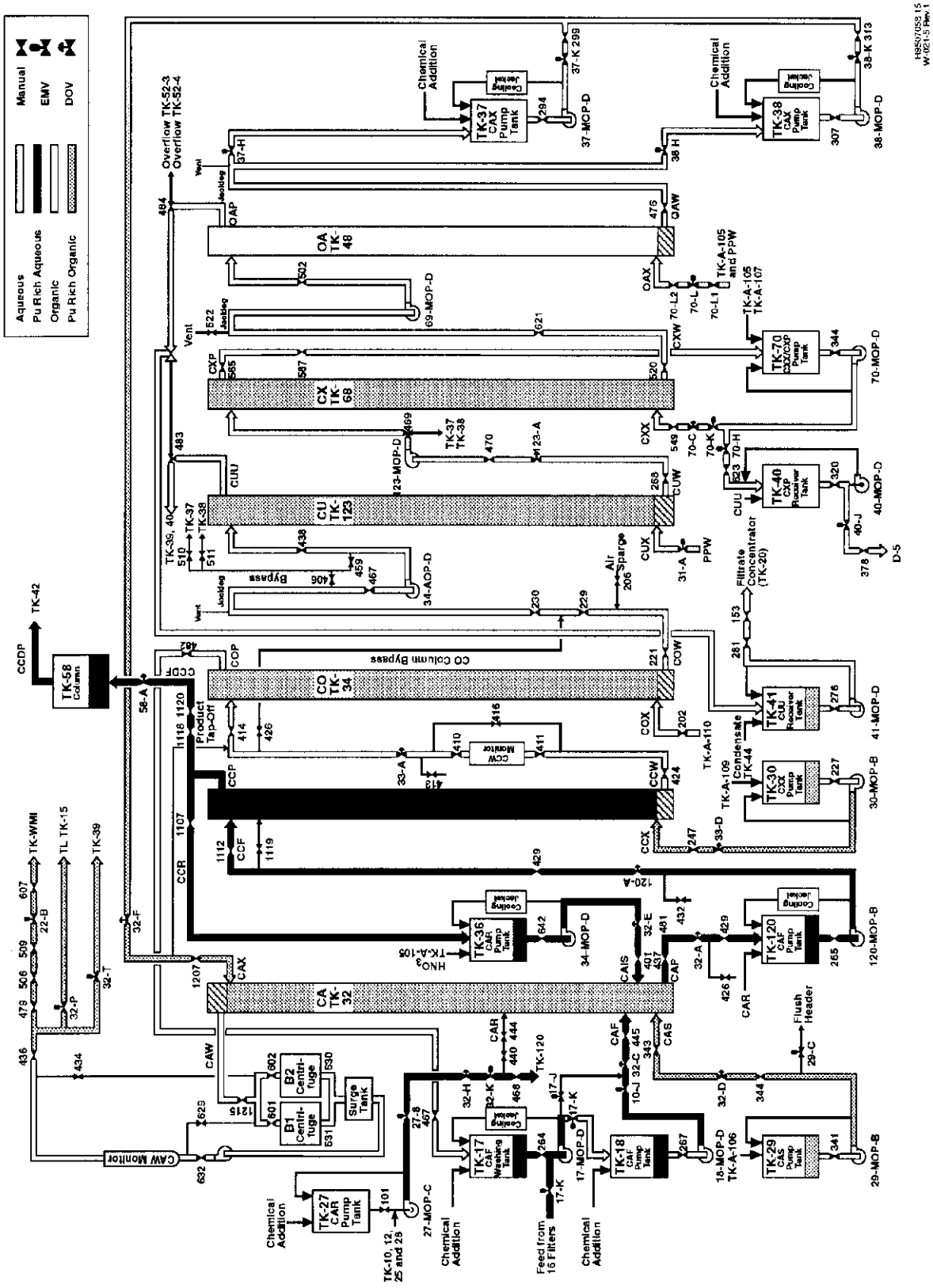


Figure 5-27. Typical Four-Barrel Bank Tanks.

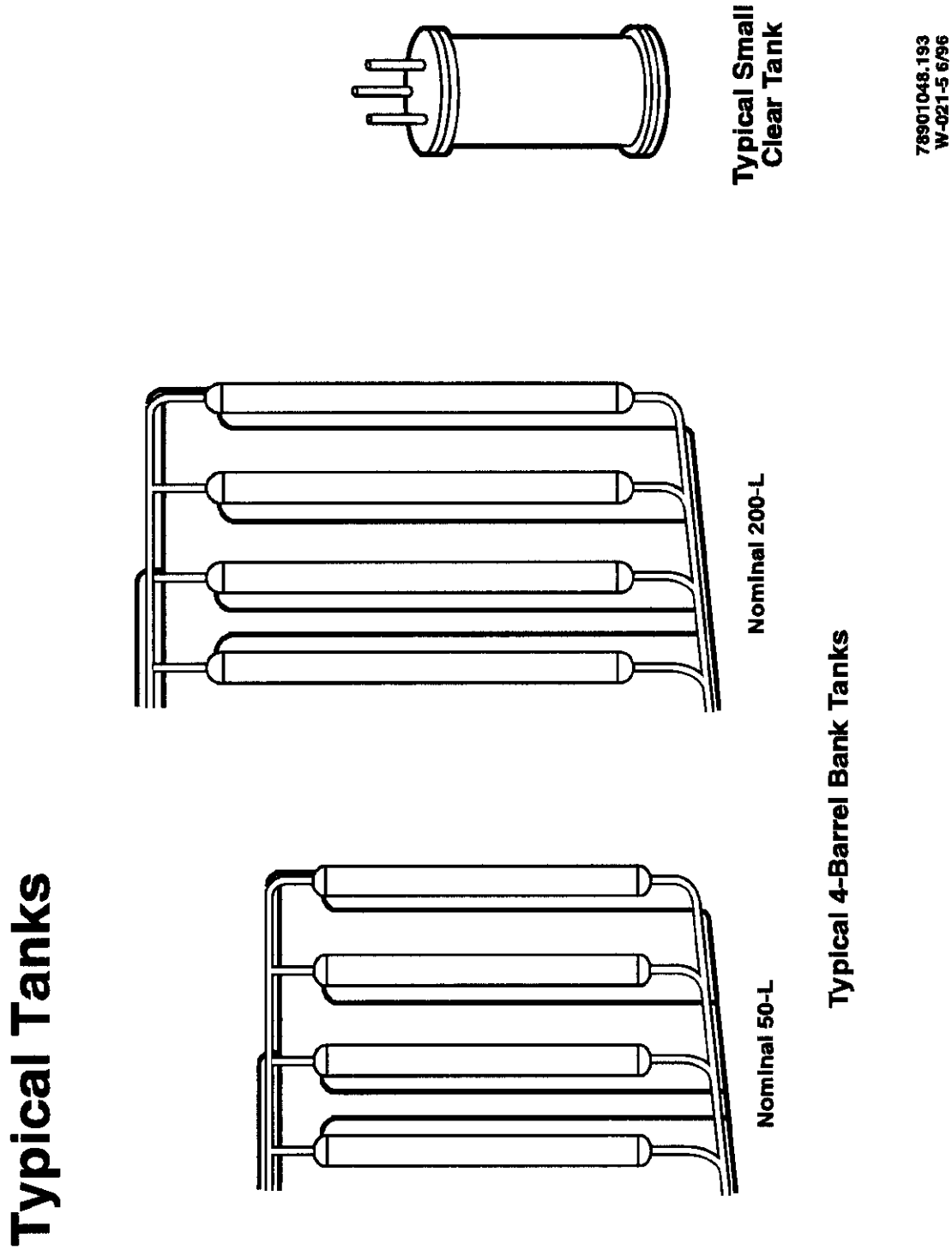


Figure 5-28. Columns and Concentrators. (Inactive)

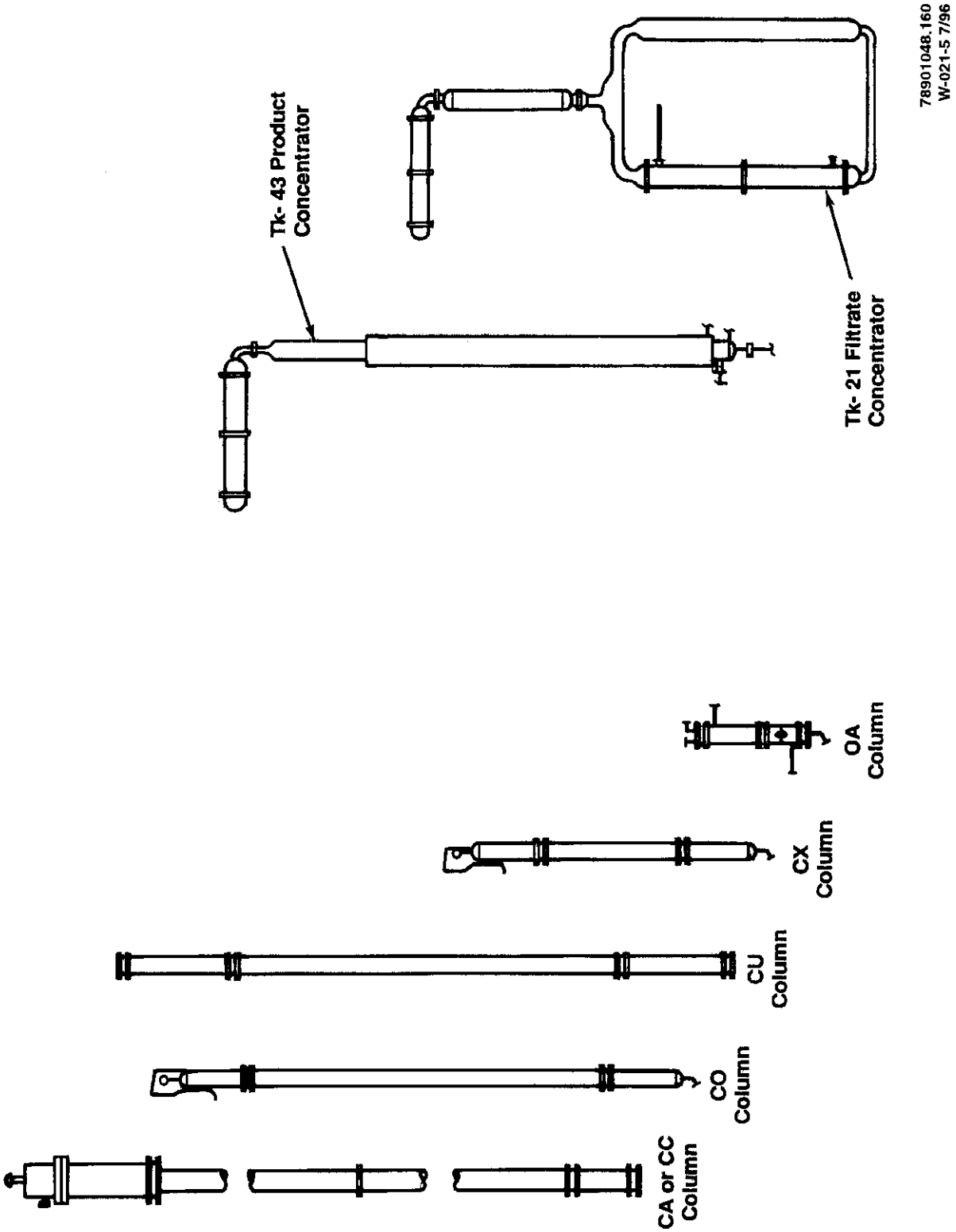


Figure 5-29. Product Concentration. (Inactive)

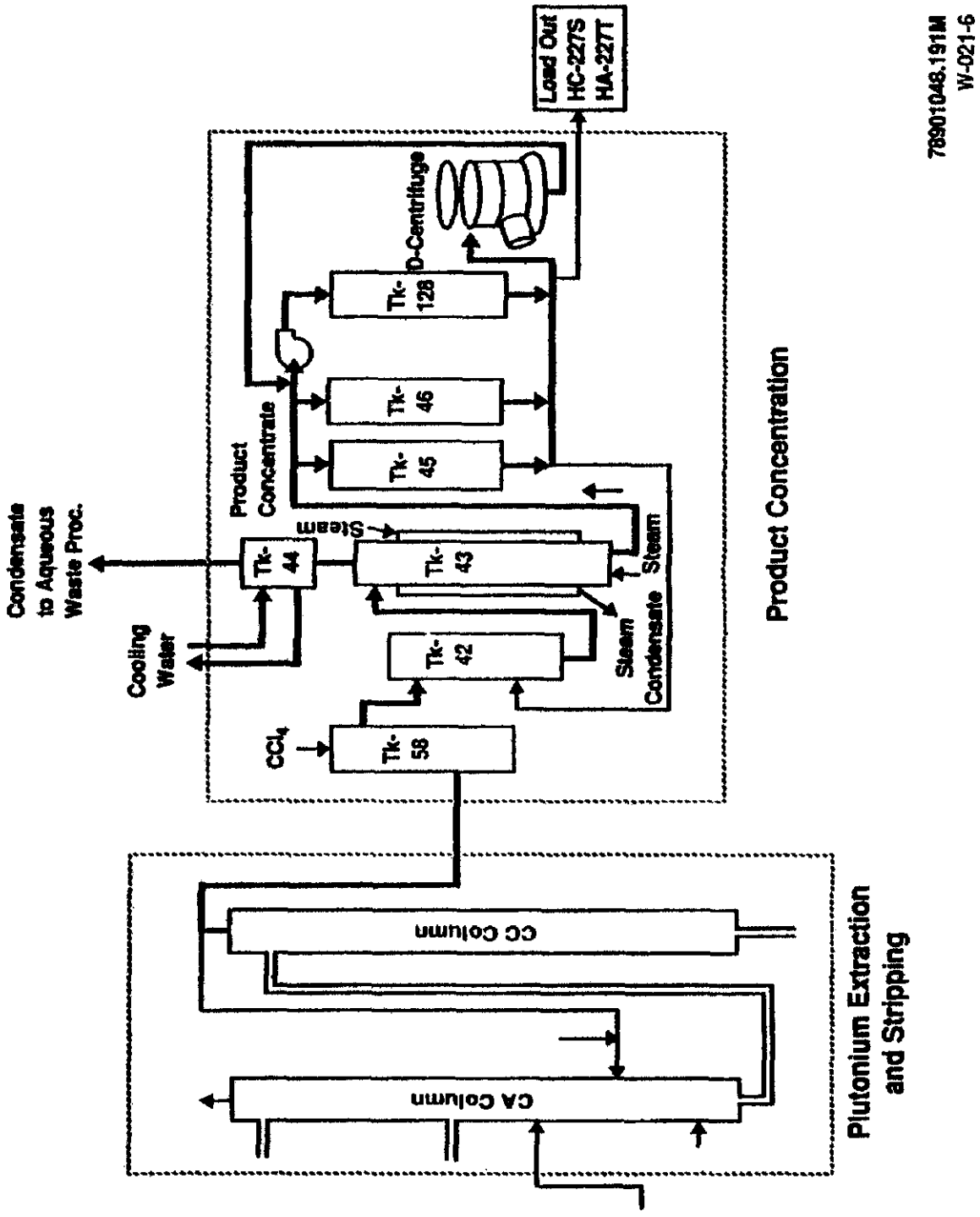
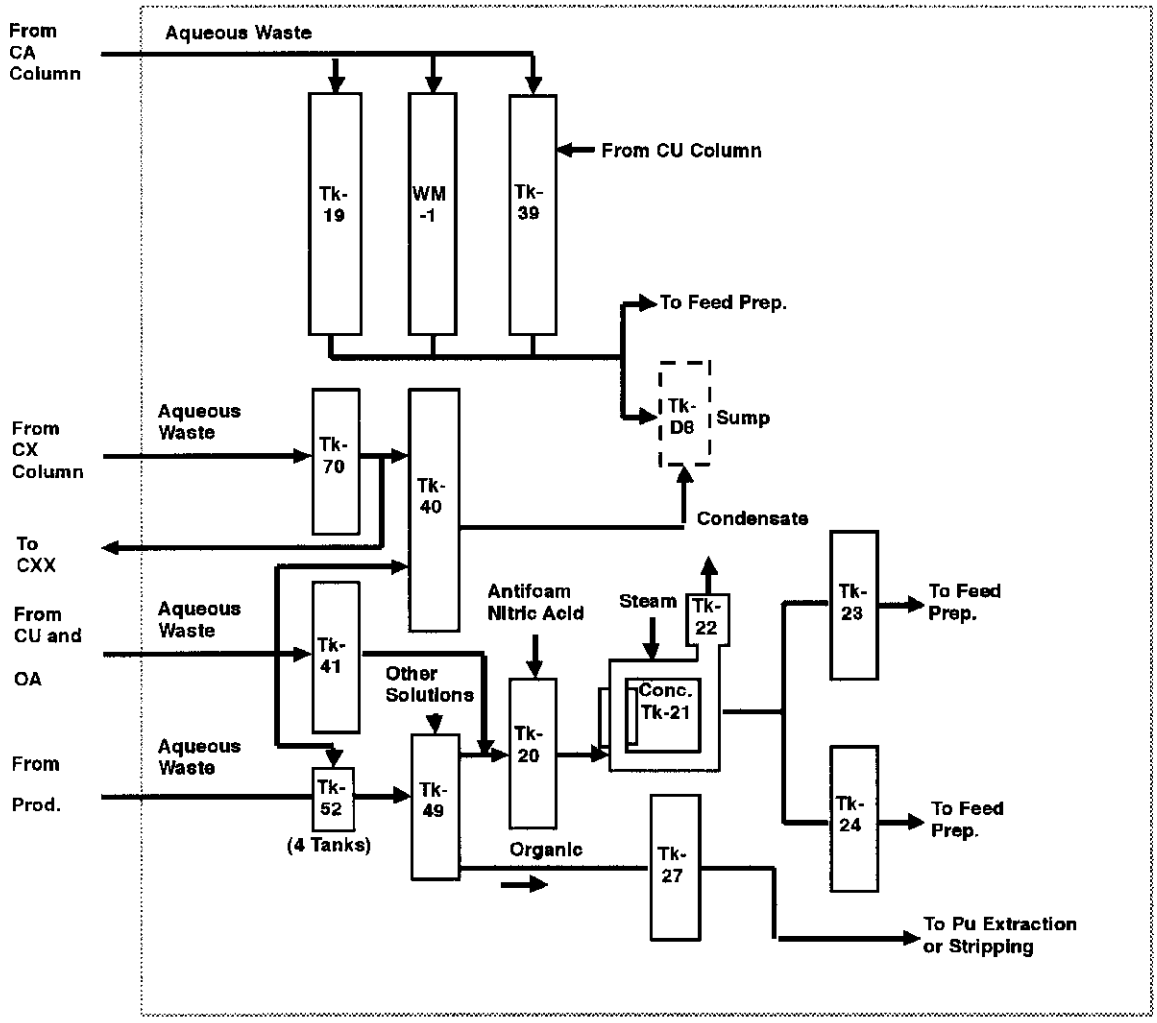


Figure 5-30. Agueous Waste Processing. (Inactive)



Aqueous Waste Processing

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Figure 5-31. Cutaway View of the 232-Z Building.

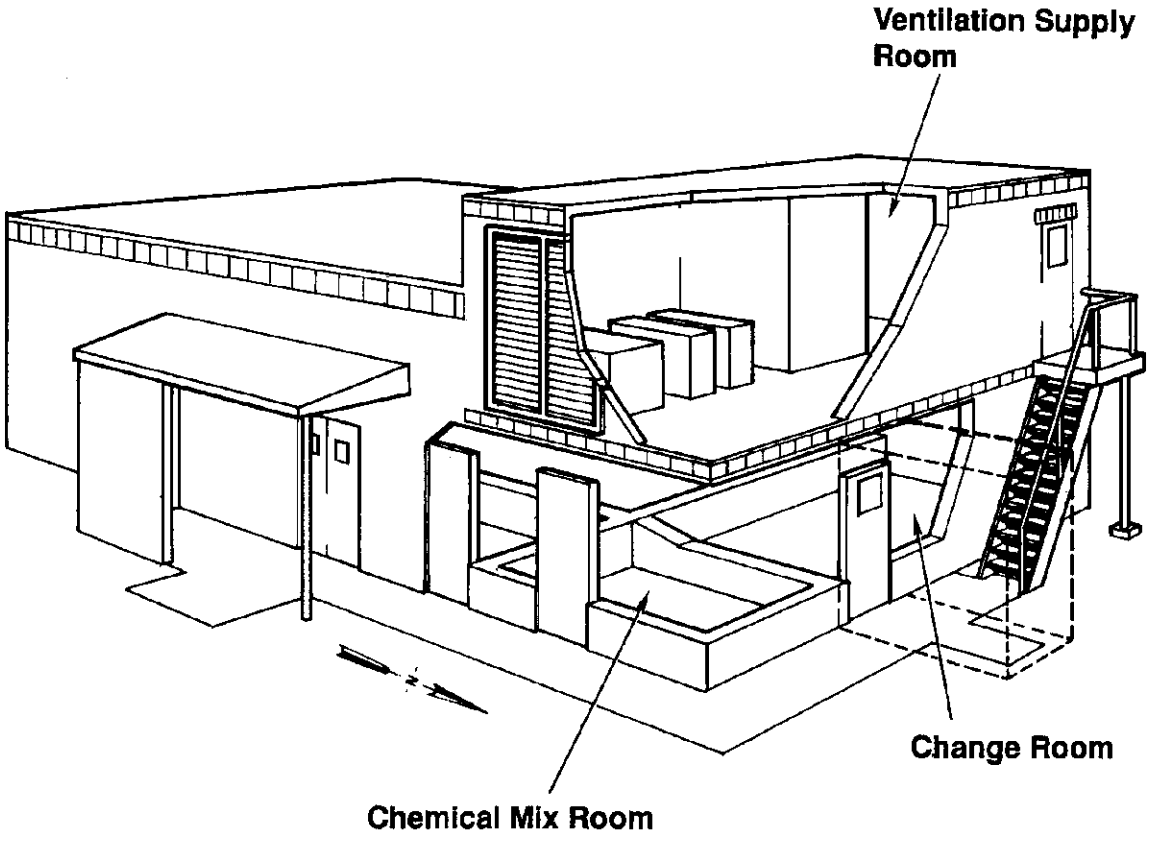


Figure 5-32. Building 241-Z Sumps and Tanks Layout.

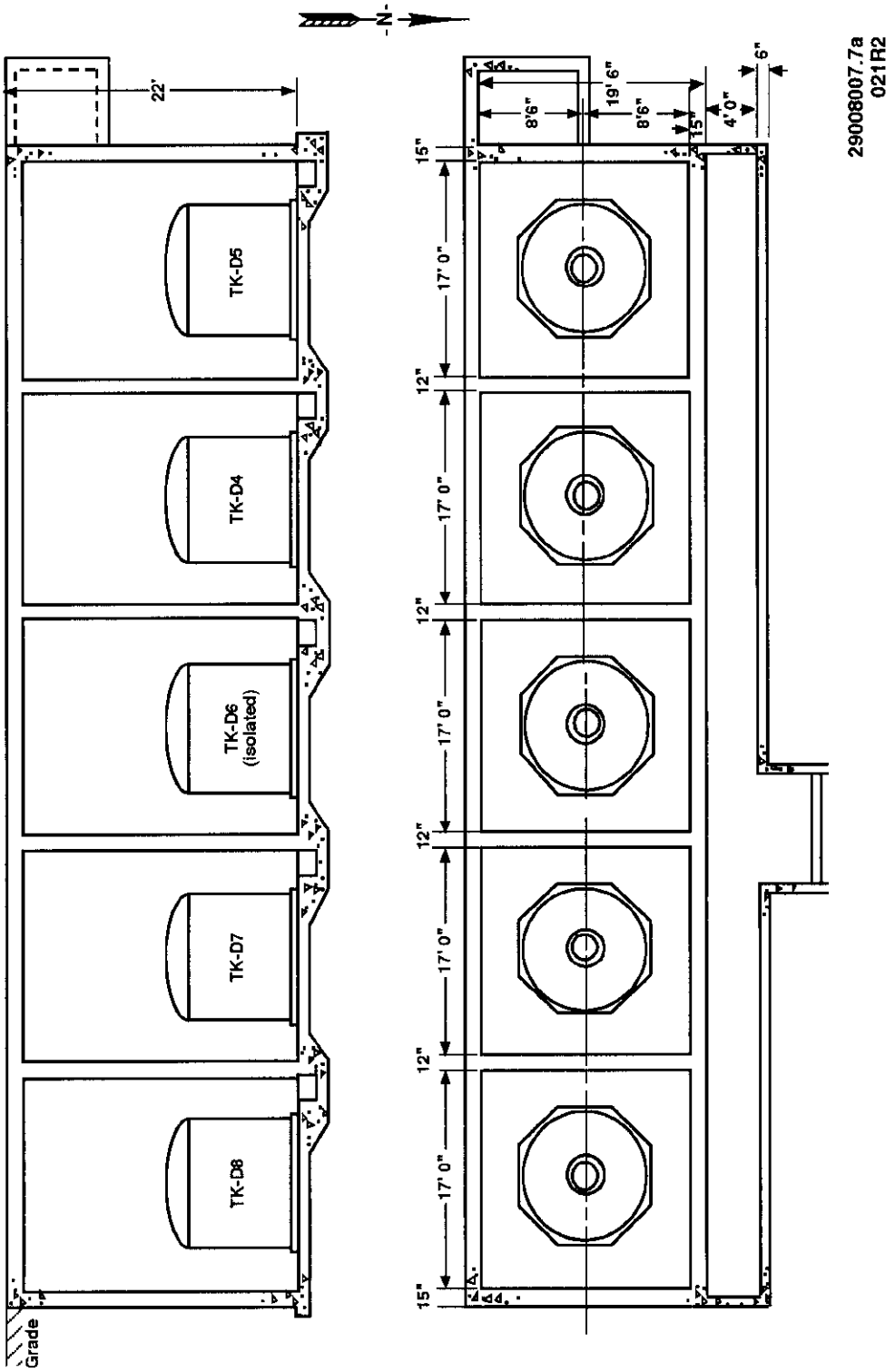


Figure 5-33. Building 241-Z Typical Storage Tank.

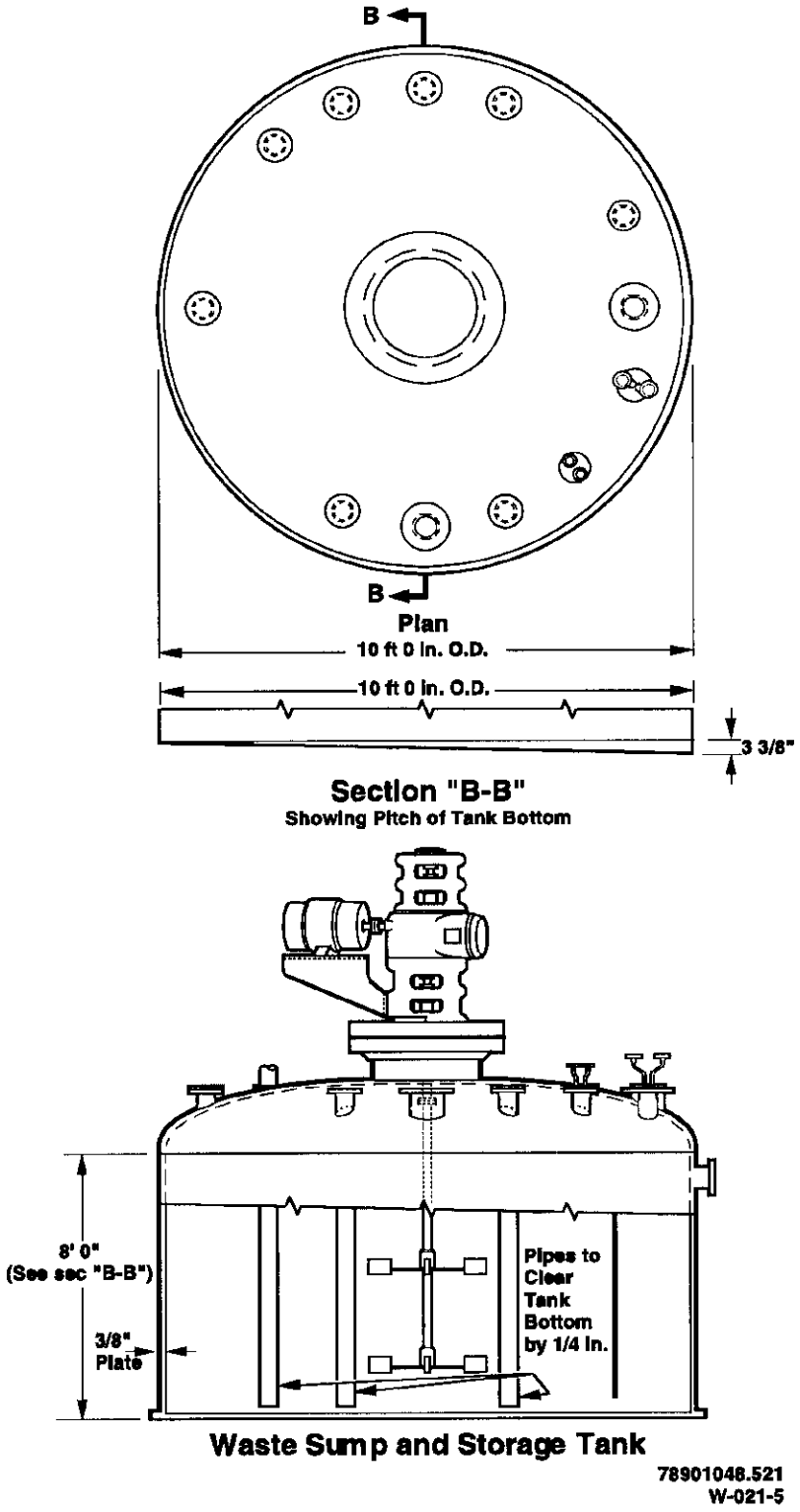


Figure 5-34. Cutaway View of the 242-Z Building.
(Inactive and Sealed From Personnel Entry)

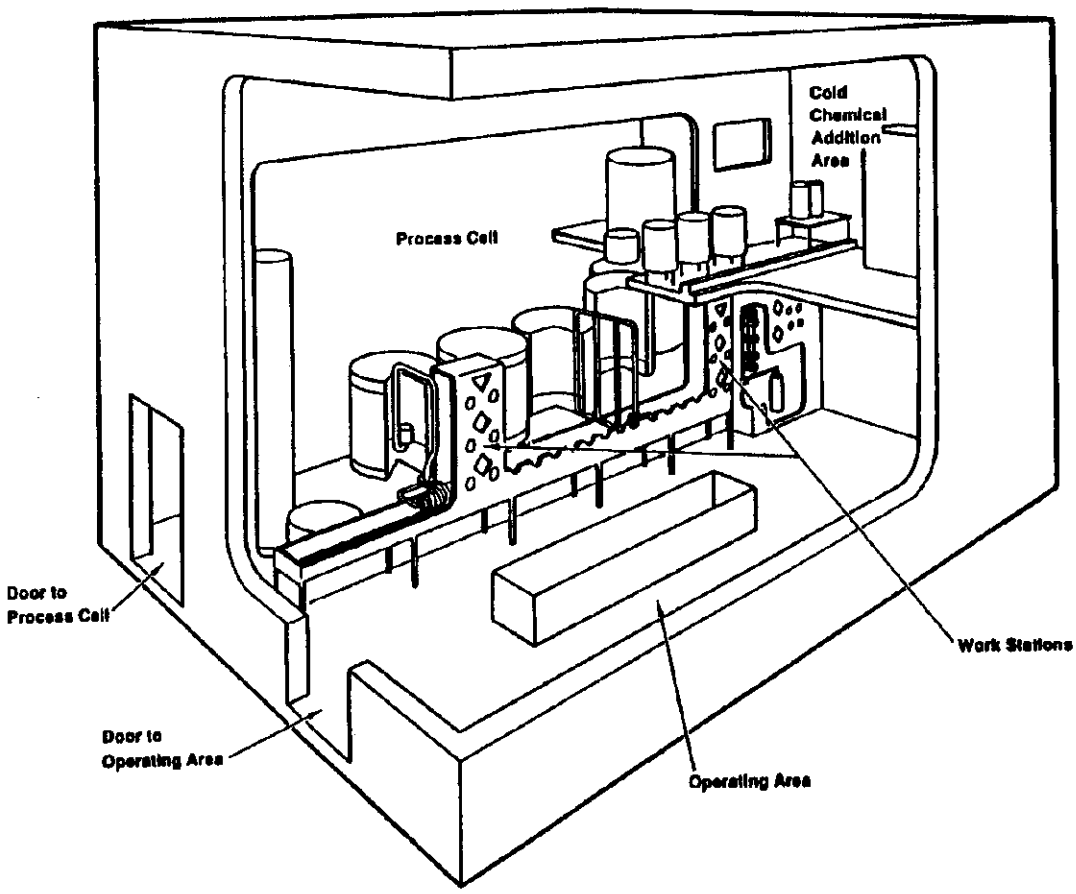


Figure 5-35. Cutaway View of the 291-Z Building.

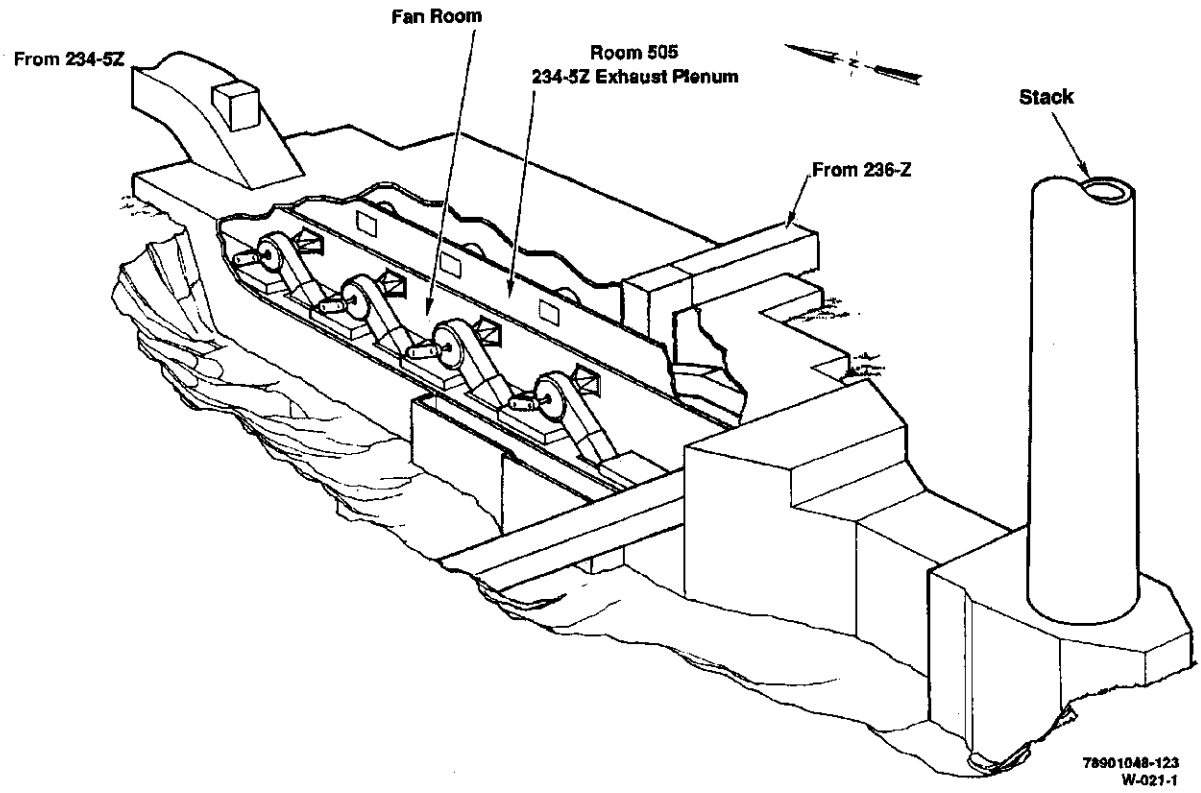


Figure 5-36. Cutaway View of the 2736-Z Building.

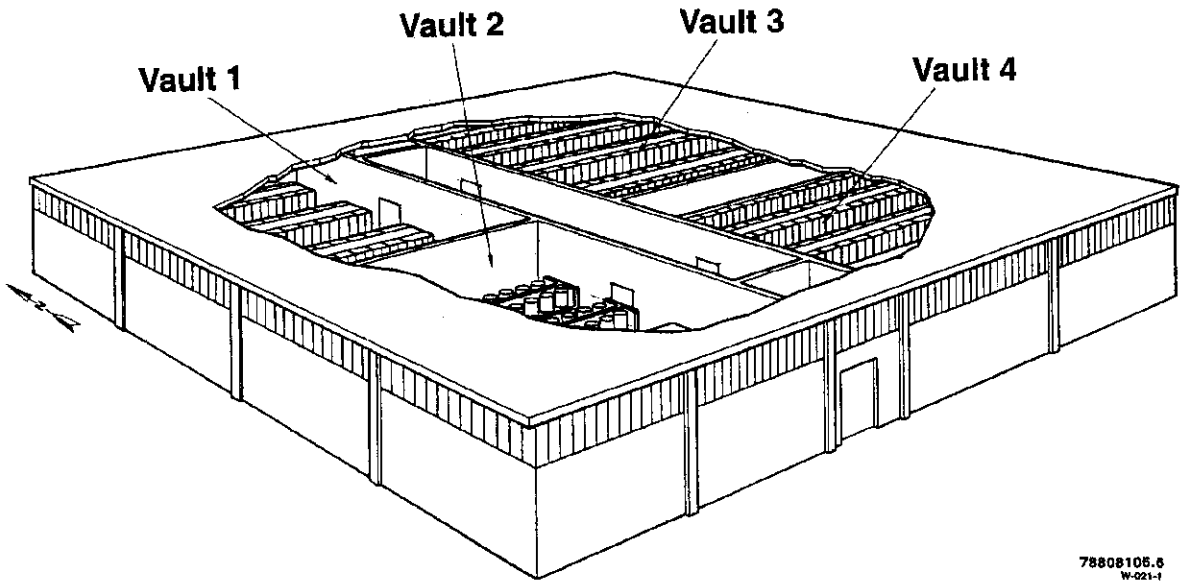


Figure 5-37. Cubicle Storage.

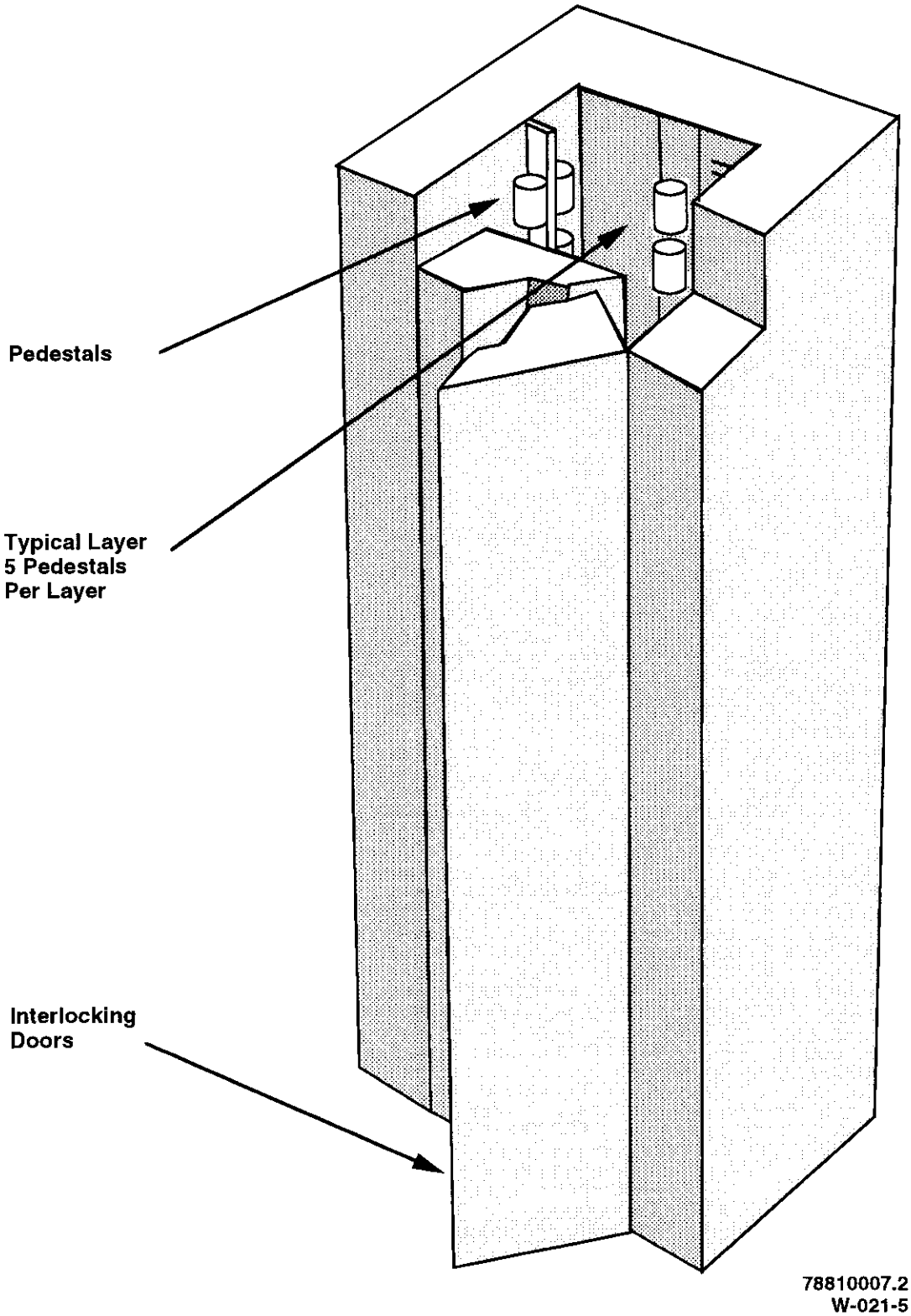


Figure 5-38. Cutaway View of the 2736-ZB Building.

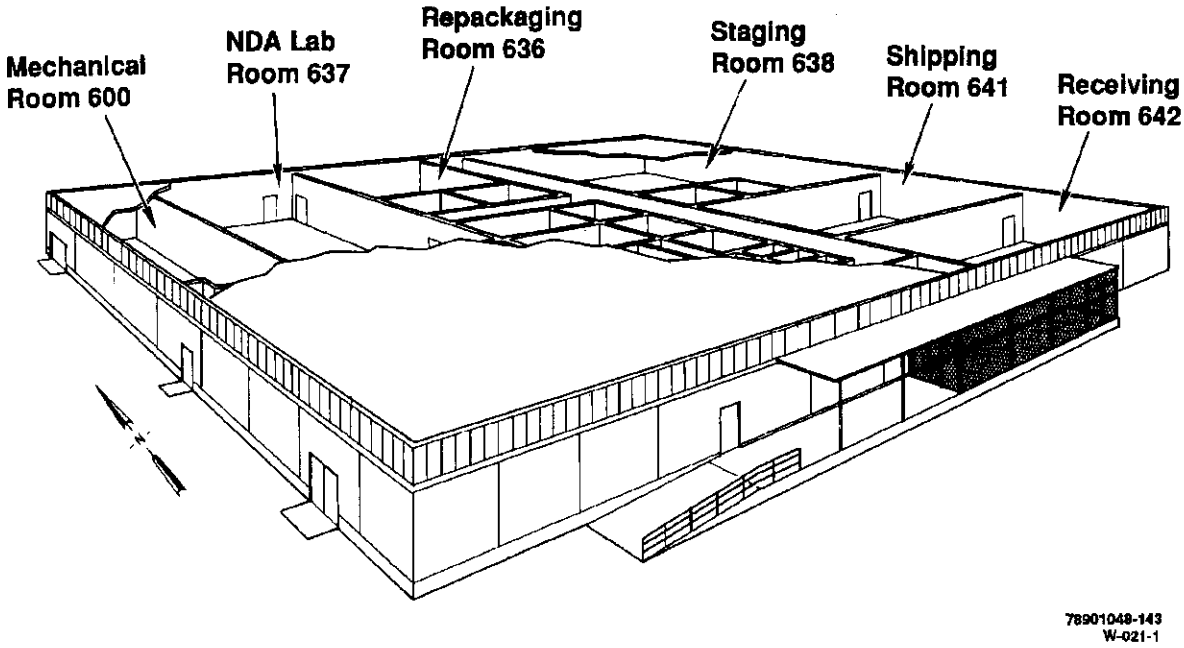


Figure 5-39. Building 2736-ZB Repackaging Glovebox.

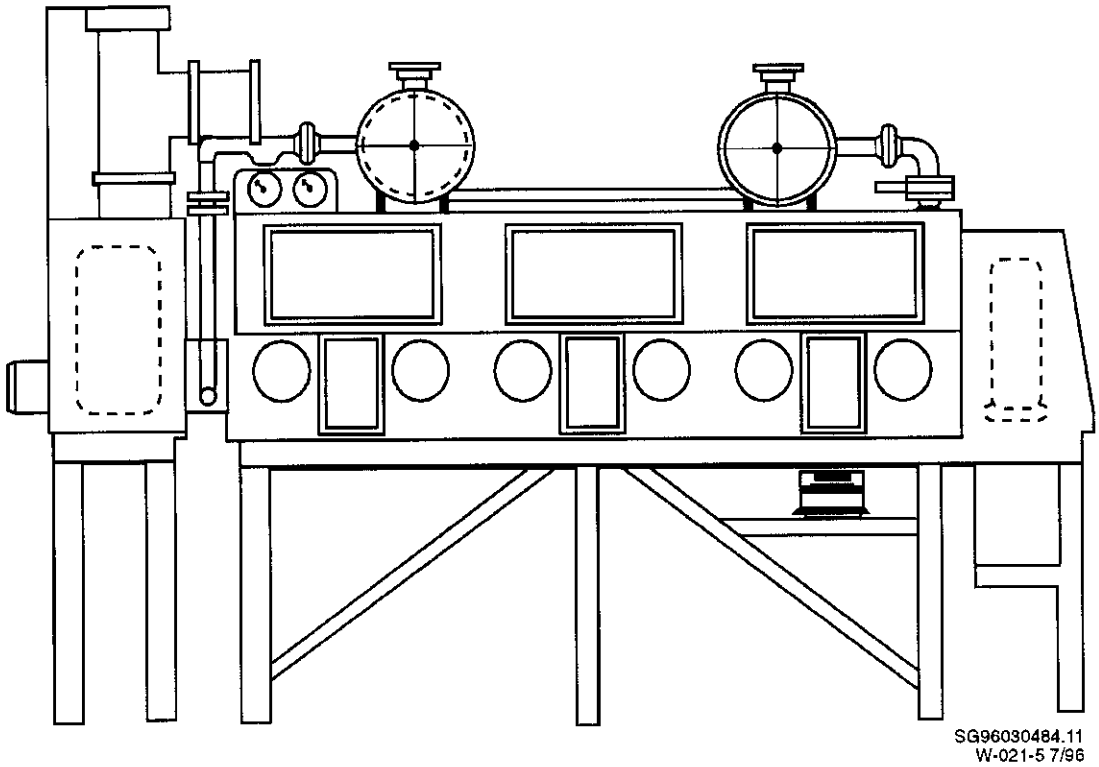
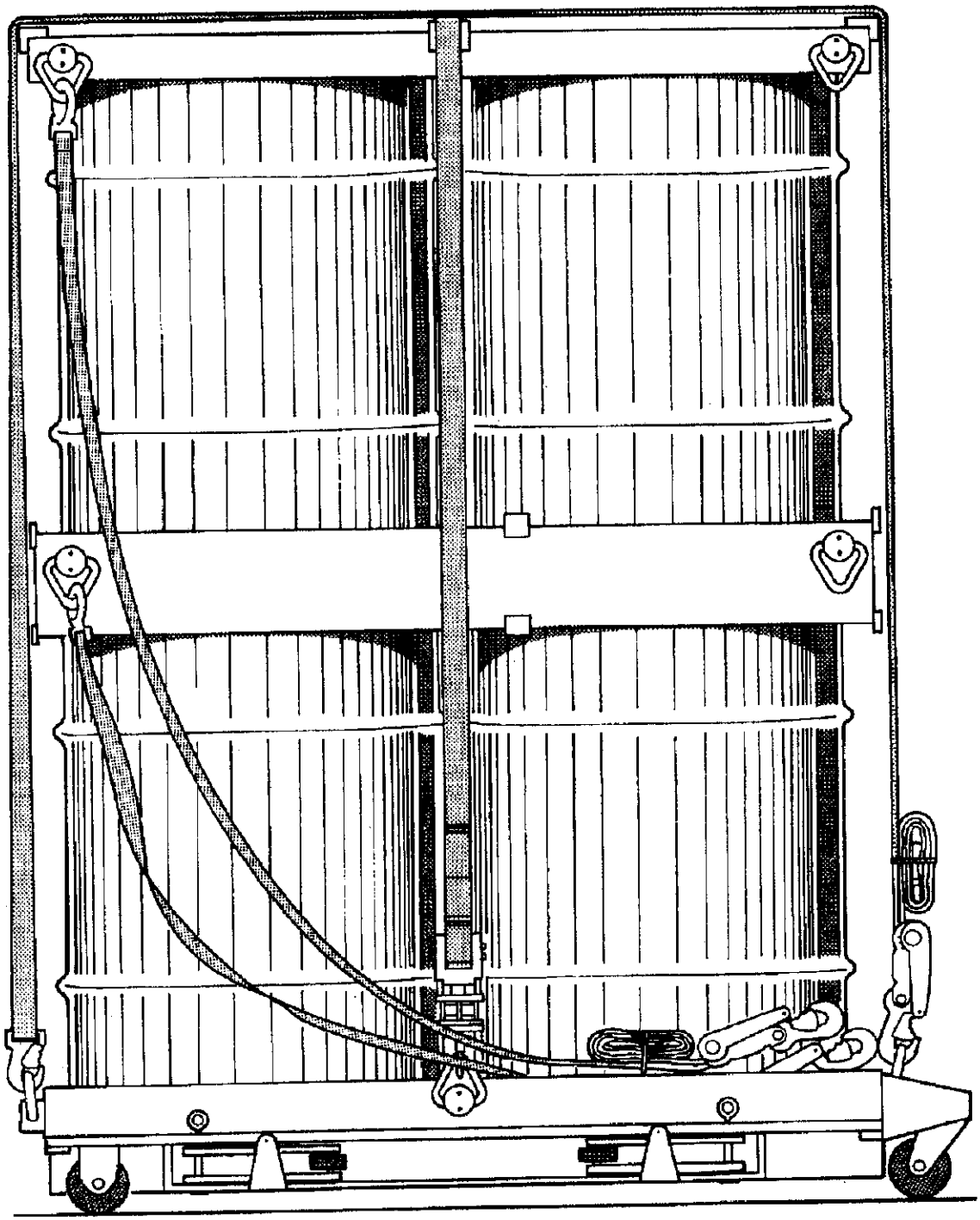


Figure 5-40. Cargo Restraint Transporter.



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Figure 5-41. Plutonium Finishing Plant Zone Ventilation Schematic (234-5Z, 232-Z, 236-Z, 241-Z, 242-Z, 291-Z Buildings).

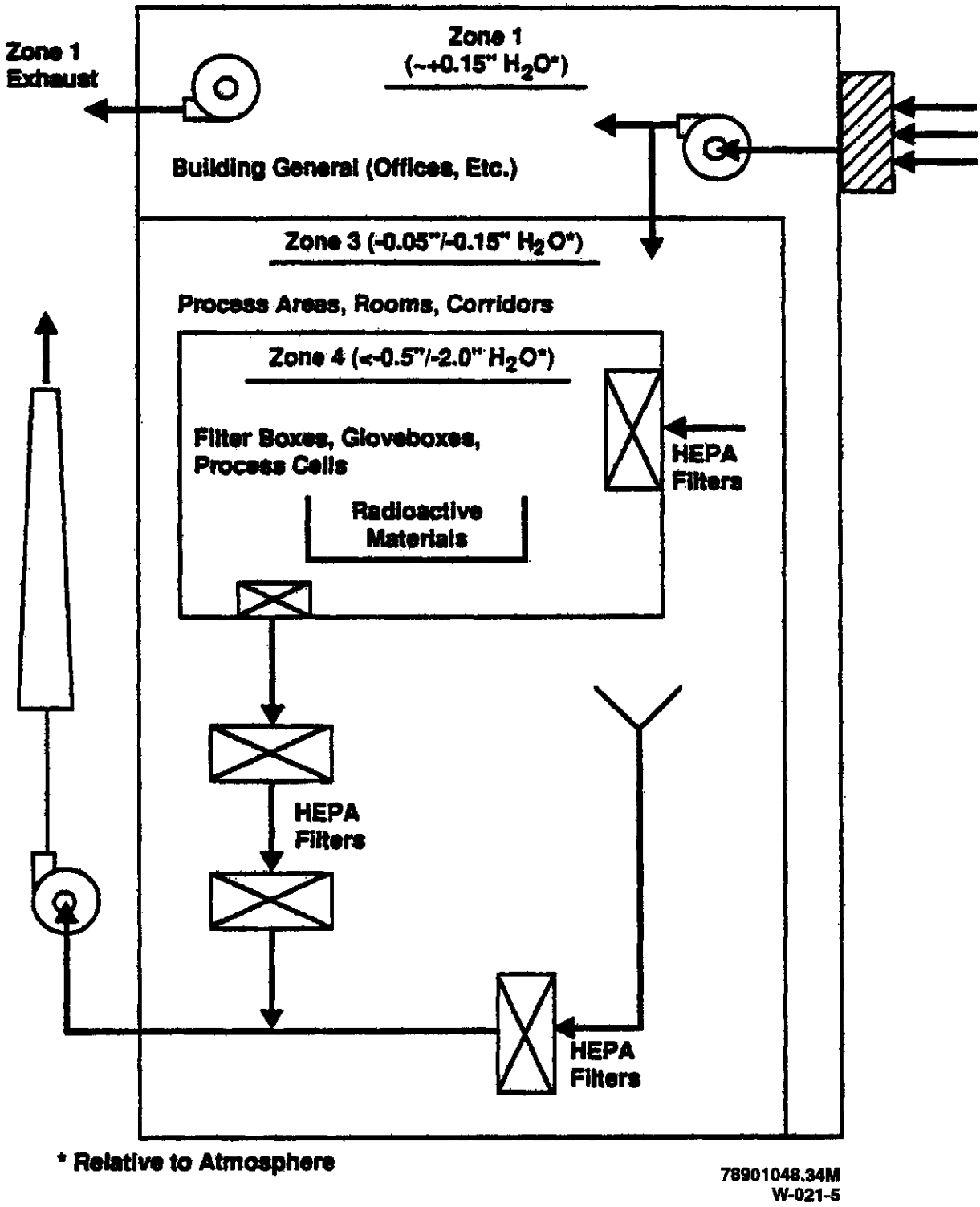


Figure 5-42. Typical Ventilation Flow Pattern through Building 234-5Z.

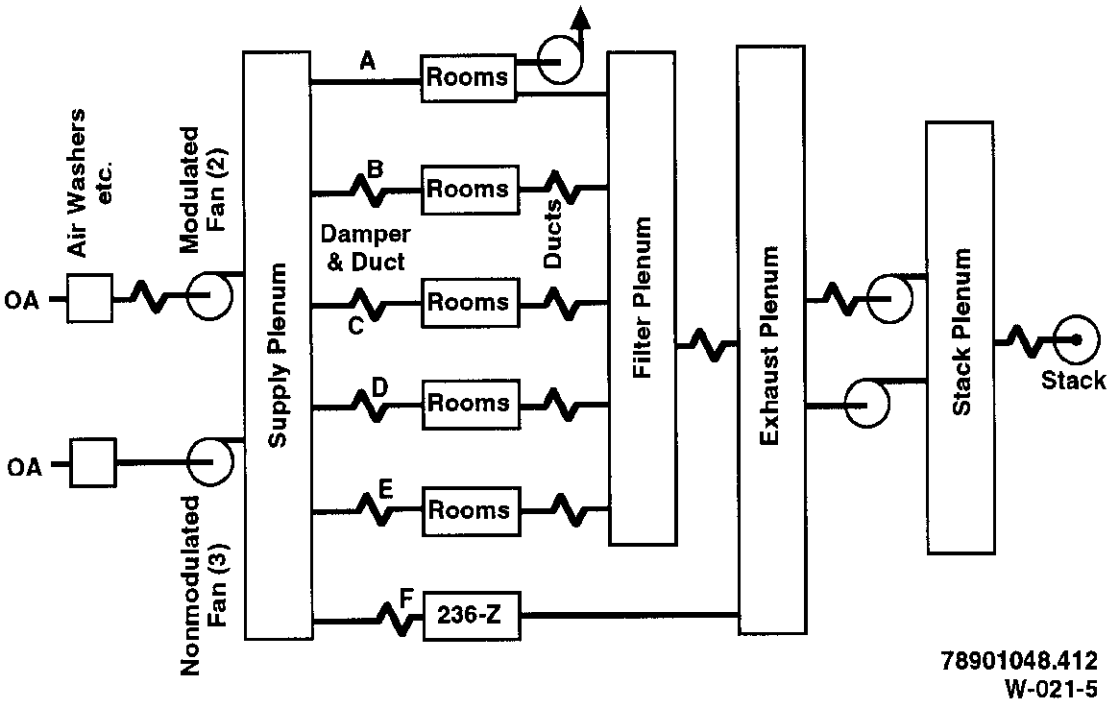


Figure 5-43. Simplified Building 234-5Z
Ventilation System Air Flow.

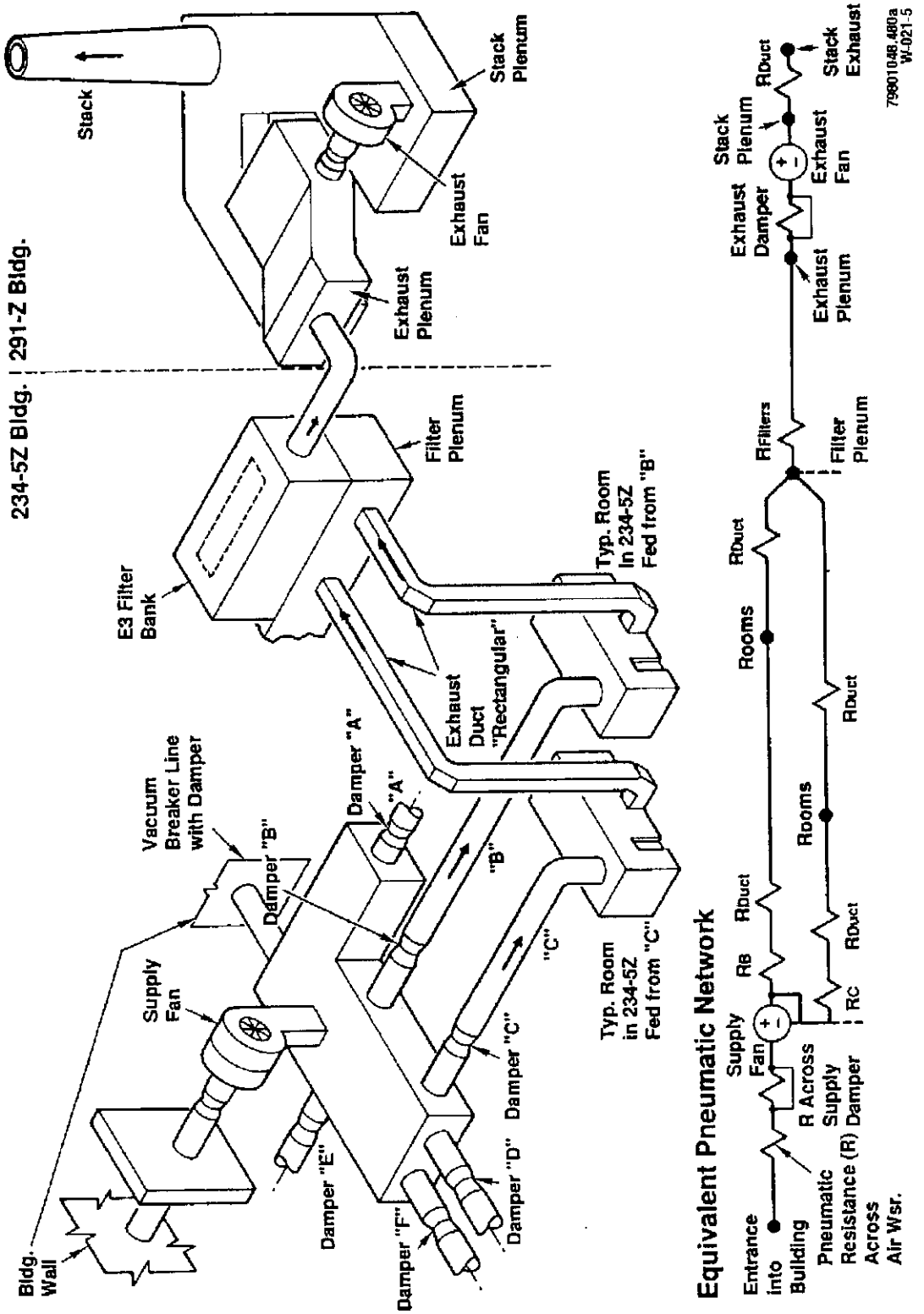


Figure 5-44. Room 321 Equipment Layout.

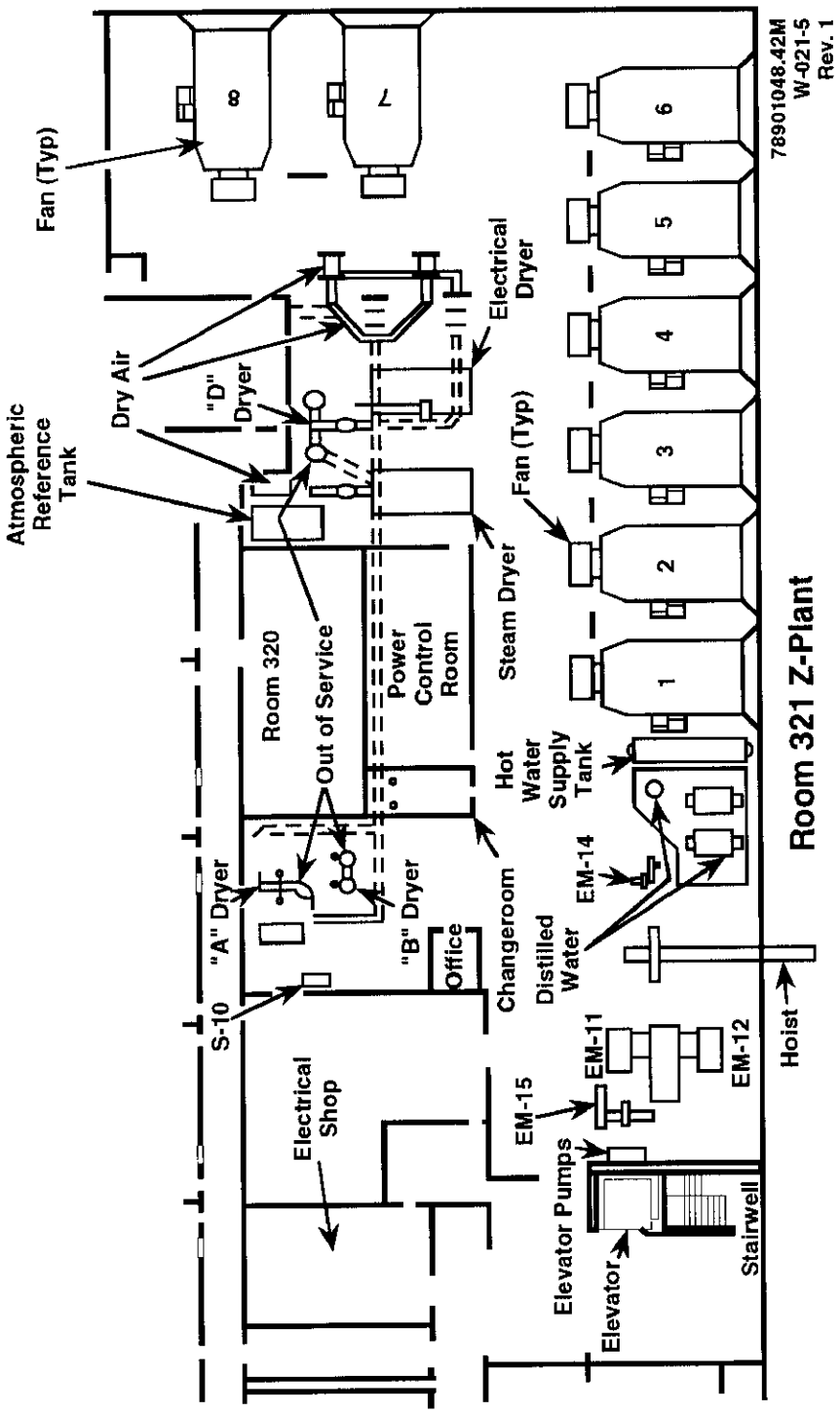


Figure 5-45. Typical Filter Bank in Filter Rooms.

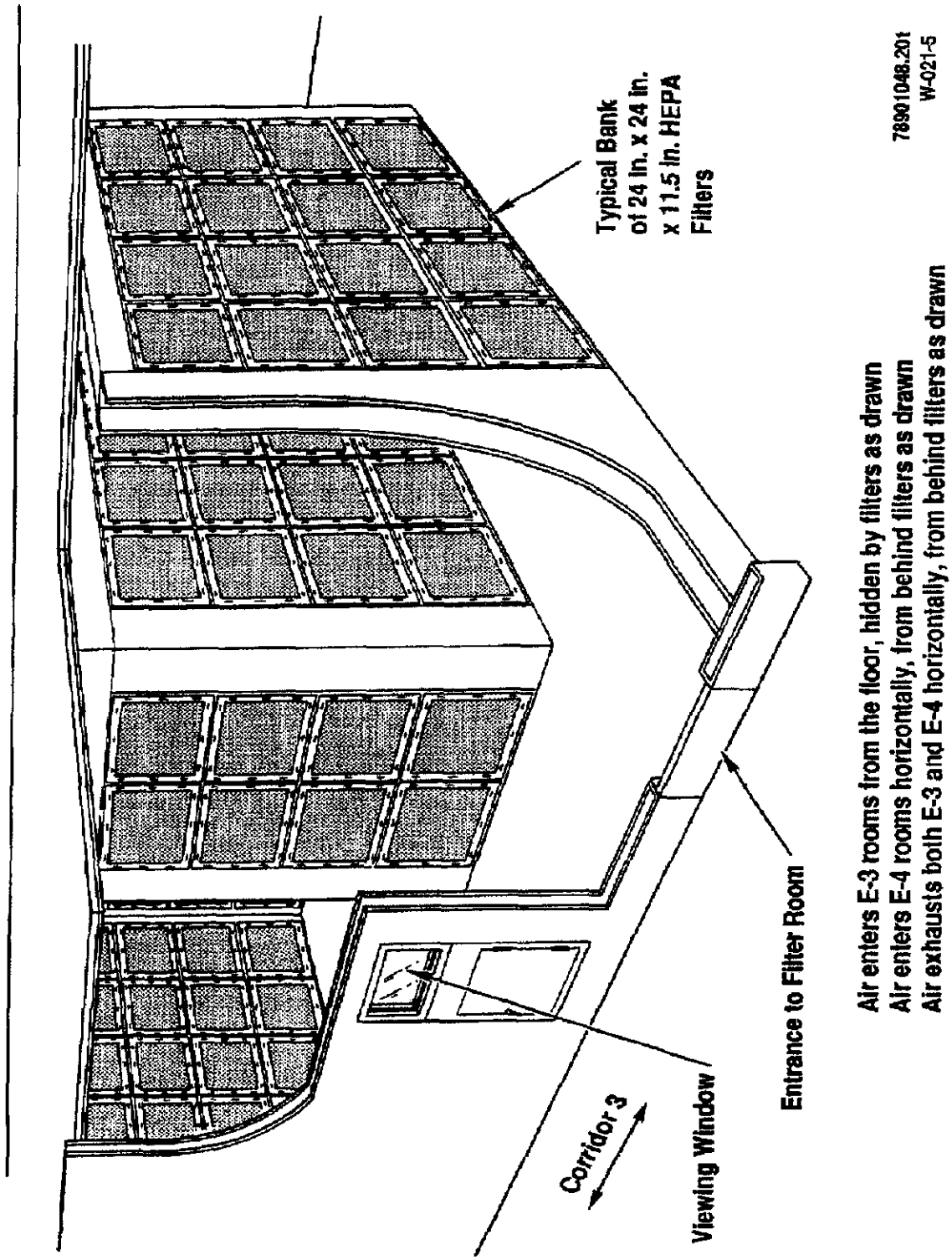


Figure 5-46. Ventilation Flow Diagram for Building 236-Z.

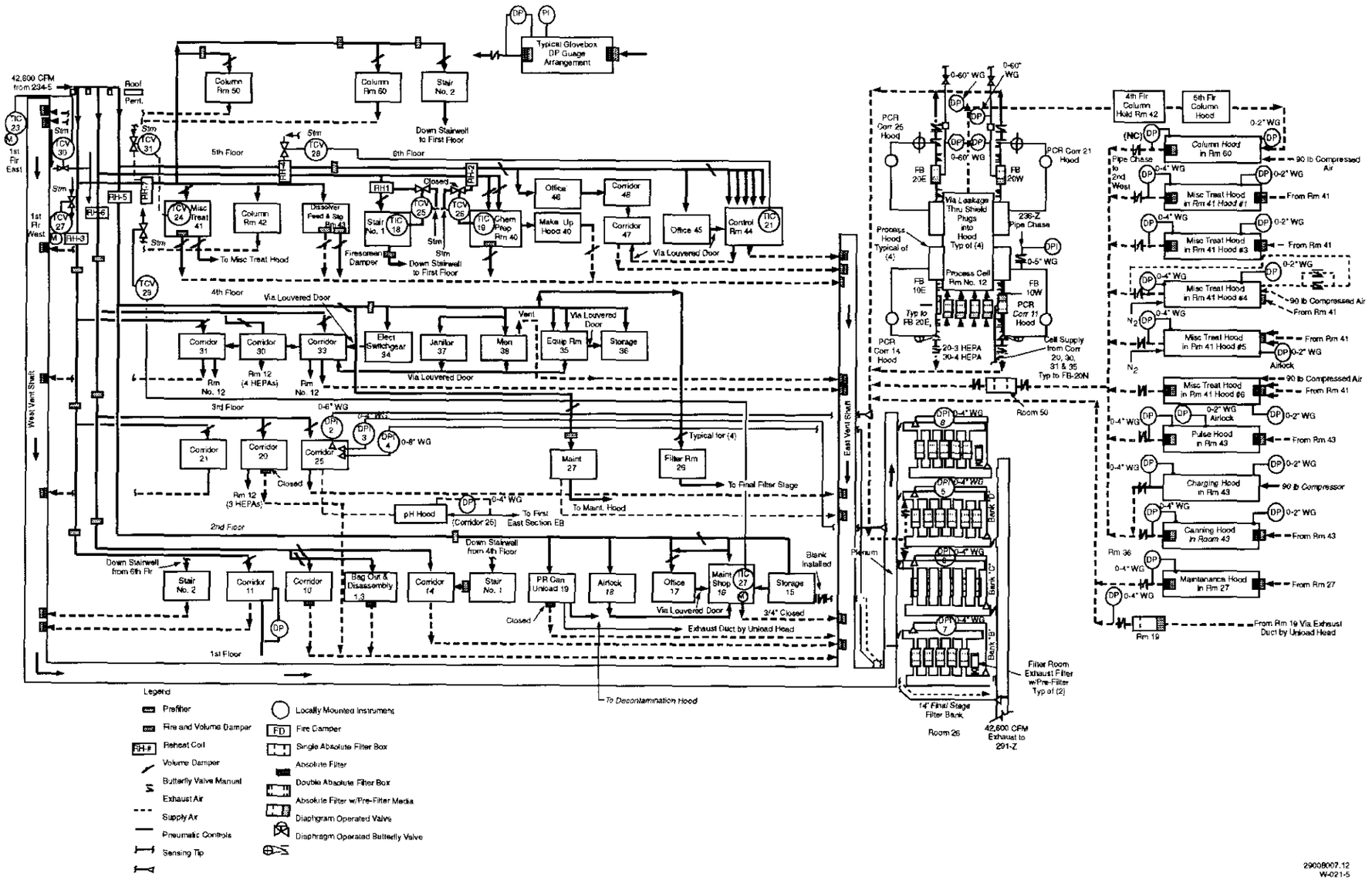


Figure 5-47. Building 232-Z Ventilation Supply and Exhaust.

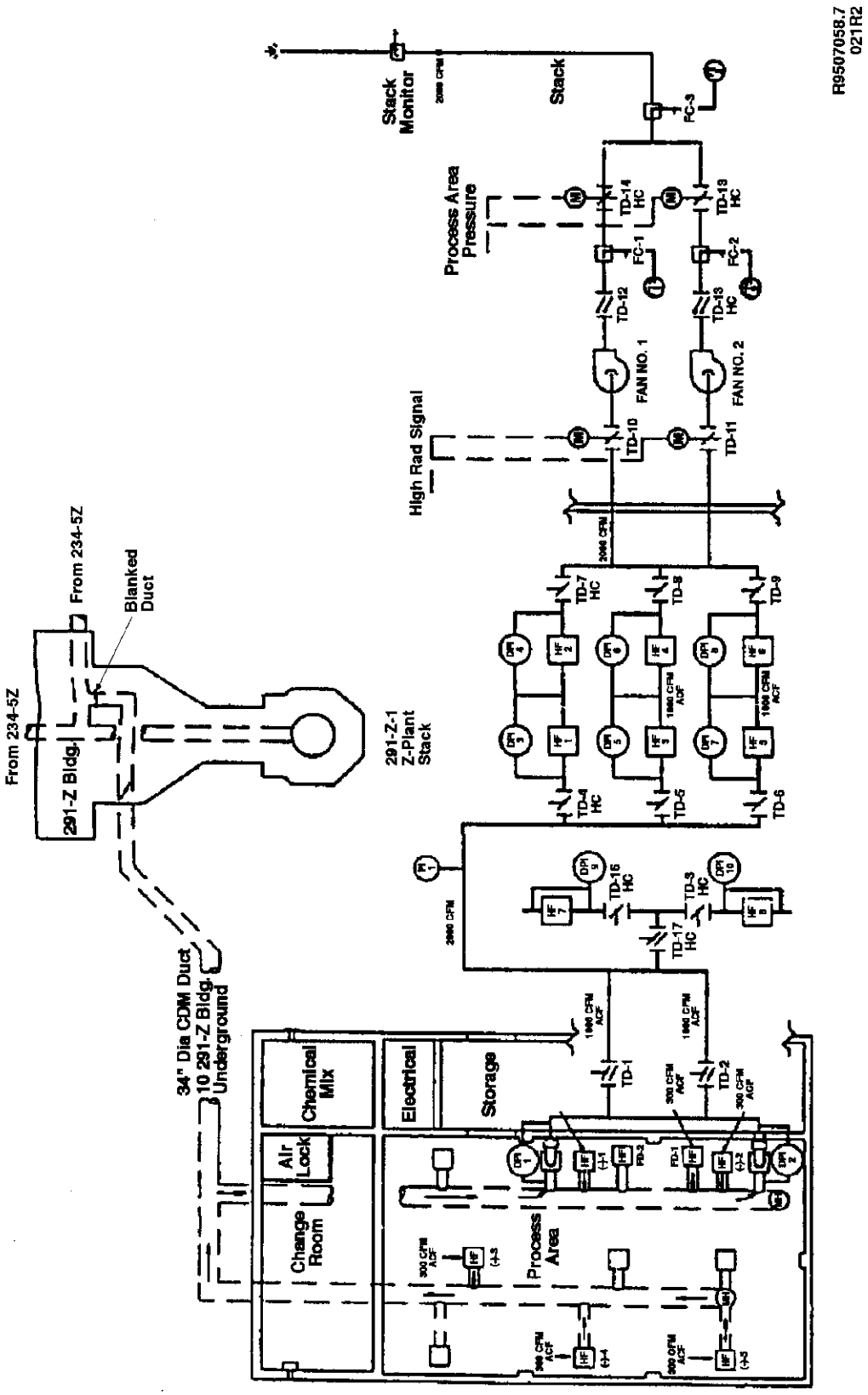


Figure 5-48. Building 241-Z Exhaust System.

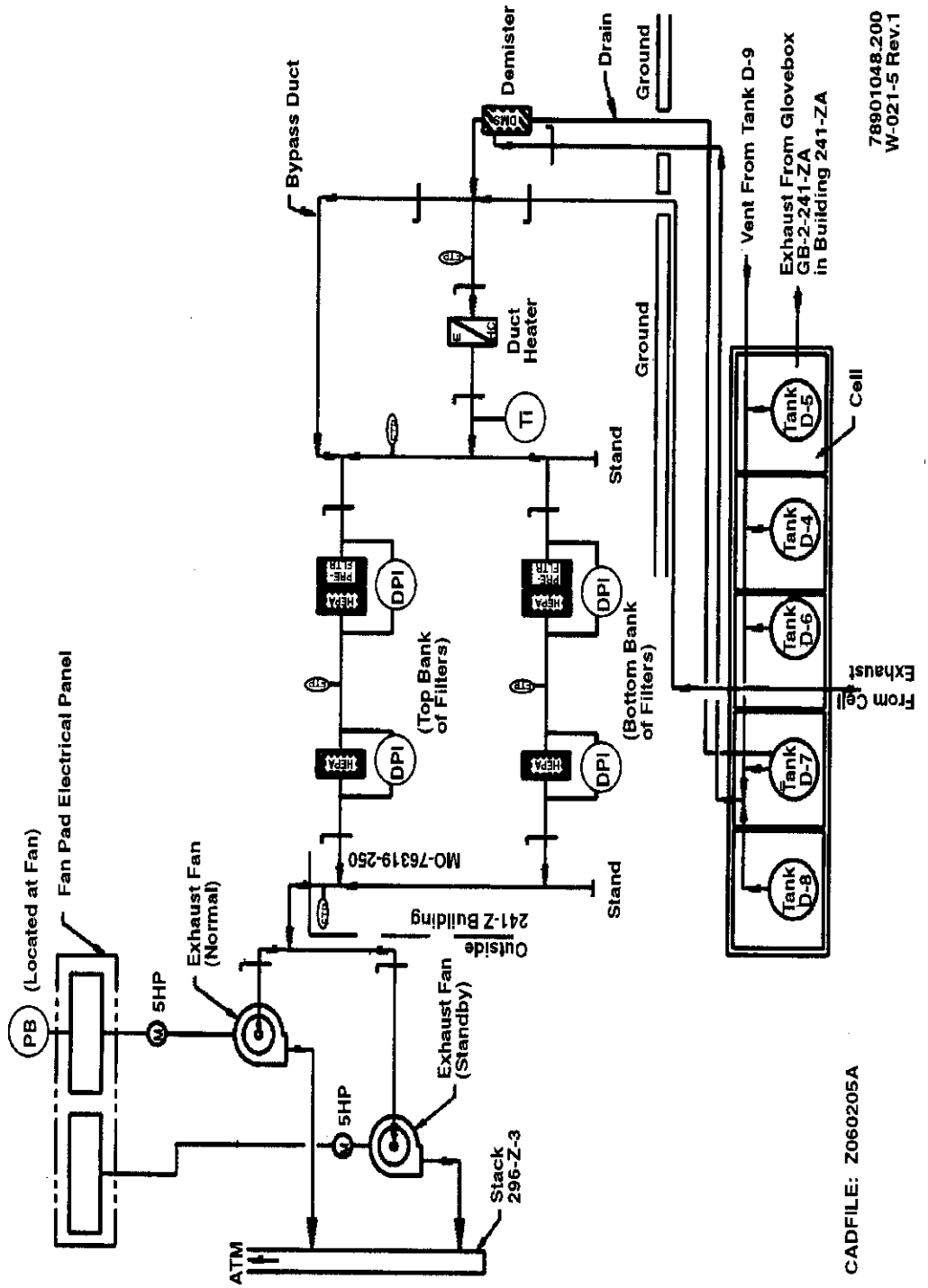


Figure 5-49. Ventilation System for the 2736-Z, 2736-ZA, and 2736-ZB Buildings.

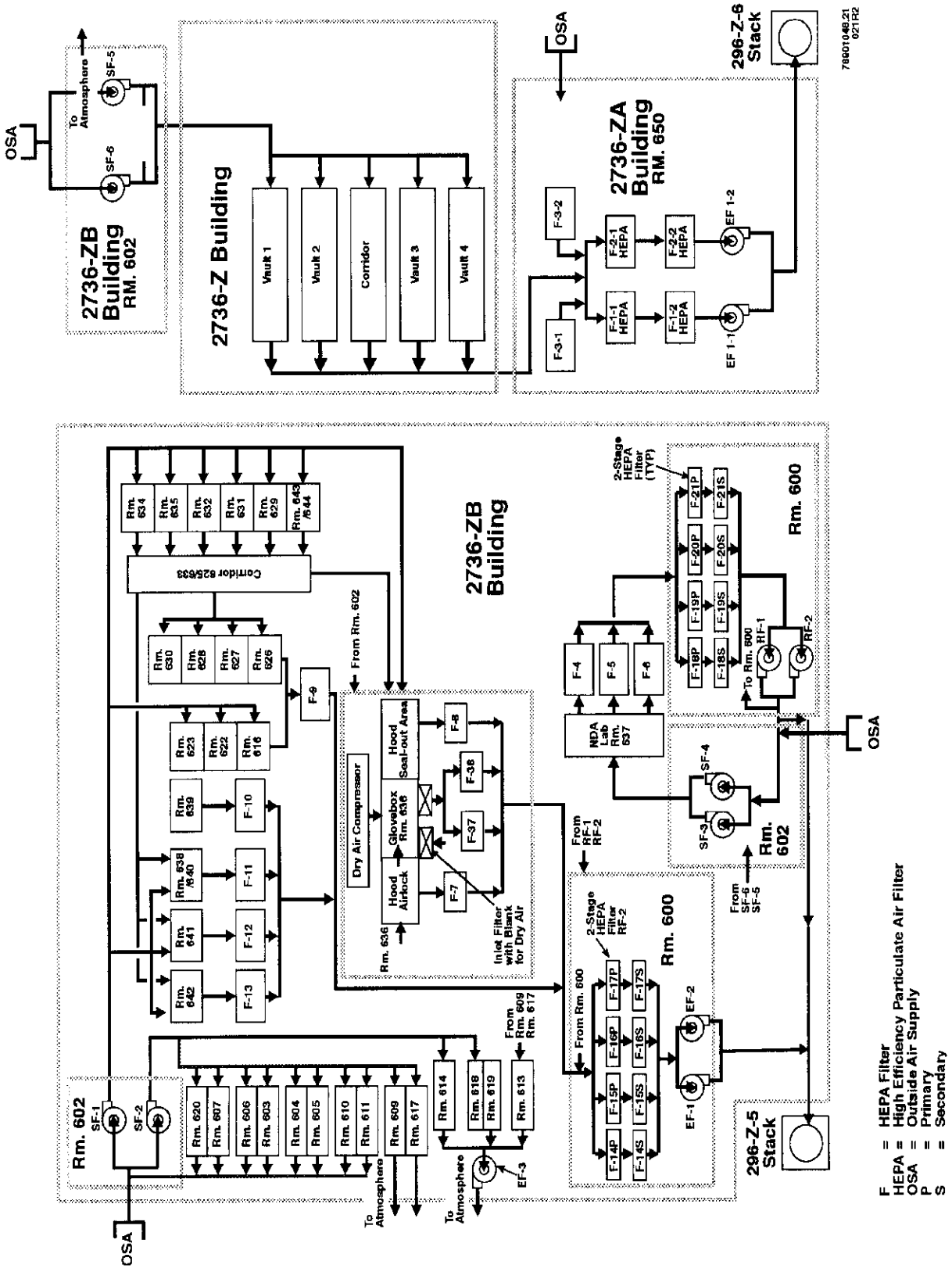
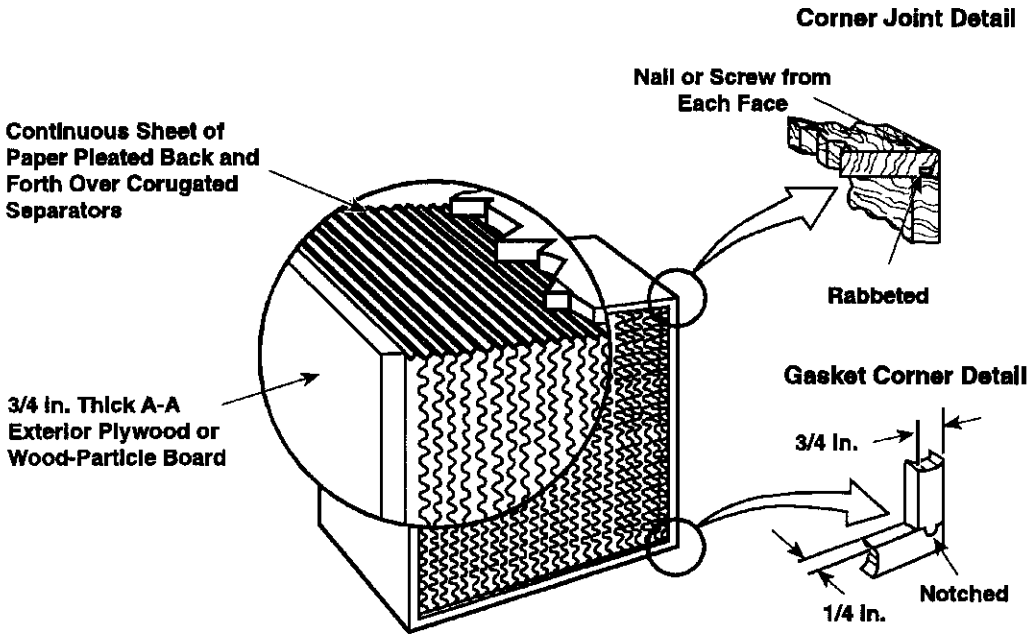
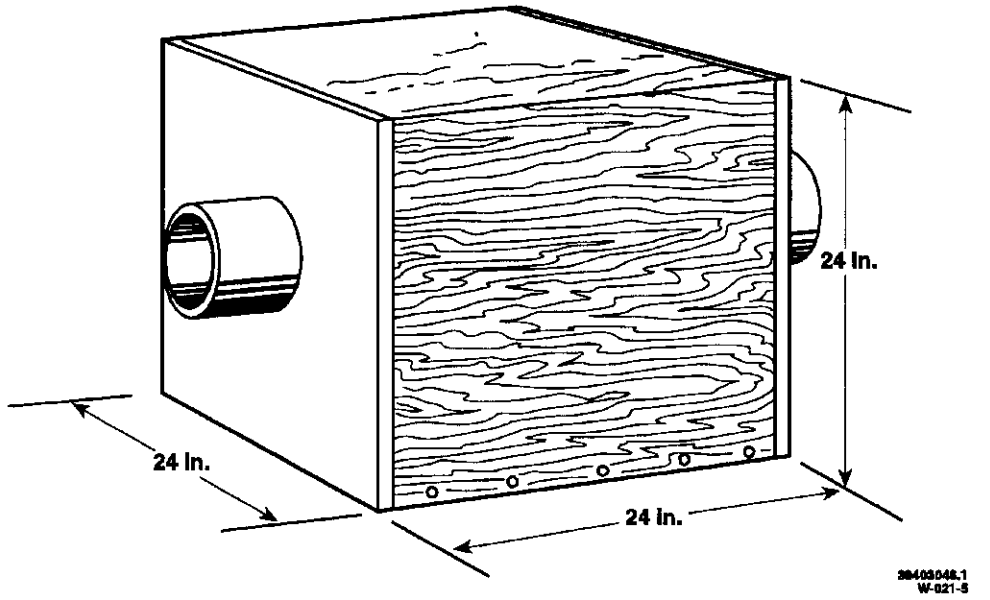


Figure 5-50. High-Efficiency Particulate Air Filter.

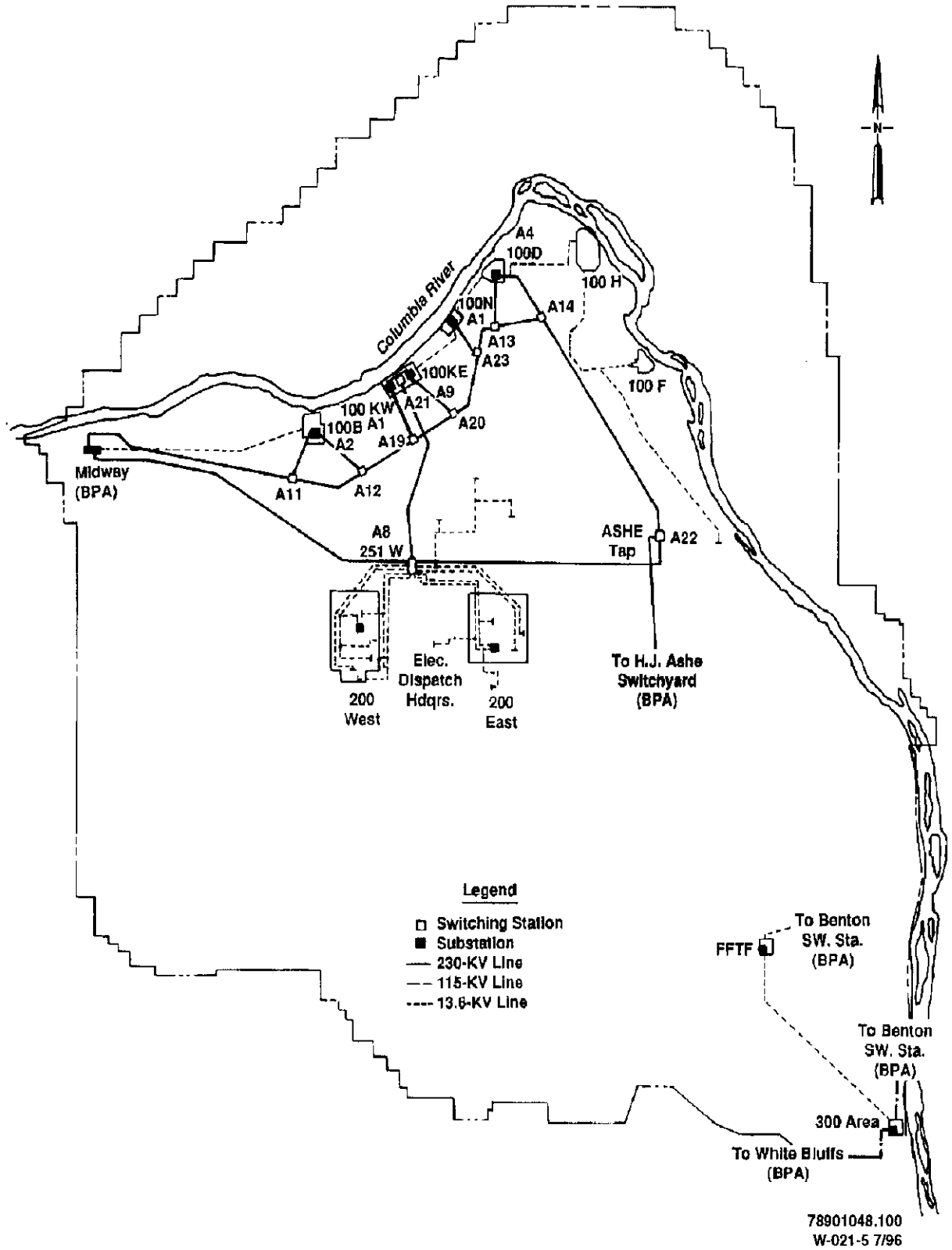


Wood-Cased HEPA Filter



Box HEPA Filter

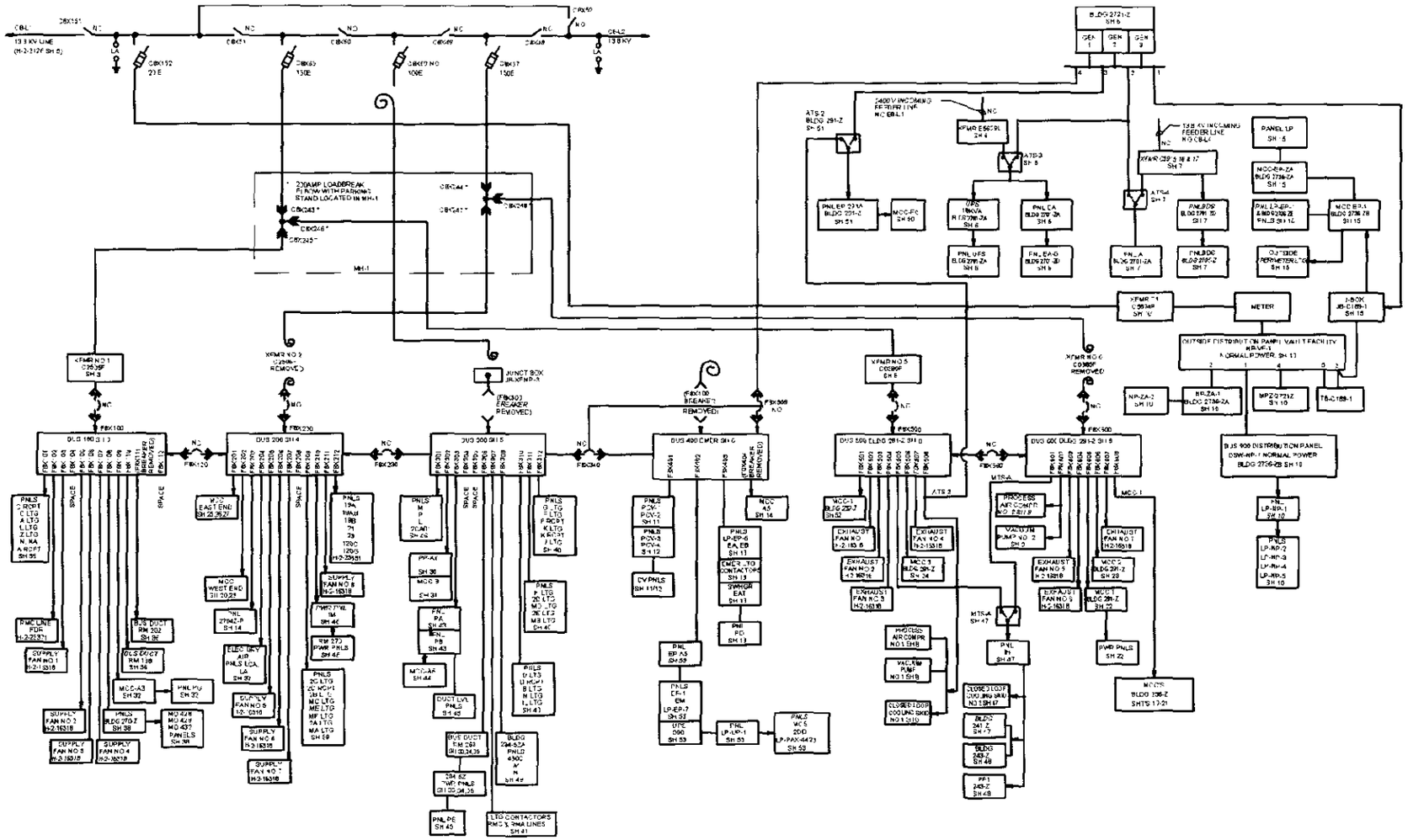
Figure 5-51. Distribution of Electrical Power at the Hanford Site.



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Figure 5-52. Electrical Distribution System.

(Ref. Dwg. H-2-26538, Sheet 2)



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Drawing needs updating for backup power system modifications and for backup power supplied from diesel-generators for exhaust fans EM-1 and EM-2.

Figure 5-53. Plutonium Finishing Plant Facility-Typical Uninterruptible Power Supply Installation.

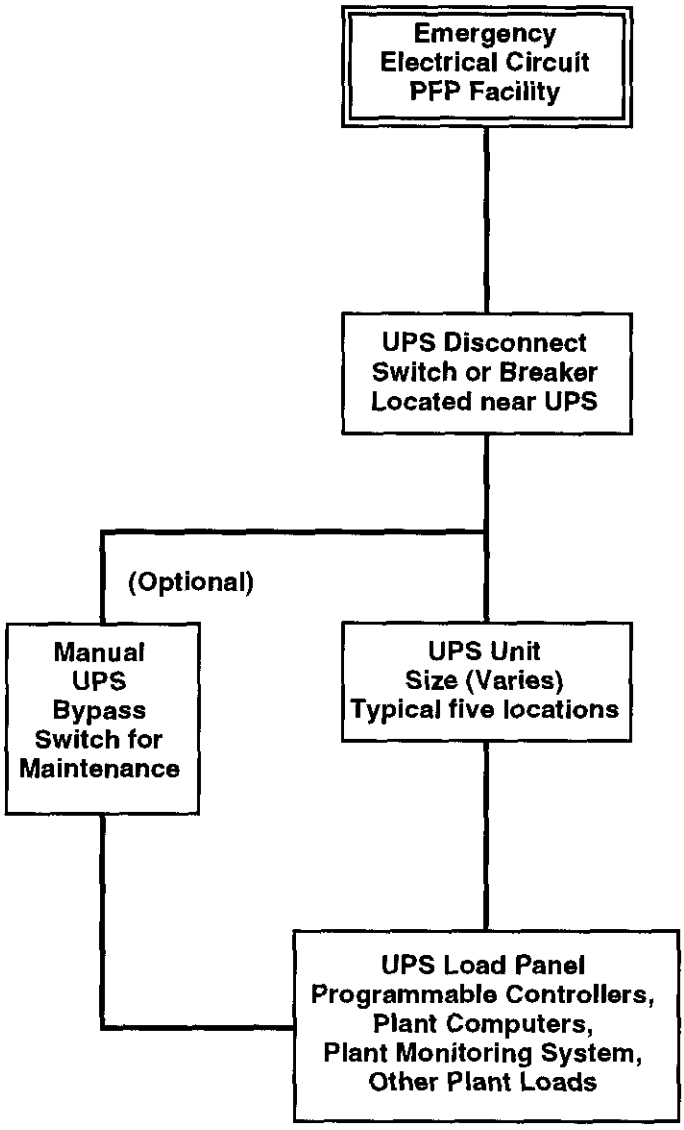


Figure 5-54. Location of External Chemical Storage Facilities at the Plutonium Finishing Plant.
(Figure needs updating re: current storage area uses per Table 5-20; 2735-Z should be 2734-Z; 2735-Z is located between HNO_3 tank and 2734-Z)

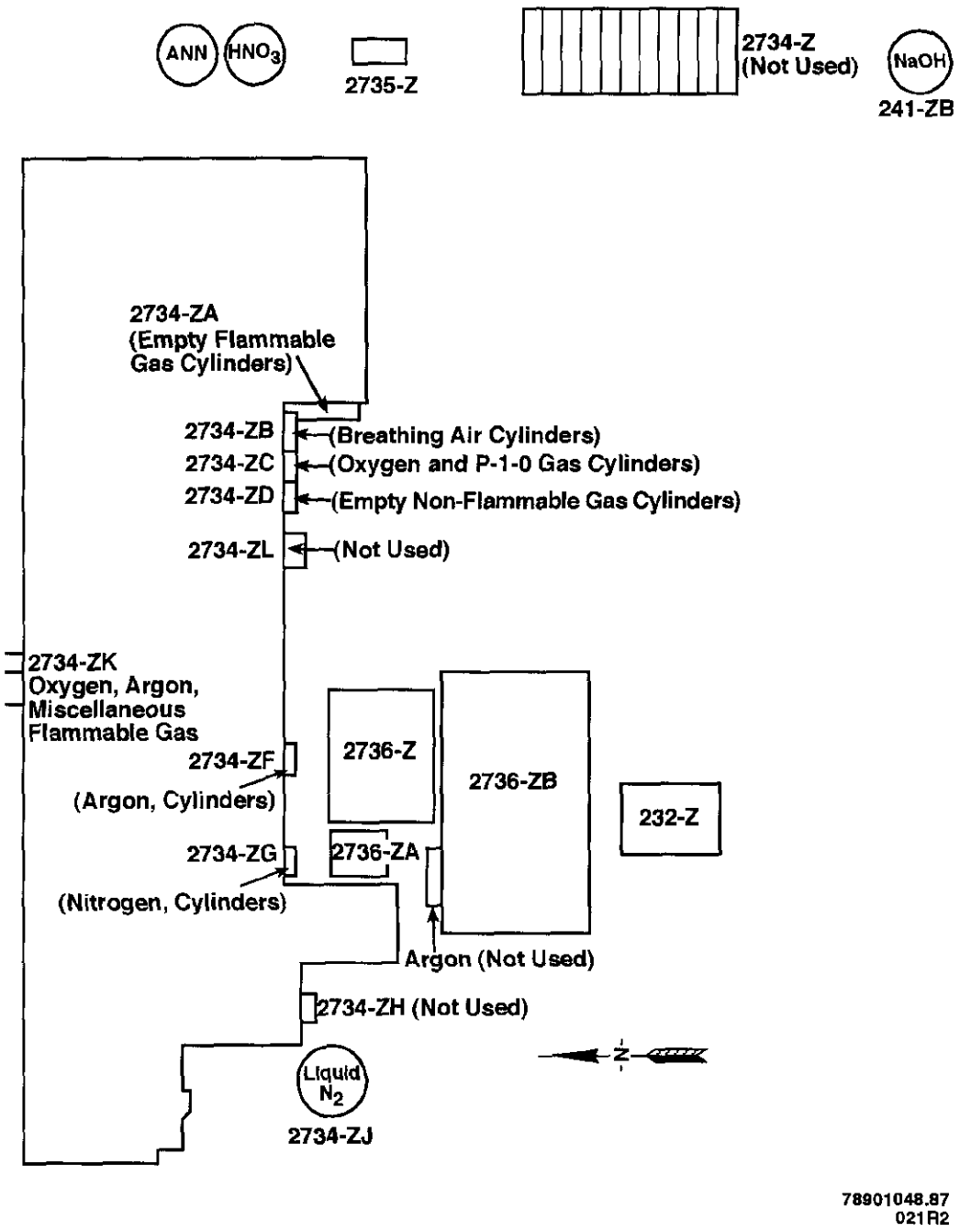


Figure 5-55. Simplified Schematic 26-in.
Mercury Process Vacuum System.

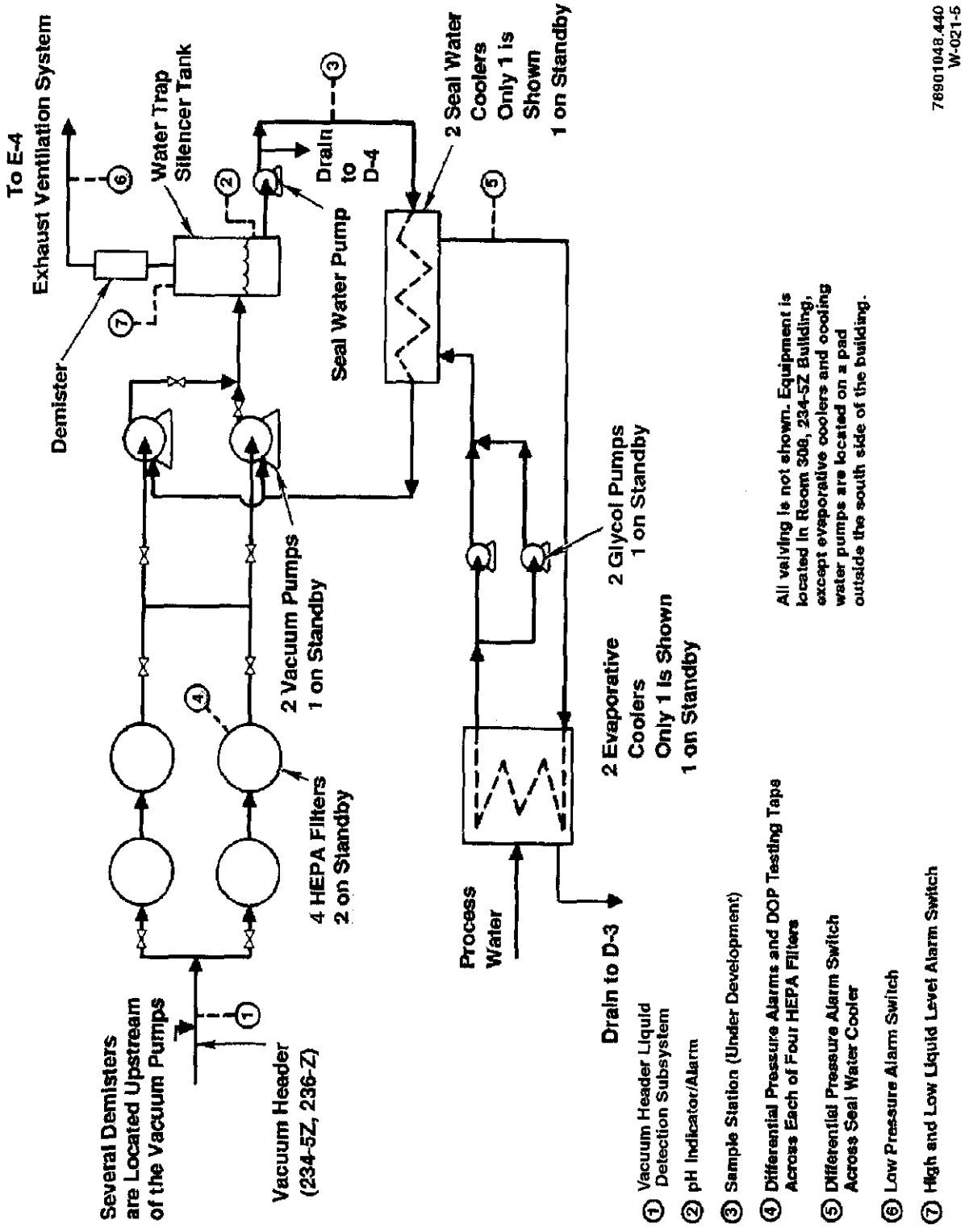


Figure 5-56. Plutonium Finishing Plant Steam Supply Flow Schematic.

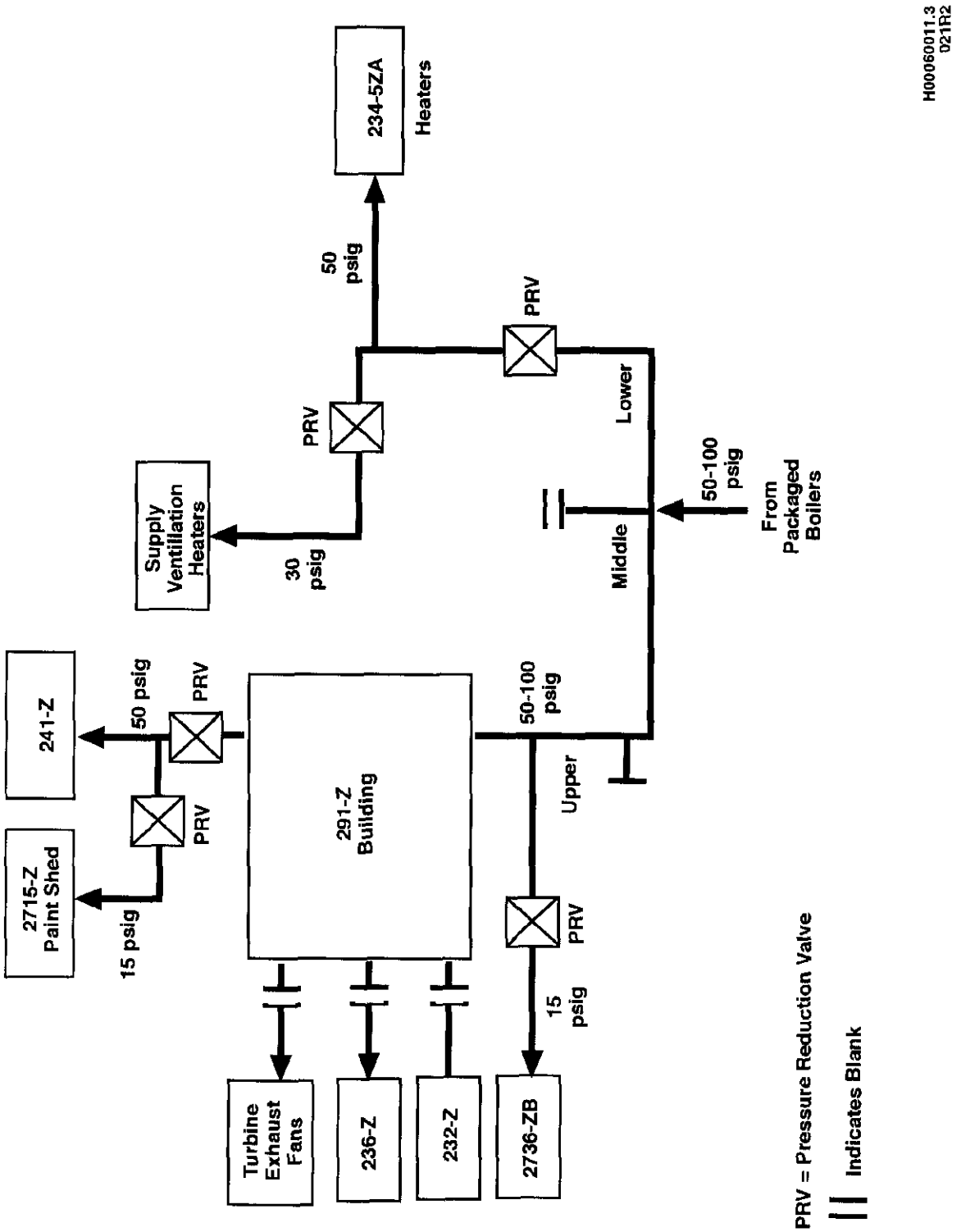


Figure 5-57. Building 236-Z Steam Supply Schematic.

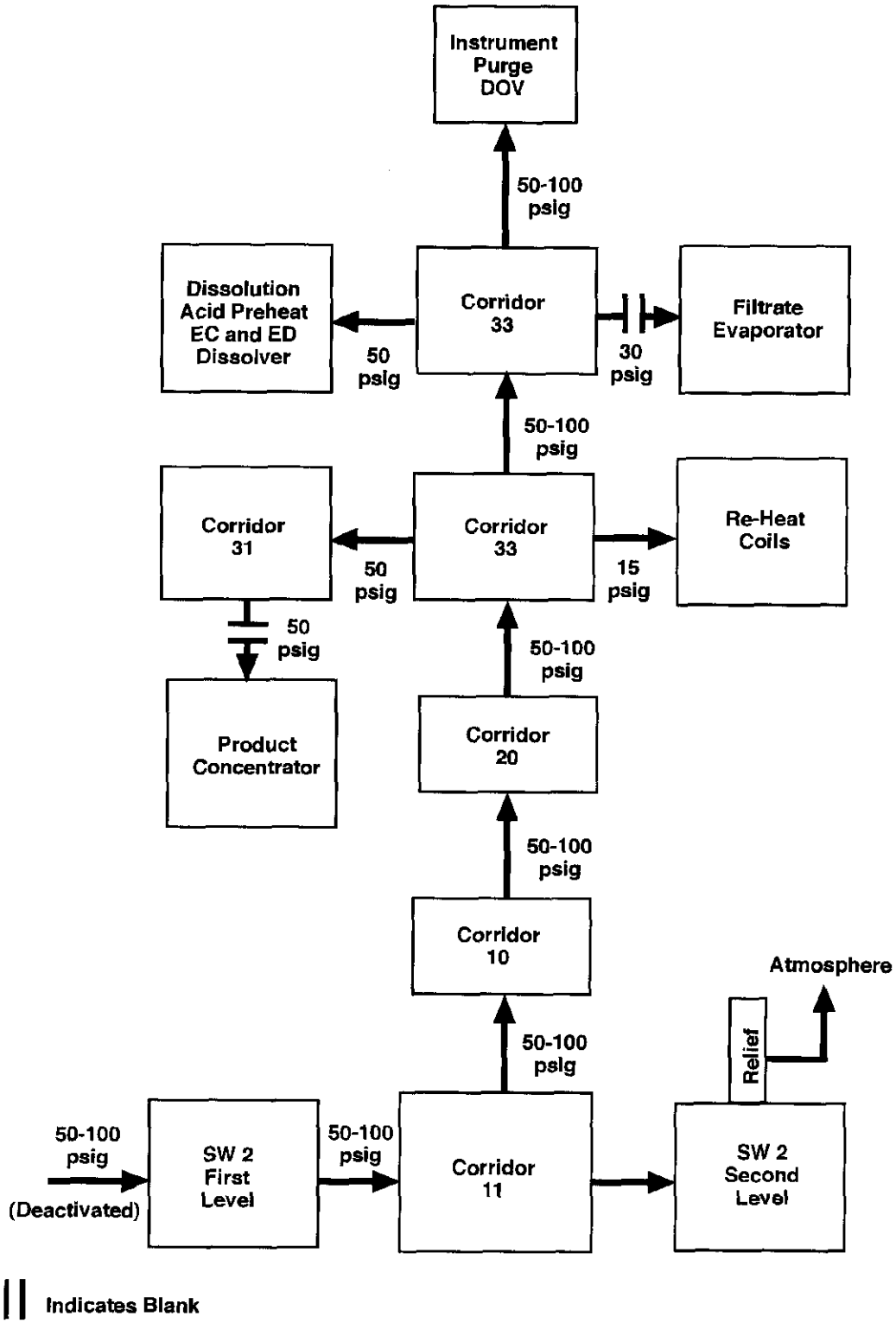


Figure 5-58. The 200 Areas Water Supply Schematic.

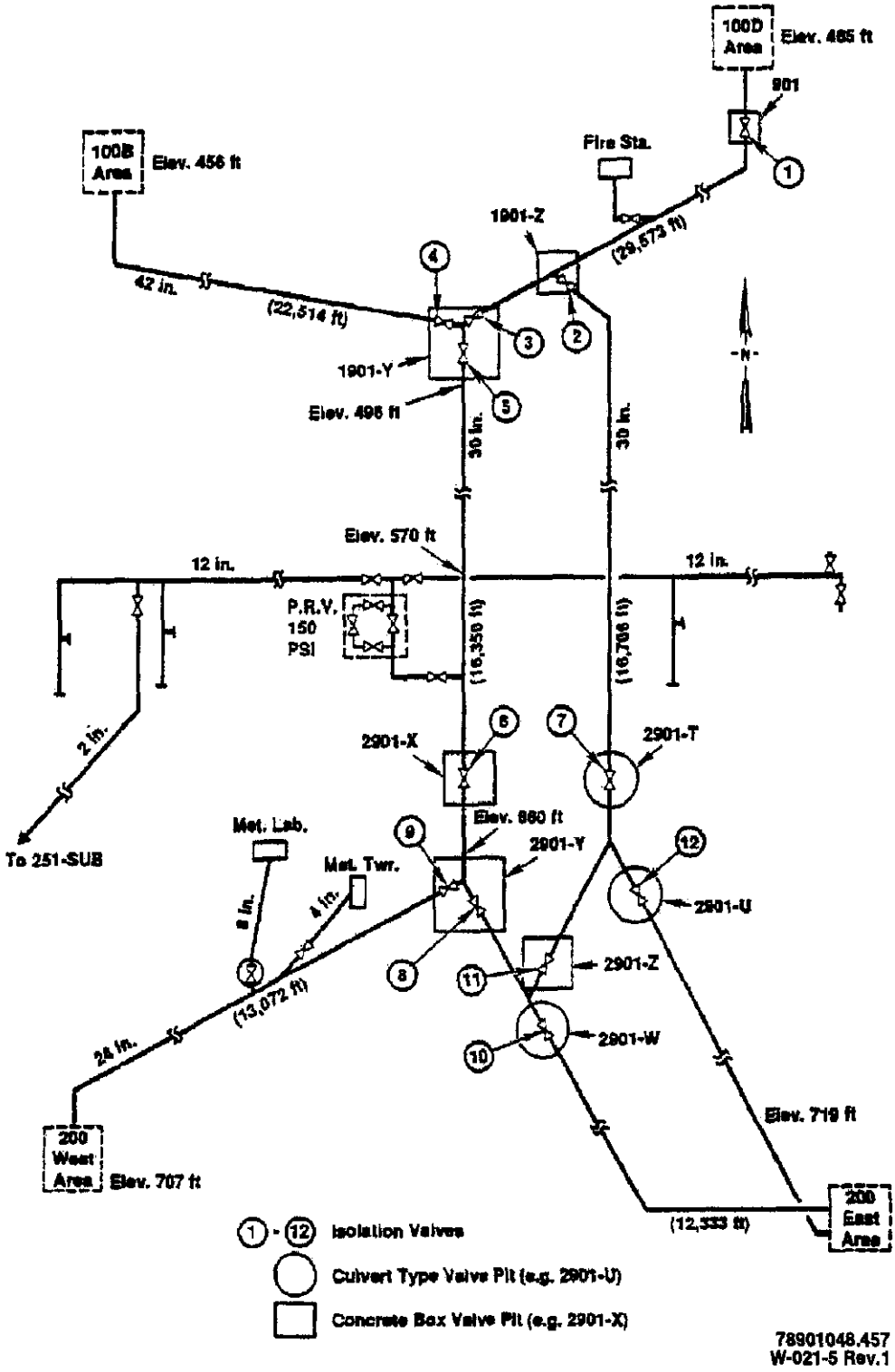


Figure 5-59. Sanitary Water Service Connections.

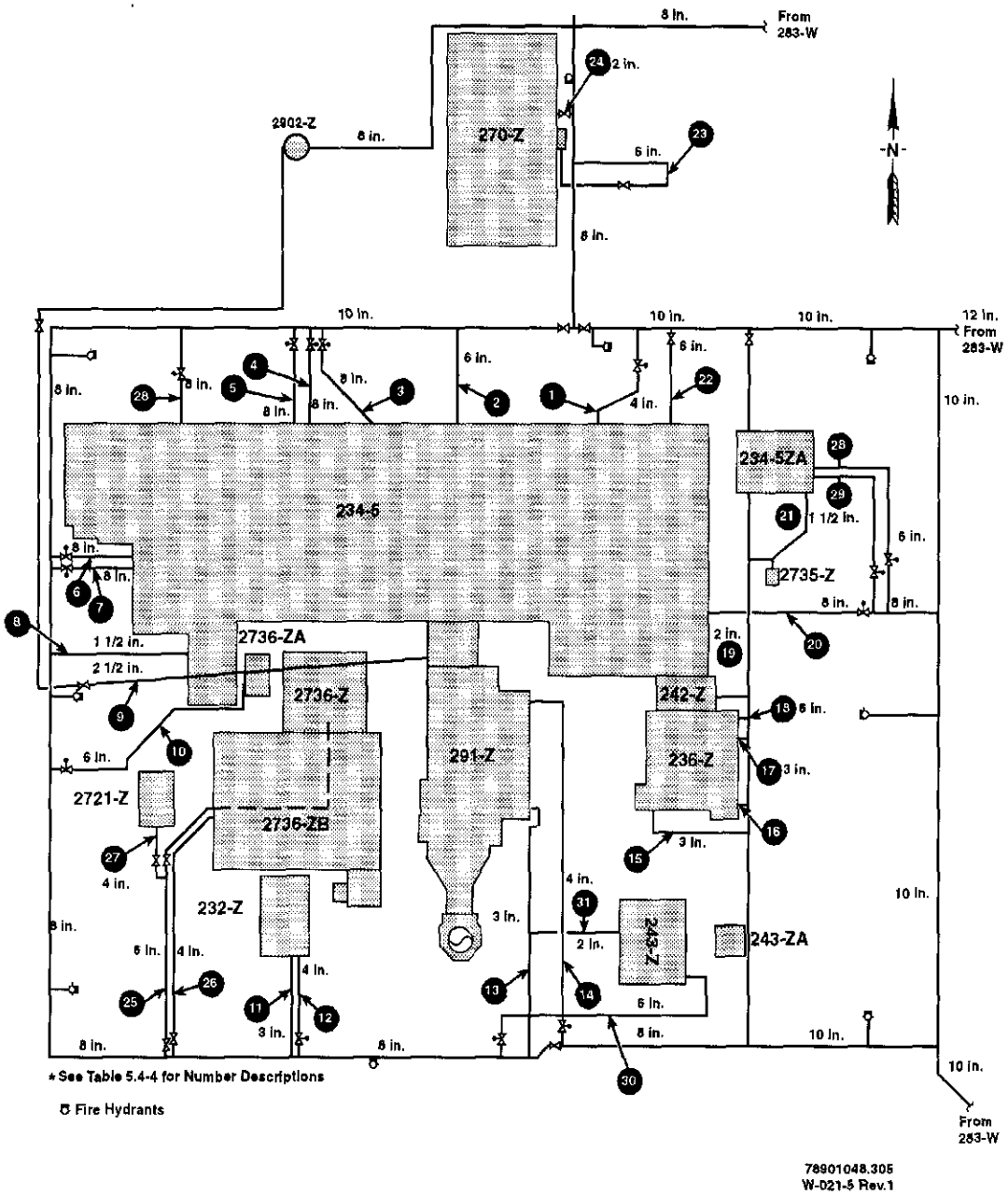


Figure 5-60. Plutonium Finishing Plant
Sanitary Sewer Systems.

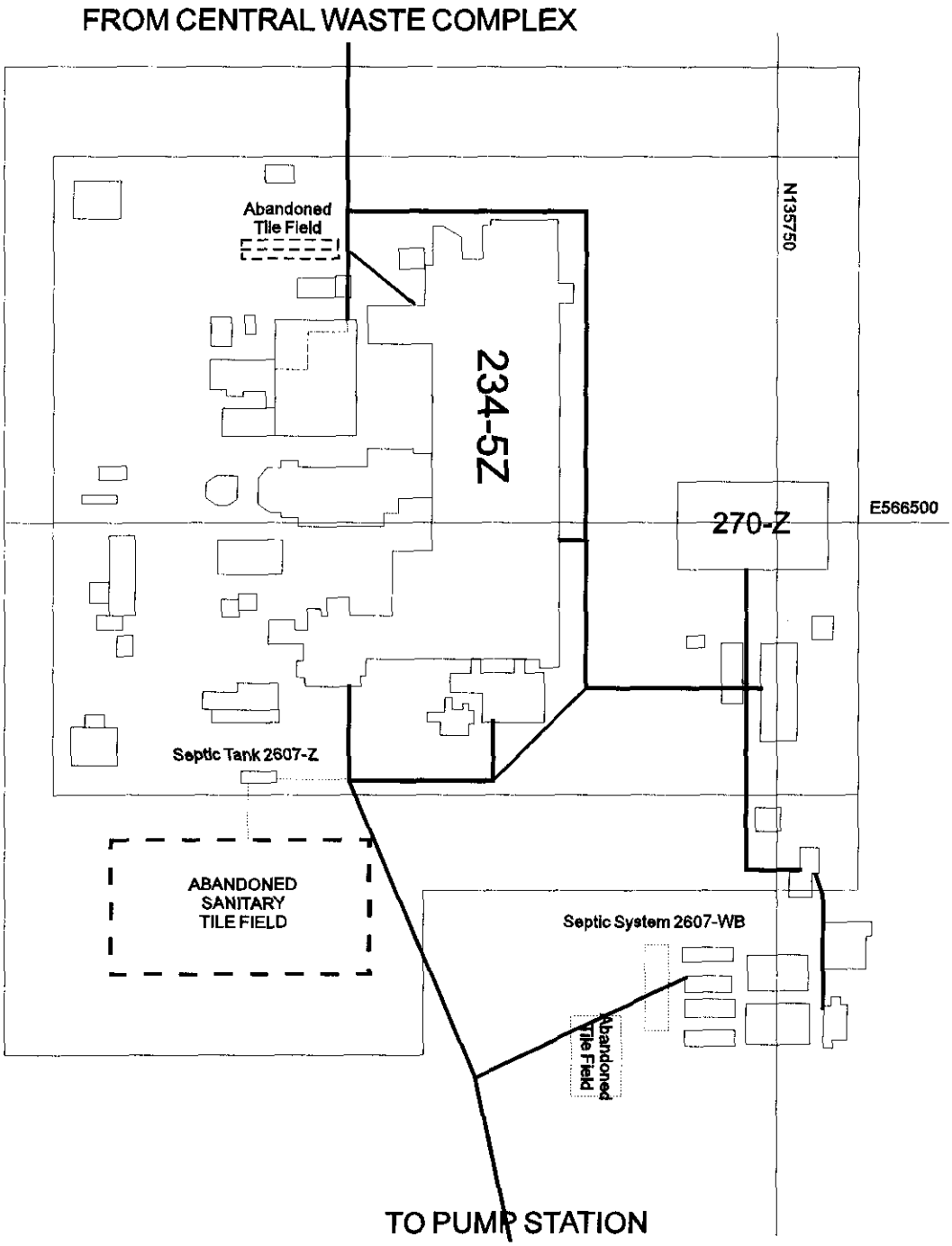


Figure 5-61. Facility Waste Water Stream.

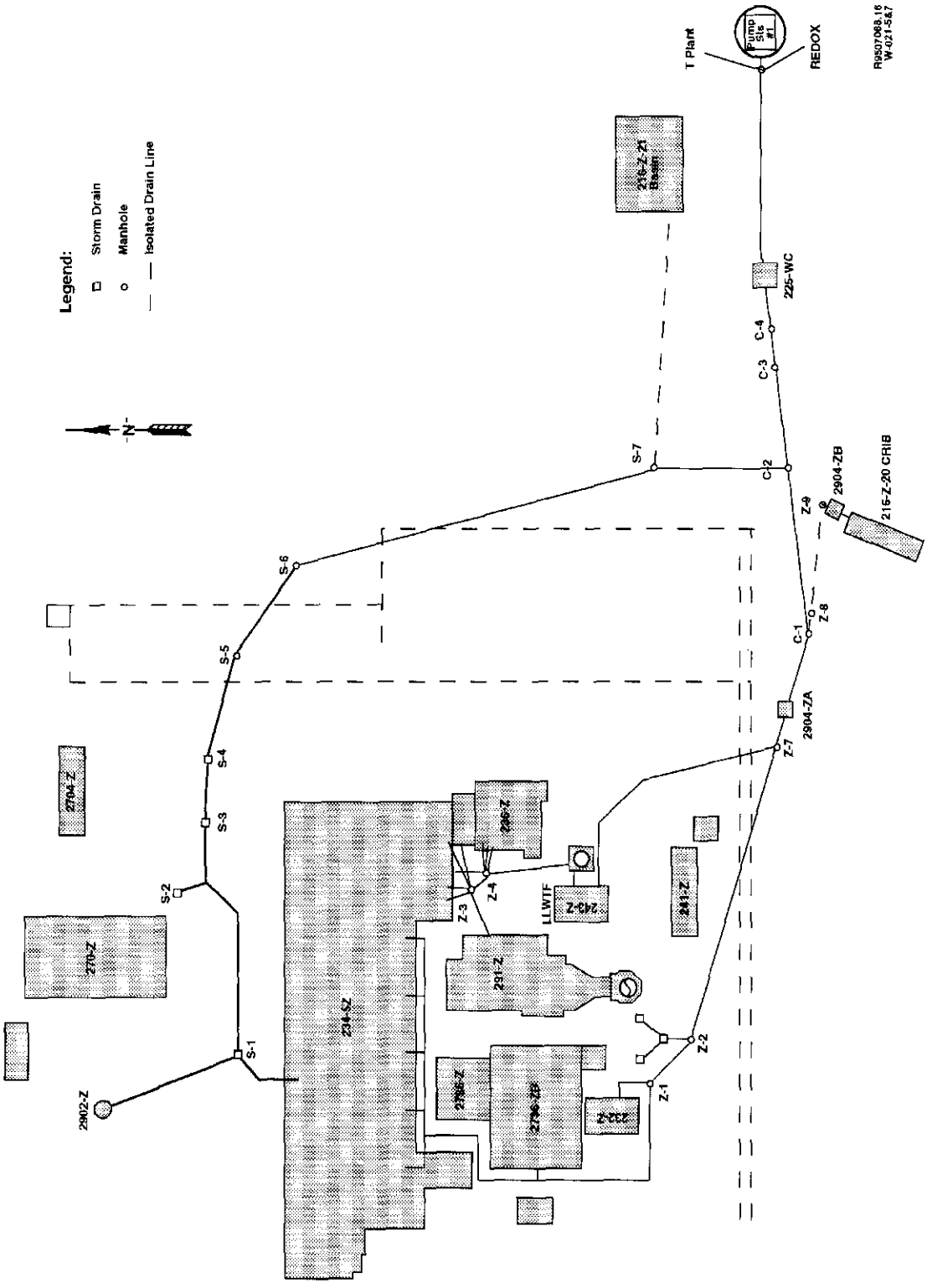


Figure 5-62. Building 241-Z Radioactive Waste Treatment System.

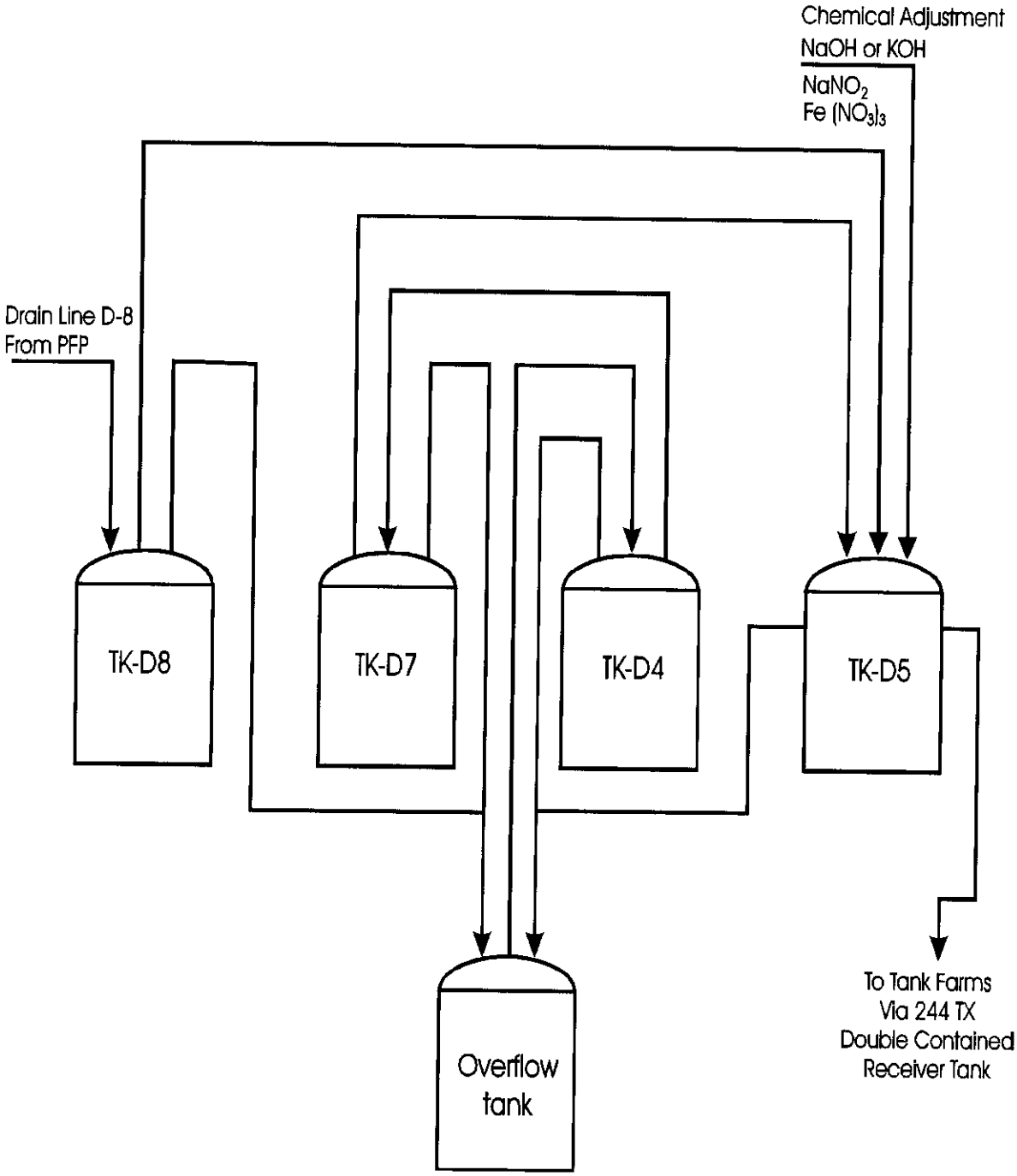


Figure 5-63. Plutonium Finishing Plant Suppression Coverage and Fire Zones.
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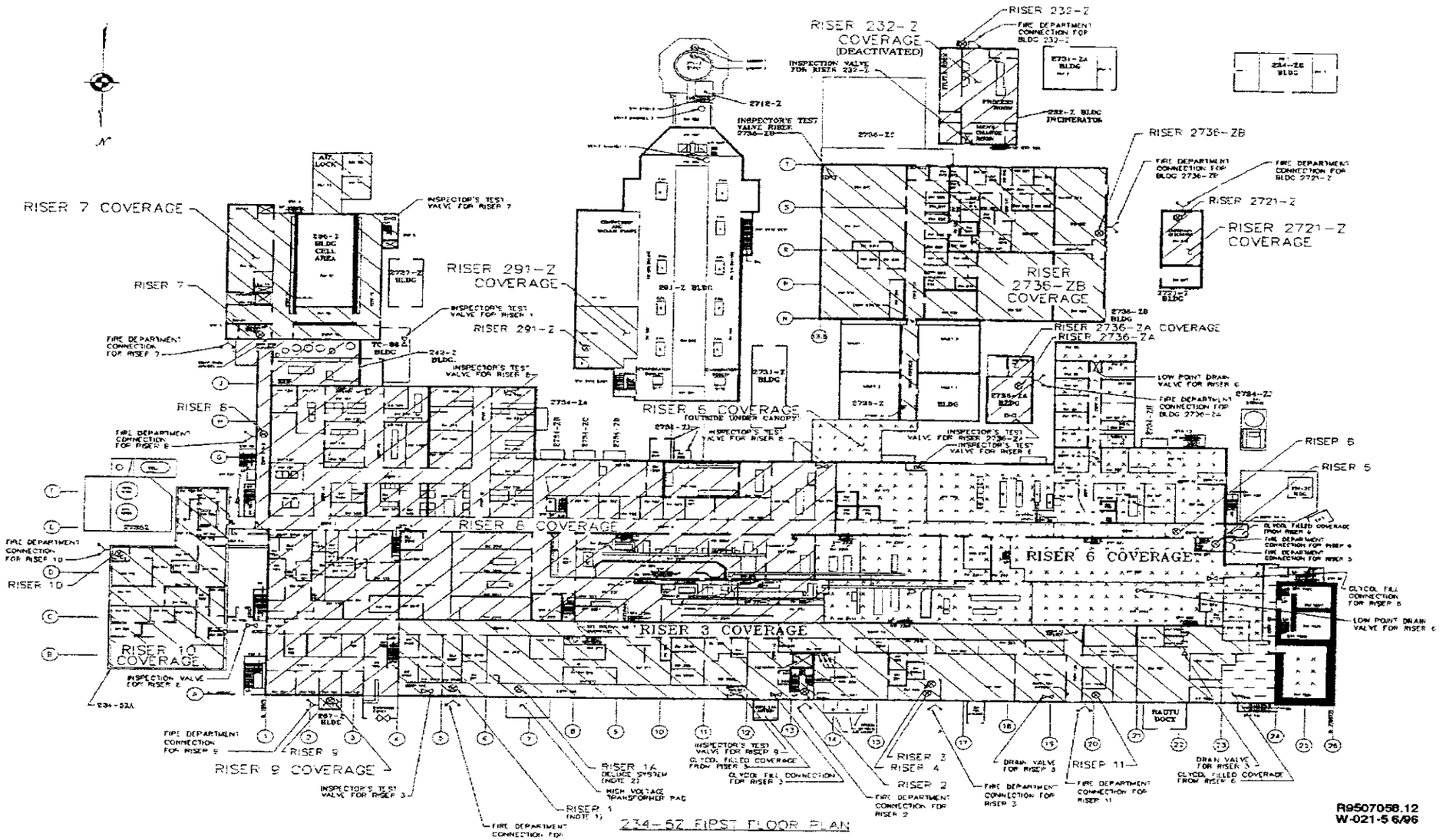


Figure 5-63. Plutonium Finishing Plant Suppression Coverage and Fire Zone.
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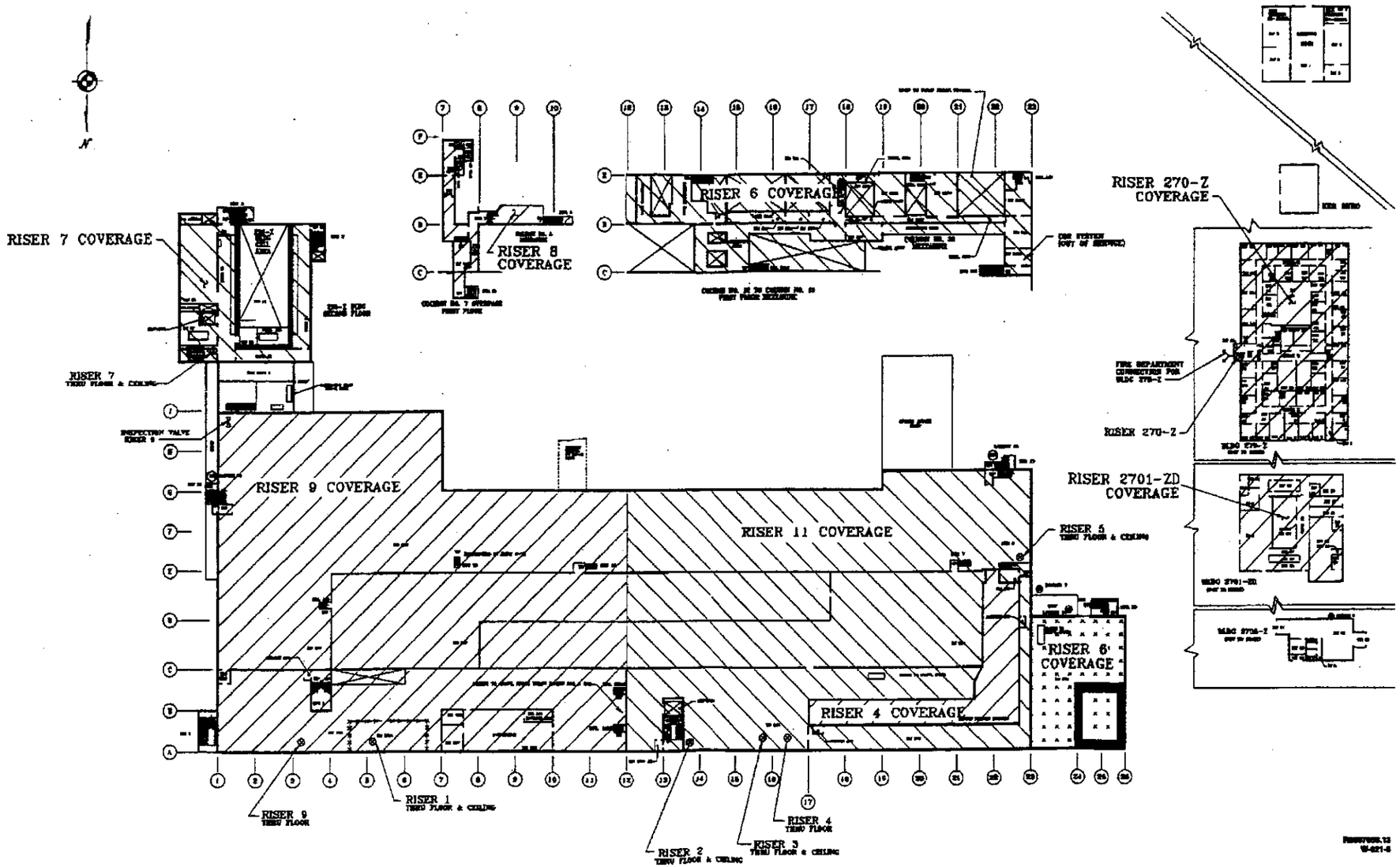
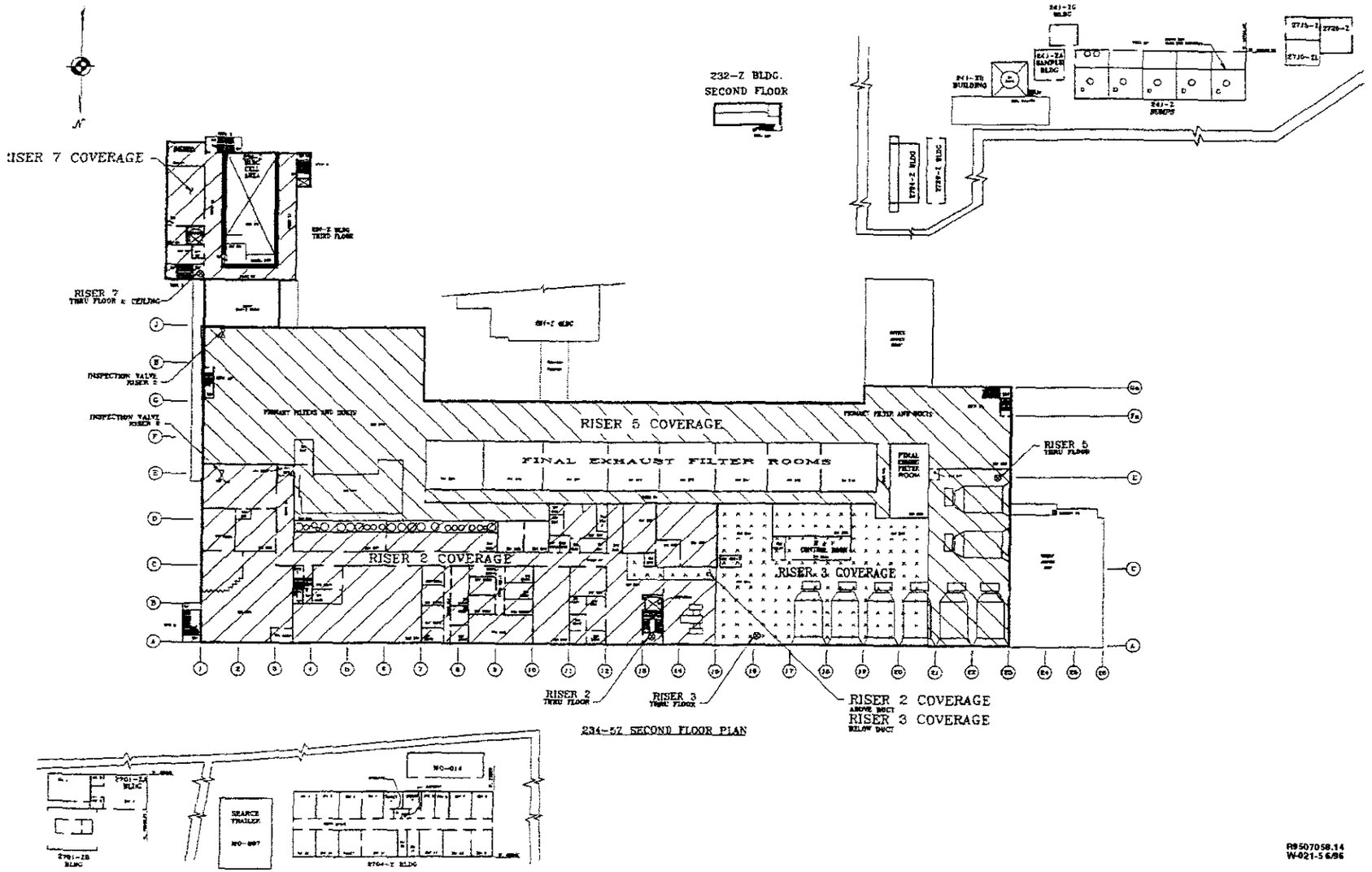


Figure 5-63. Plutonium Finishing Plant Suppression Coverage and Fire Zone.
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Figure 5-63. Plutonium Finishing Plant Fire Suppression Coverage and Fire Zones.
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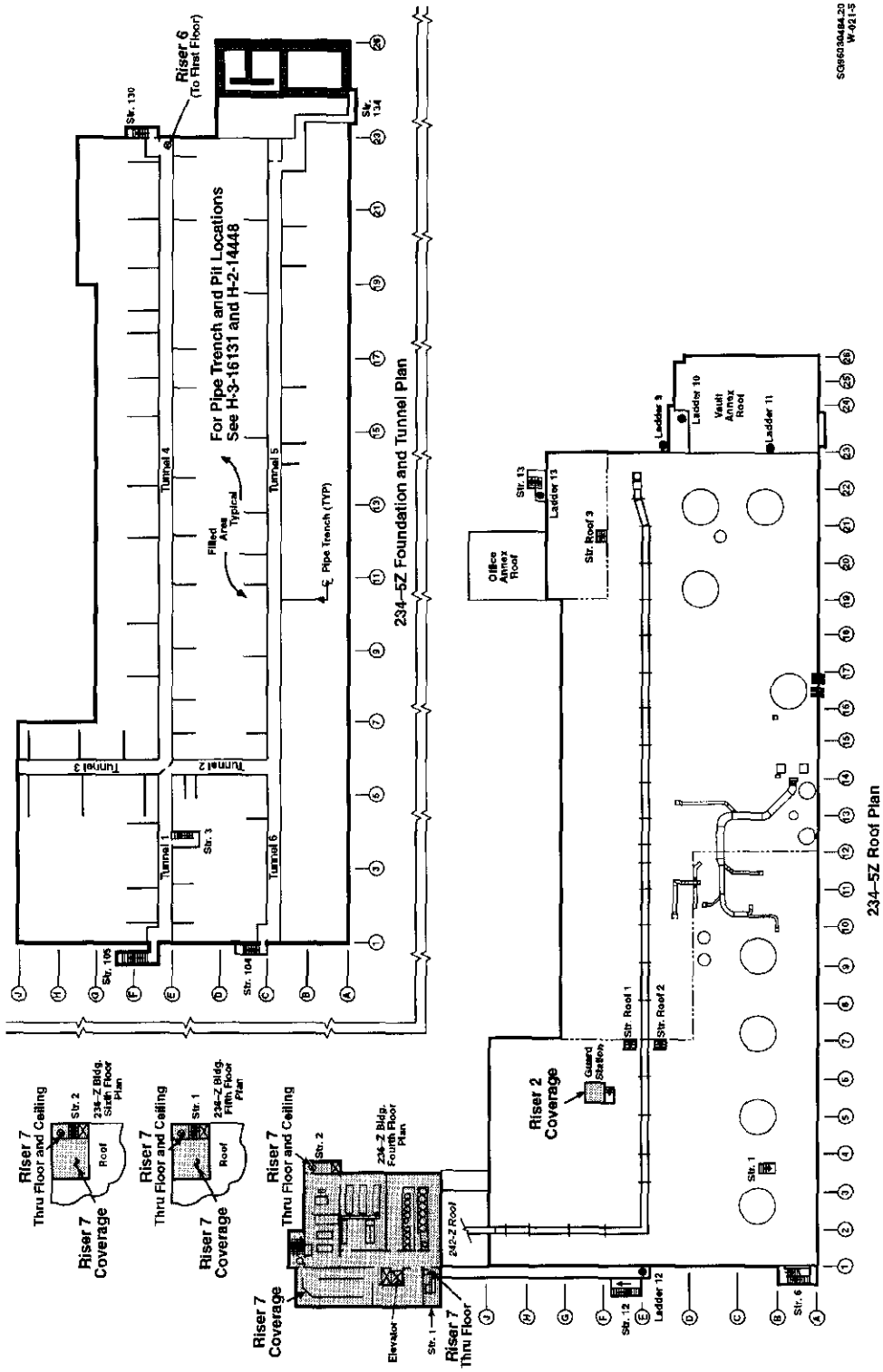


Figure 5-64. Chemical Preparation Room 40 (236-Z Building).
(Ref. Dwg. H-2-80249, Sheet 5)
(Needs to be updated to delete tank A-109)

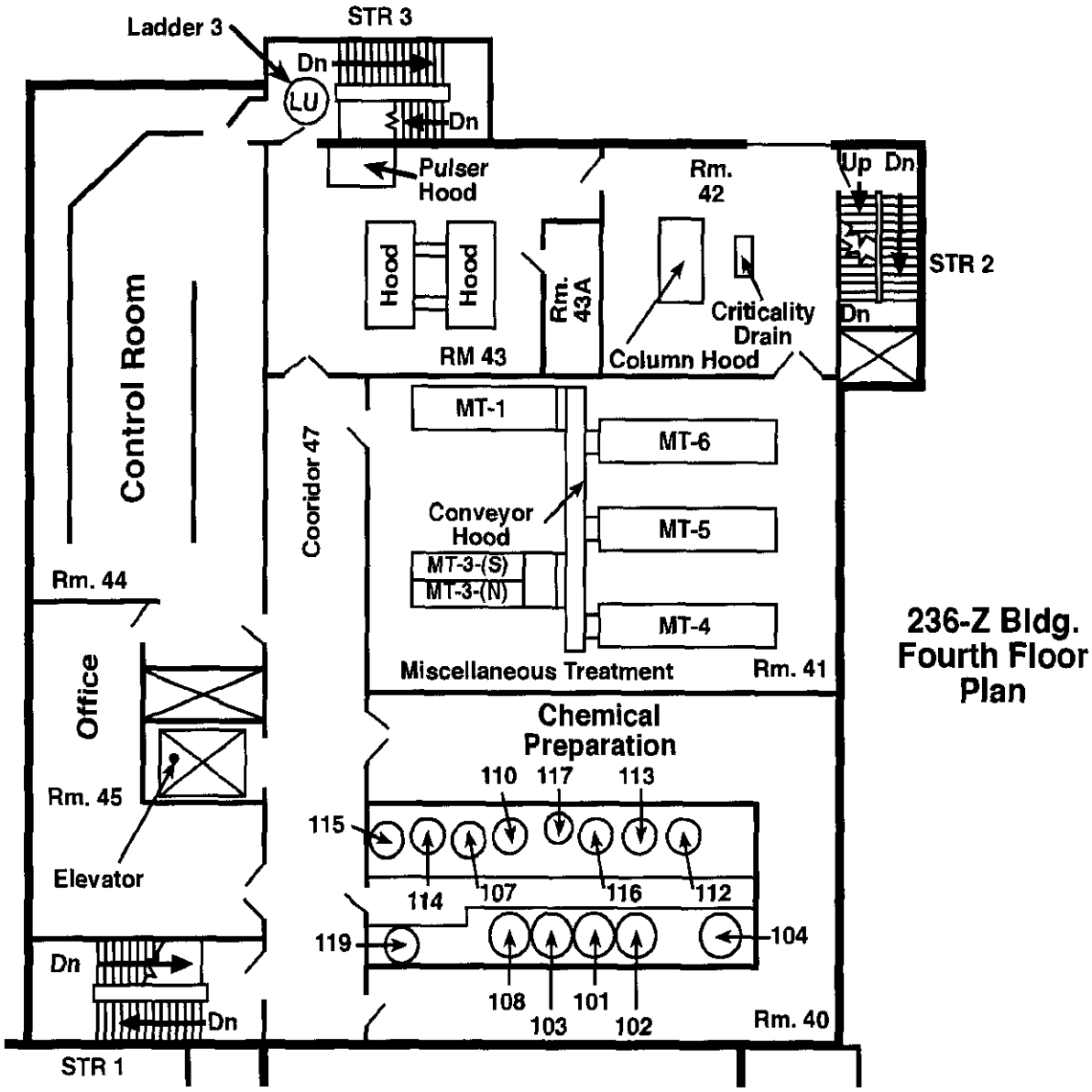


Figure 5-65. Glovebox HC-230C-2.

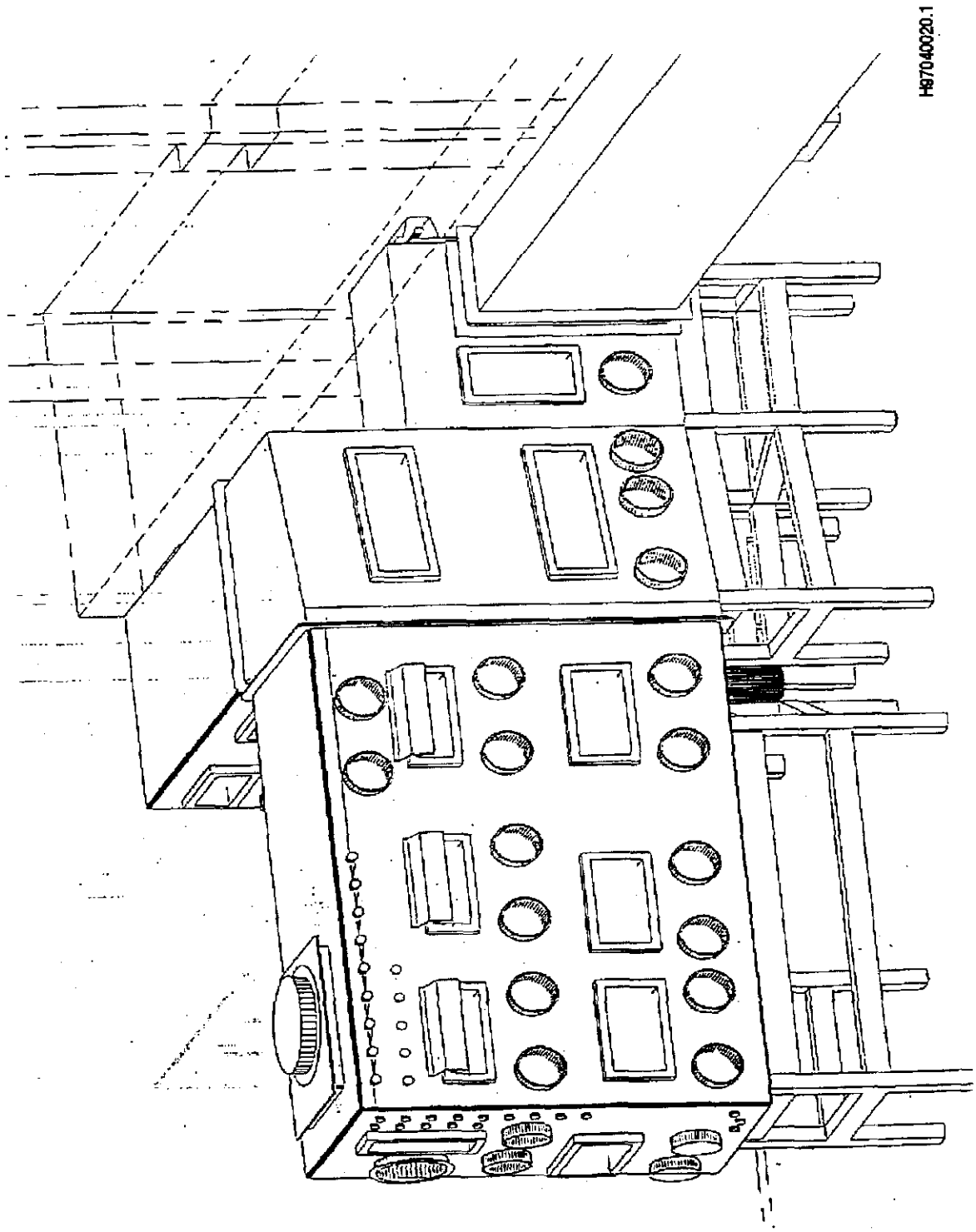


Figure 5-66. Glovebox HC-230C-2 - Production Vertical Denitration Calciner Flow Diagram.

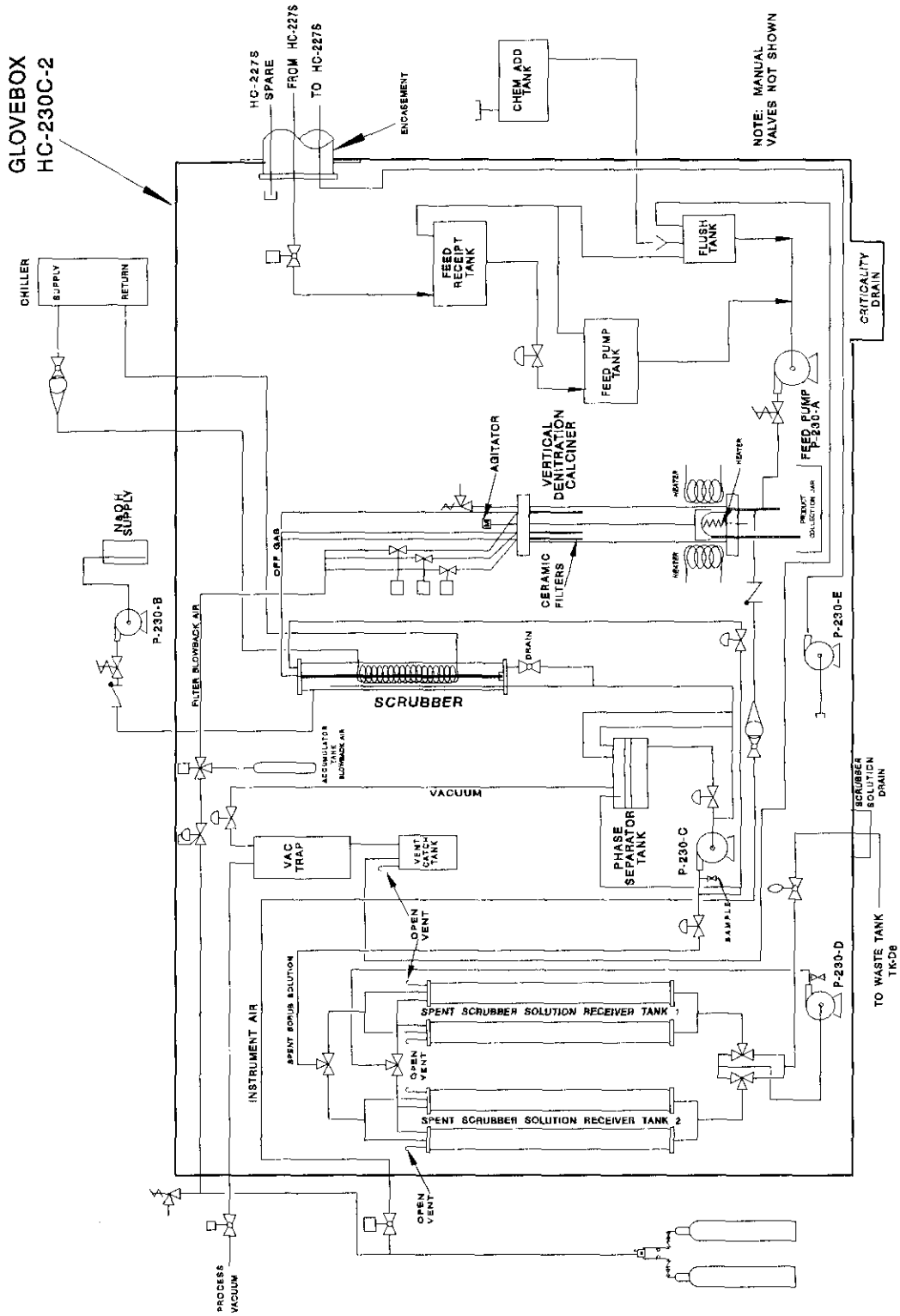
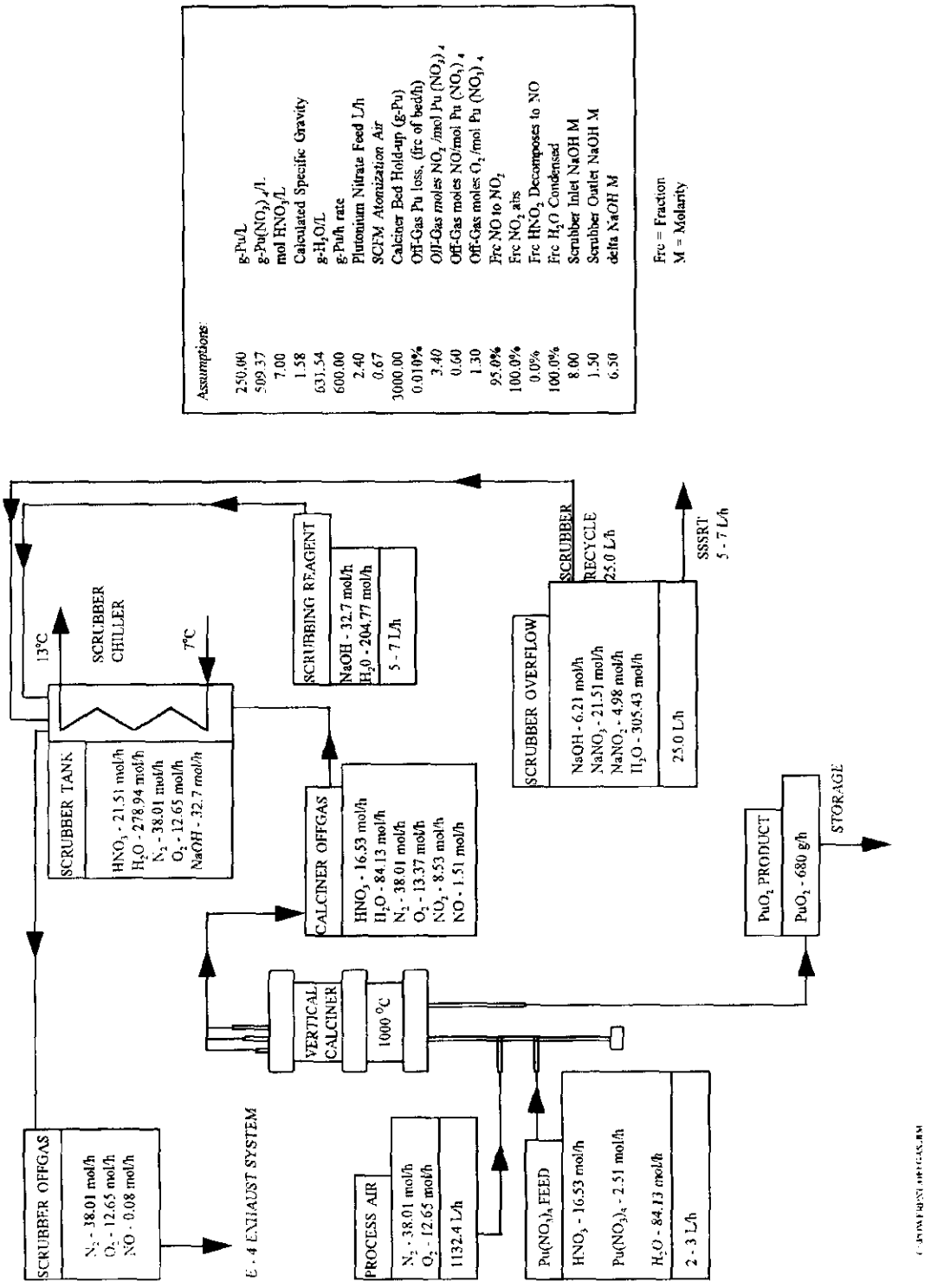


Figure 5-67. Production Vertical Denitration Calciner Process Flowsheet - Glovebox HC-230C-2.



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Figure 5-68. Schematic Diagram of Glovebox HC-227S and Hood HC-227T.

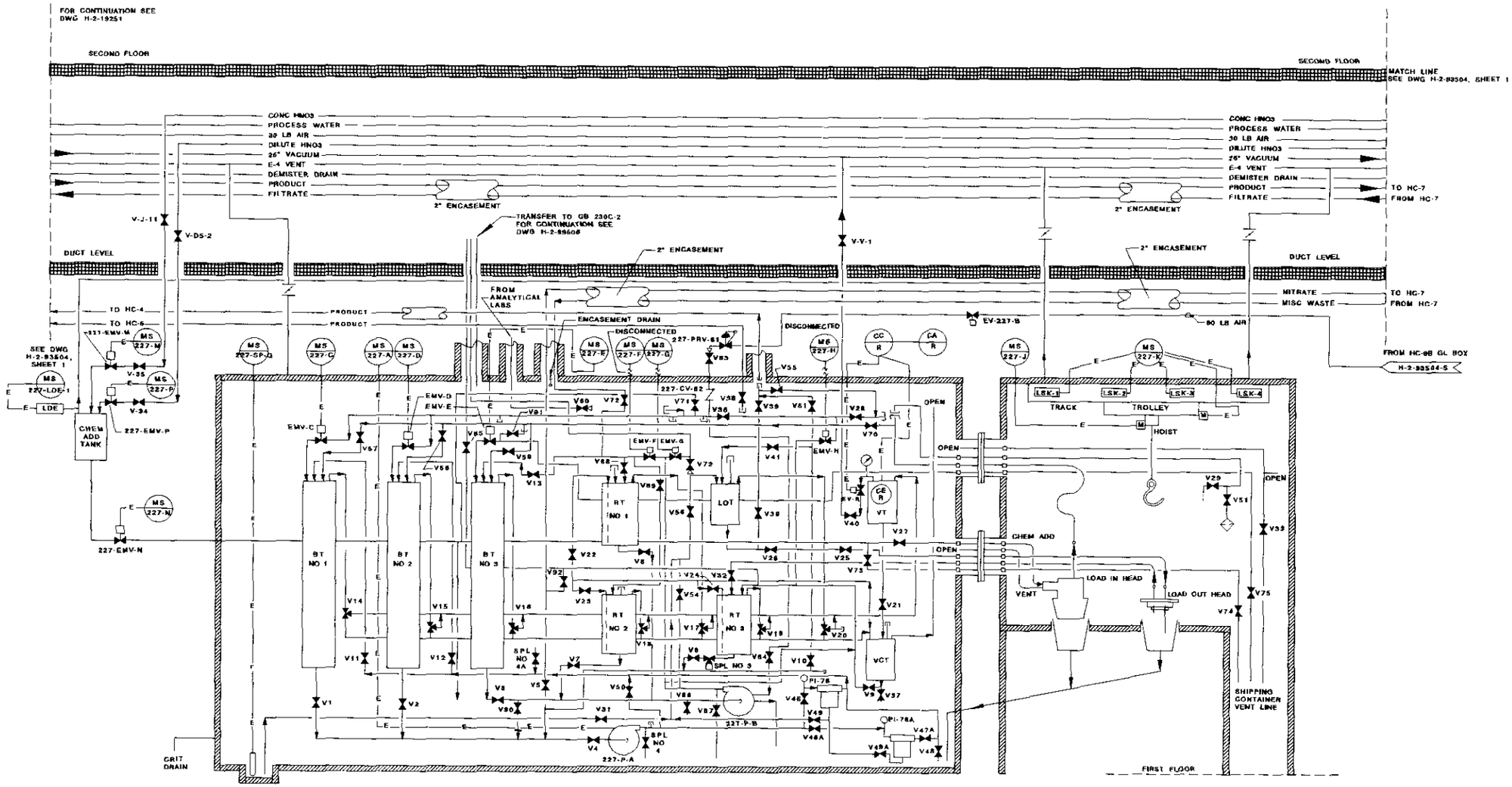


Figure 5-69. Stages of Pressurization of Pu Metal Containers.

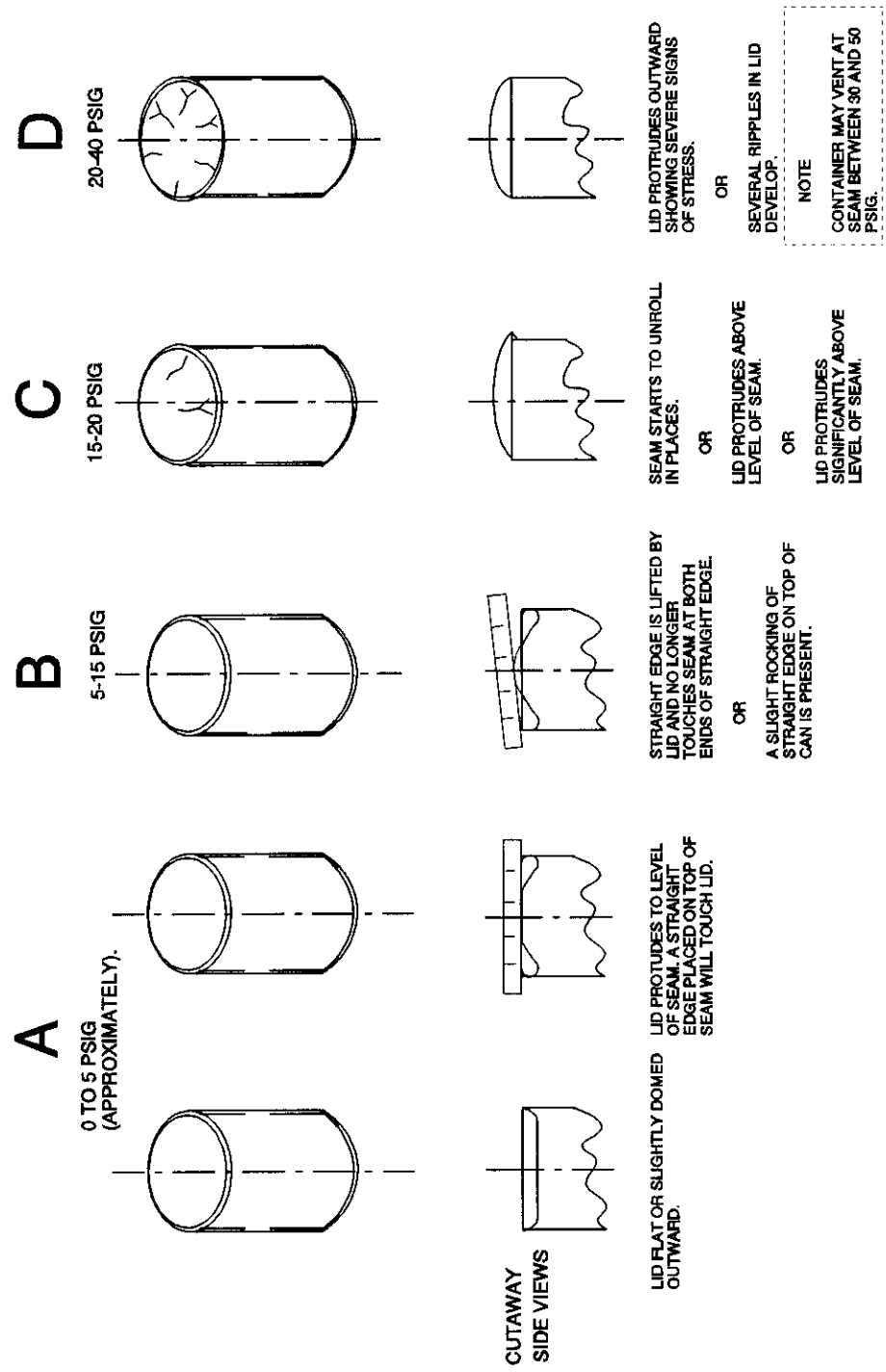
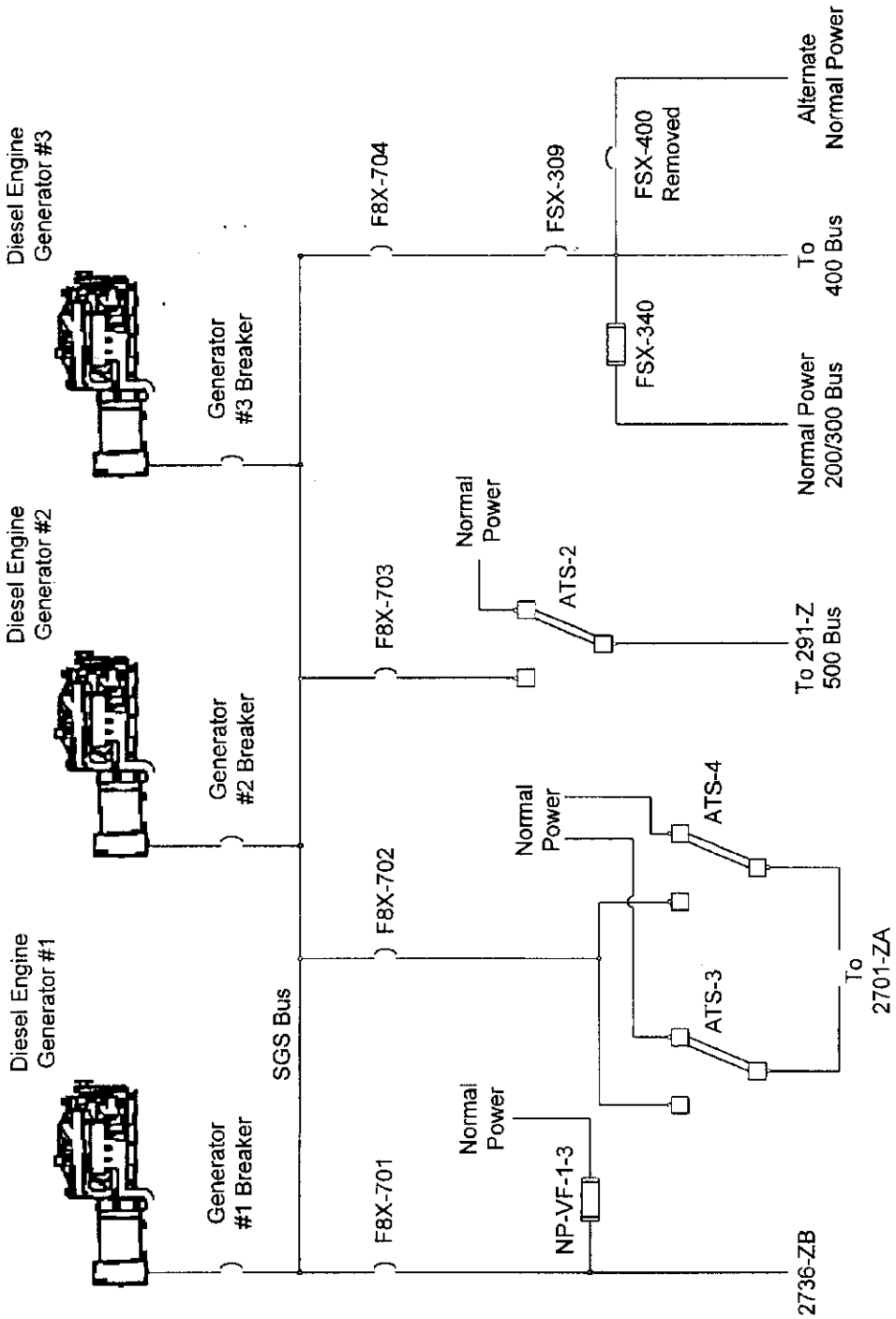


Figure 5-70. Standby Power System.



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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 6.0

PROCESS SYSTEMS

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 6.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) includes modifications for the following:

- Clarification of PR Can description and PR can handling
- Clarification of Seal-in/bag-out operations
- Incorporation of the Magnesium Hydroxide Precipitation Process
- Incorporation of the Bagless Transfer System

Other minor changes include editorial changes and additional clarifications.

The following summarizes the active and inactive processes performed at the PFP. Process and systems descriptions are provided for both active and inactive processes. The active systems are currently or will be authorized for operation following approval of the FSAR revision 2 and controls implementation. The inactive descriptions are retained for historical purposes to support future D&D activities.

Active Processes.

- Plutonium material storage and support activities in the 2736-Z, 2736-ZA, and 2736-ZB Buildings, 2736-ZD vault, and the gloveboxes and vaults in the 234-5Z Building
- Reactive plutonium-bearing material stabilization in the 234-5Z Building using Glovebox HC-21C and HA-21I
- Waste packaging and reactive residue storage
- Transfer operations in gloveboxes HC-227S/T in the 234-5Z Building
- Low-level waste and waste water treatment in the 241-Z Complex and 243-Z Building, respectively
- The PFP Analytical Laboratory (PFP AL), Standards Laboratory, and Plutonium Process Support Laboratory (PPSL) in the 234-5Z Building
- Facility support systems [e.g., heating, ventilation, air conditioning (HVAC), radiation monitoring, steam, electricity, etc.].
- Bagless Transfer System operations in Glovebox HA-53BTS in the RMA Line in the 234-5Z Building
- Magnesium Hydroxide Precipitation Process operations in Gloveboxes HC-230C-3 and HC-230C-4 in the RMC Line in the 234-5Z Building.

Inactive Processes.

- Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner and Laboratory Prototype Calciner in the 234-5Z Building
- Plutonium recovery in the 236-Z Building
- Plutonium conversion in the 234-5Z Building
- Waste treatment in the 242-Z Building
- Laboratory waste concentrator.

It is noted that various sections of Chapter 6.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner in the Plutonium Process Support Laboratories. Operation of either the production calciner or laboratory calciner for solution stabilization is not authorized at this time and the related portions of Chapter 6.0 will be updated, if necessary, prior to initiation of operations.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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6.0 PROCESS SYSTEMS

6.1 INTRODUCTION

Since the beginning of operations in 1949, the Plutonium Finishing Plant (PFP) has performed numerous diversified plutonium processing, handling, storage, and support operations. All operations at PFP are conducted in accordance with reviewed and approved operating procedures, which are listed in Table 6-1. Current operations include the following:

- Plutonium material shipping/receiving
- Plutonium material storage
- Remote Mechanical A (RMA) and Remote Mechanical C (RMC) Line operations, including reactive plutonium-bearing material stabilization, plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner (VDC) and the Magnesium Hydroxide Precipitation Process and plutonium material packaging using the Bagless Transfer System
- Laboratory support
- Facility cleanout activities
- Radioactive waste handling.

These operations (with the exception of radioactive waste handling, which is discussed in Chapter 7.0), and their associated support systems are described in this chapter. Discussion of two inactive operations, the former RMA and RMC Line processes for plutonium conversion and the Plutonium Reclamation Facility (PRF) process systems for plutonium recovery, is presented. These operations are included as plutonium recovery and conversion, and were historically the principal operations conducted at the PFP. The residual quantities of radioactive material remaining from these operations are important considerations of the safety basis. The 232-Z Waste Incinerator Facility and the 242-Z Waste Treatment Facility are also addressed.

The operations, process chemistry and associated support systems for the Magnesium Hydroxide Precipitation Process are described in the Magnesium Hydroxide Precipitation Process addendum to this FSAR (Carson 2000). The operations associated with packaging of stabilized plutonium using the Bagless Transfer System (BTS) are described in the calculation notes for the BTS (FH 2000). No further discussion of either process is provided in this chapter.

6.2 PLUTONIUM MATERIAL SHIPPING/RECEIVING

6.2.1 Process Description

6.2.1.1 Narrative Description.

6.2.1.1.1 Shipping. Only solid plutonium-bearing materials are shipped offsite. The materials are contained in sealed cans in compliance with the certificate of compliance (COC). The steel cans are of the food packaging type, referred to as "food pack cans" (see Section 6.3.3.1). The cans containing metal buttons, which have been held in storage for an extended period of time, are transferred to room 636, Building 2736-ZB, and moved into the repackaging glovebox. The plutonium metal button is removed from the package, inspected, and any loose oxide is removed by brushing with a paint brush. The button is then weighed, recanned, bagged out, and overpacked in two food pack cans.

The PuO_2 packages are also inspected. If required, the can is repackaged in the repackaging glovebox.

The packages to be shipped are placed in shipping containers and moved to the 2736-ZC loading dock where they are placed in cargo restraint transporters, which are secured in the safe secure transport (SST) truck or the Exclusive Use Vehicle for shipment.

6.2.1.1.2 Receiving. Most shipments of plutonium material are received at the 2736-ZC loading dock. One exception is the Fast Flux Test Facility (FFTF) fuel, which is stored in shipping containers in vault 192-A, and received at the door 135 dock of the 234-5Z Building. Offsite shipment to the PFP requires a preapproved shipping plan that complies with the PFP storage specifications. Shipment is made by SST truck. The shipping documents are checked, and the shipping containers are brought into the 2736-ZB Building for inspection, weighing, and nondestructive analysis (NDA) measurement of fissile material contents (see Section 6.5.1.1.4 for a description of the NDA Laboratory). If the material requires repackaging, this is also done in the 2736-ZB Building. If the materials are determined to be unstable (gas evolution, liquid, etc.), a recovery plan is developed and implemented that provides for interim safe storage and stabilization of the material. Stable materials are moved to the vaults in the 2736-Z Building for storage until final disposition. Section 6.2.3 provides details of this operation.

Load-In/Load-Out Process. The load-in/load-out (LI/LO) of plutonium nitrate [$Pu(NO_3)_4$] solutions is performed in the 234-5Z Building, room 227, in glovebox HC-227S and hood HC-227T. Hood HC-227T is primarily used for the vacuum transfer of solutions between product receiver (PR) cans and other containers in the hood and tanks in glovebox HC-227S. Glovebox HC-227S is used to blend and transfer plutonium nitrate solutions to smaller containers (e.g., 4.2 L polyjugs) for transport to the Plutonium Process Support Laboratories (PPSL). The glovebox is also used to blend, sample and transfer Pu nitrate solutions to glovebox HC-230C-2 in room 230C for solution stabilization operations using the Production VDC process. Solutions may also be transferred from glovebox HC-230C-2 to glovebox HC-227S. Additional

information on the LI/LO of plutonium nitrate solutions is found in Section 6.2.3.

Glovebox HC-227S is also the source of plutonium nitrate solutions for processing in the Laboratory Prototype Calciner in Glovebox 188-1 in the PPSL. The equipment and process involved in the transfer of solutions to the laboratory calciner are described the Laboratory Prototype Calciner addendum to this FSAR.

6.2.1.2 Flowsheets. Plutonium material is routinely shipped from and received at the 2736-ZC Building, the loading dock of the 2736-Z Support/Storage Complex. The overall schematic flow diagram for dry SNM material handling at the PFP is shown in Figure 6-1.

6.2.2 Process Chemistry and Physical Chemistry Principles

There is no process chemistry associated with plutonium material shipping/receiving.

6.2.3 Mechanical Process Systems

6.2.3.1 Functional Description. The major mechanical process activities for the 2736-Z Support/Storage Complex are shown in the simplified flow diagram, Figure 6-1. The major areas of activity are shown in the cutaway view of the 2736-ZB Building in Figure 6-2.

6.2.3.1.1 Shipping. Packages containing plutonium material designated for offsite shipment (off of the Hanford Site) are prepared for shipment as follows:

- Packages are placed in shippable form, meeting all specifications for shipping
- Packages undergo NDA
- Packages are transported to staging room 638 in the 2736-ZB Building
- Packages are loaded in DOT-6M (see Figure 6-11) or other approved shipping containers according to procedure, are inspected, and sealed.

Shippable forms are loaded into shipping containers according to type and destination. The containers are surveyed, moved out of the building to loading dock 2736-ZC, placed on the transport vehicle, and secured for shipment.

6.2.3.1.2 Receiving. Offsite transfers of solid plutonium material (metal, oxide, or other plutonium-bearing materials) are made in DOT-6M shipping containers in a SST vehicle. The SST vehicle is received at the loading dock 2736-ZC. Before receiving any plutonium material, requirements for receipt listed in Table 6-2 must be met.

Material containers are transferred to room 641 in the 2736-ZB Building for sorting. Sorted containers are transferred to staging room 638, where they are prepared for repackaging, shipping, or storage in the 2736-Z Building. Staging area activities include inspection and weighing; pneumatic, hydrostatic, and leak testing of shipping containers when necessary; and decontamination of empty shipping containers.

While N Cell was in operation at the Plutonium-Uranium Extraction (PUREX) Facility, AL-M6 and DOT-6M shipping containers were used for shipping plutonium oxide to PFP. During weapons production, PR container drums were received from the PUREX Facility. Nuclear material item transfer (NMIT) records were checked to ensure the shipment was correct, and a Radiological Control Technician (RCT) surveyed the process truck to ensure that radiation levels were within the limits of less than 50 mrem/h at contact around truck and less than 6 mrem/h in the truck cab. The transfers were made with security and RCT escorts. Upon receipt, the containers of plutonium oxide were transported to the 2736-Z Building for vault storage. The PR container drums that contained the Mark IV/V and Emergency PR cans (see Figures 6-3 and 6-4) were transported to the 234-5Z Building, room 236, for storage.

Load-in/Load-out Process In Glovebox HC-227S and Hood HC-227T. The LI/LO of plutonium nitrate solutions is performed in the 234-5Z Building, room 227, in glovebox HC-227S and hood HC-227T. Hood HC-227T (see Figure 6-5) is an open-faced hood that covers the south half of the east wall in room 227, while glovebox HC-227S covers the north half of the same wall.

Hood HC-227T was used to LO material from the PRF. Hood HC-227T is now used for the vacuum transfer of solutions between containers (e.g., PR cans and 10 liter polyethylene bottles) and tanks in glovebox HC-227S and can be used for venting PR cans. Glovebox HC-227S was used to blend and sample plutonium nitrate and to transfer solutions to the PRF or to nitrate staging tanks in glovebox HC-4 in room 166 of the 234-5Z Building. Glovebox HC-227S is now used to transfer plutonium nitrate solutions to containers (e.g., 4.2 liter and 3 liter polyethylene bottles) for transport to the PPSL and for transfer of solutions to and from the Production VDC.

Various activities are associated with LI/LO. The LI activities include LI of solutions from transport storage container assemblies (e.g., PR, 10-L, L-10, and FL-10) in hood HC-227T, solutions from flushing of containers in the hood, accounting for solution volume, and blending and sampling in glovebox HC-227S.

The LO activities include LO of solution from glovebox HC-227S to transport container assemblies (e.g., PR, 10-L, L-10, and FL-10) in hood HC-227T, accounting for volume transferred, and transferring solution from glovebox HC-227S to storage containers (4.2 liter, 3 liter polyethylene bottles, and other small containers). Solutions transferred to storage containers are removed from the glovebox through seal-out ports and transported to plant process areas or to storage in designated containers. Bottles containing plutonium solutions may be placed into an isolated transport container (ITC) for transport. Long-term storage in ITCs is not permitted. Other solution containing 3 liter polyethylene bottles are transported and stored utilizing the PR container rack and drum assembly

equipped with a 6 inch diameter sleeve to support the bottle within the drum rack (see supplement to Figure 6-3).

Miscellaneous activities include accepting solution from the Plutonium Finishing Plant Analytical Laboratory (PFPAL) into glovebox HC-227S (note the plutonium nitrate transfer line from the Analytical Laboratory entering room 227 has been capped), flushing glovebox HC-227S and hood HC-227T equipment, sampling PR can contents for plutonium assay purposes, and performing emergency shutdown in room 227 in case of malfunction.

The LI/LO activities are essentially the same regardless of which process is operating. The principal differences are in the type of solution and the final destination of the solution.

RMC Line operation for Pu metal production is currently an inactive and unauthorized process. Plutonium nitrate feed solution was loaded into batch tanks in glovebox HC-227S from PR cans via hood HC-227T. In glovebox HC-227S, nitrate solutions were blended and sampled, and the plutonium nitrate feed was transferred to staging tanks in glovebox HC-4. Occasionally, during RMC Line operation, LO of concentrated filtrate solution was required. The concentrated filtrate was transferred from glovebox HC-7 to glovebox HC-227S for LO into PR cans (via hood HC-227T) for storage, until it was used as feed for the PRF operation. RMC Line operations currently consist of reactive material stabilization using the thermal stabilization process and Pu-bearing solution stabilization using the vertical denitration calciner process.

The PRF operation is also currently an inactive and unauthorized process. Concentrated filtrate removed to PR cans during RMC processing was loaded back into glovebox HC-227S and transferred to tank TK-49 for use as PRF feed. The plutonium nitrate solution produced during PRF processing was transferred from tanks TK-45, TK-128, and TK-46 to glovebox HC-227S for LO into PR cans. This solution was stored until RMC Line resumed operation and then it was used as feed for the RMC Line process.

The transfer of solution from the PFPAL to glovebox HC-227S via the transfer line is also currently an inactive and unauthorized process. The PFPAL has, in the past, transferred solution from the laboratory concentrator (located in glovebox 552 of room 152) to glovebox HC-227S. This solution was loaded out or sent to the PRF, depending on solution storage and/or PRF operating status. Historically, transfers from the PFPAL were infrequent and usually involved relatively small volumes (less than 10 liters).

Other containers may be stored next to or along the pathway between the designated PR can storage room and room 227. Therefore, operators in room 227 may need to use transportation devices such as the L-10 cart, PR can carts or the drum/barrel carts.

The L-10 cart suspends the container being transported by a cradle and chain device that supports the container. The steering bar on the cart is used to raise and lower the container. The cart is designed to minimize any swinging motion; however, a second operator is assigned to steady the container during transport.

The PR can cart is a commercially available flatbed type of cart used to transport containers and is equipped with channel bar skids. All three types of PR cans can be transported using these carts. The PR can carts have either mechanically leveraged or hydraulically operated decks that are operated from the handle.

Two types of commercial drum/barrel carts are used at the PFP. One type has two wheels and is like a hand truck. The other type has four wheels, which allows the transport of heavy barrels. These carts are used to transport 30- to 50-gal drums. The foot pads on these carts support the drums from the bottom, and a hook mechanism locks the drum securely in place during transport. The hook mechanism releases when the drum is set on the floor.

Transfers of plutonium material from offsite are made in SST vehicles and are coordinated by transportation personnel. After receipt, the material at the 2736-ZC Building is handled as an onsite transfer.

6.2.3.2 Safety Features. Safety features related to criticality, radiological, and industrial safety are discussed in the following sections.

6.2.3.2.1 Criticality Safety. The requirements of the criticality safety program are established in *Criticality Safety General Requirements*, HNF-PRO-334. Each room, glovebox, and shipping container has been analyzed by the methods outlined in Section 6.2.9.1 to ensure compliance with the criticality safety criteria presented in Chapter 4.0, Section 4.4.4. Criticality safety features incorporated into the design of the SNM shipping and receiving operations include the following.

- Shipping containers and inner containers are equipped with gaskets or sealed to prevent water inleakage
- Inner packages of shipping containers are designed to be geometrically favorable even for flooded conditions
- Spacers are used in shipping containers to ensure the required spacing between adjacent containers is maintained
- Process containers used in repackaging operations are designed to be subcritical even if overbatched and moderated
- Vaults and transport carts provide physical barriers to separate inner packages from other fissile material in storage
- Concrete shielding walls in vaults reduce neutron interaction between SNM stored in adjacent storage cubicles
- Storage racks and contents are secured to withstand a design basis earthquake (DBE).

Administrative practices are also documented and applied to the operations for criticality safety control (CSC). For example, each room, glovebox, and storage area has specific criticality prevention specifications (CPSs), postings, and operating procedures that incorporate the criticality safety requirements. In addition, incoming miscellaneous plutonium materials

are assayed with NDA equipment, either at the PFP or at their source. This provides not only an accountability check, but also a check for criticality safety inventory control.

6.2.3.2.2 Radiological Safety. The requirements of the radiological control program are established in HSRCM-1, *Hanford Site Radiological Control Manual* (DOE 1994). Exposure to radiation is controlled to as low as reasonably achievable (ALARA) standards. Specific actions taken to achieve this include the following:

- Radiation surveys of all incoming shipments of plutonium are performed to ensure that the materials are contained
- Radiation surveys of workstations and areas are performed to detect releases of plutonium and to assess radiation levels
- Shielding is provided at work locations as needed.

At the PFP, personnel exposure is administratively controlled to 500 mrem/yr, although higher exposures (5 rem/yr) are permitted by U.S. Department of Energy (DOE) regulations. Lead shielding, water walls, or Lexan™ plastic are used to reduce exposure. Shielding is strategically located so that the average exposure rate at workstations is approximately 0.5 mrem/h. See Chapter 8.0, Section 8.3 for more details.

Internal deposition of plutonium and other transuranic (TRU) radioisotopes is of particular concern. Internal deposition of plutonium (and other radioisotopes) can occur through injection via cuts, through inhalation of airborne particulates, and (more uncommonly) through ingestion. Actions taken to reduce the probability of internal deposition include the following:

- Opening containers with plutonium solutions only in designated hoods and gloveboxes
- Ensuring that operation is shut down if negative pressure is 0.3 in. w.g. or less (glovebox negative pressure relative to room pressure must normally be more negative than the 0.5 in. w.g. alarm setting)
- Ensuring that operation is shut down if pressure drop across high-efficiency particulate air (HEPA) filters reaches 4 in. w.g. or higher (pressure drop across HEPA filters must normally be less than 3 in. w.g.)
- Replacing failed glovebox gloves before starting or continuing inspection or repackaging of plutonium-bearing material
- Using leather gloves over rubber gloves when handling some plutonium-bearing materials
- Inspecting and changing out gloves on a prescribed frequency
- Training personnel to use special care when handling material that could have sharp edges, or working in the vicinity of equipment having sharp edges

- Carefully inspecting containers for bulging or other indications of internal pressure buildup

- Using respiratory protection when handling containers suspected of holding reactive material or having internal pressure, or opening solution containers in room 227

- Using vacuum transfer of solutions whenever possible.

Continuous air monitors (CAMs) are provided to monitor breathing air in occupied areas where a person without respiratory protection is likely to be exposed to a concentration of radioactive materials in the air exceeding 1 derived air concentration (DAC) over a prolonged period of time or where there is a need to alert potentially exposed workers to significant increases in the level of airborne radioactive material levels, which could result in 40 DAC-hours in a typical work shift. Portable CAMs are used when working in a greenhouse or other areas not adequately covered by a CAM. The CAMs alarm locally, with both audible and visual alarms. Personnel are required to immediately evacuate a room when a CAM alarms. Air-purifying respirators are available, if needed.

6.2.3.2.3 Industrial Safety.

Fire. The requirements of the fire protection program are established in *Fire Protection Program Overview, Fire Protection Policy Statement* and *Responsibilities* (HNF-PRO-340, HNF-PRO-341, and HNF-PRO-342, respectively). The amount of combustible material in a glovebox is administratively controlled to the minimum required for the operation. Plastic bagout material around cans is removed and placed at least 1 ft from containers and metal buttons, and are moved from the glovebox before an additional button or container is brought into the glovebox.

The glovebox in the 2736-ZB Building is equipped with combustion and/or heat detectors. The glovebox is equipped with sand (MgO) and Halon fire extinguishers. The operator is trained to take action to extinguish small fires. The fire department responds whenever a fire alarm is sounded.

Glovebox panels where fires could occur are fabricated of metal/glass construction or of fire-resistant plastics such as Lexan™. Glovebox gloves are made of fire-resistant neoprene. The gloves are normally tied off outside the glovebox.

Personnel Injury. The requirements of the personnel safety program are established in *Integrated Environment, Safety and Health Management System Plan*, HNF-MP-003. Sharp objects or heavy equipment can cause personnel injuries. Operators are required to use leather gloves over the neoprene gloves when unloading miscellaneous solid materials from containers. Operators are trained to use care when working near sharp objects or using tools that could cut or pinch their hands or arms. Hoists are used to remove heavy PR inner containers when unloading solutions. Bulged containers that could generate missiles when opened are carefully punctured with appropriate tools before the lids are removed.

Appropriate equipment is used when moving shipping or storage containers. This includes use of PR can carts, L-10 carts, and drum/barrel carts. Hoists and pulleys are used to move heavy containers from carts onto shipping pallets, etc.

6.2.4 Chemical Process Systems

There are no chemical process systems associated with plutonium material shipping/receiving.

6.2.5 Process Support Systems

6.2.5.1 Instrumentation. This section describes the instrumentation systems common to all process systems and those specifically supporting plutonium material shipping and receiving. A listing of process instruments and their function, location, and calibration information is provided in the Preventative Maintenance and Surveillance (PM&S) system. The PM&S is a computer program for instrumentation calibration and preventative maintenance (PM) programs.

Common to all process systems are CAMs and the criticality alarm system (CAS). Chapter 8.0 Section 8.3.4 describes the CAS, and the CAMs are described in Section 8.3.5. The CAMs are required in all areas where there is a possibility of airborne radioactivity. The CAS is required to cover all areas where at least a minimum critical mass of plutonium could exist, unless criticality is precluded by fissile material physical form or distribution (as determined by an approved safety analysis).

General area radiation detectors and alarms are not provided. A general area radiation level detector and alarm system is not cost effective due to relatively low workplace dose rates and processes that do not create rapidly changing radiation levels. RCTs establish dose rates in work areas during routine and special surveys.

The primary instrumentation systems required for plutonium material shipping and receiving are to ensure personnel safety, accountability, safe condition of material, and security. Instrumentation systems for the handling processes are general safety class instruments, which are common to most of the PFP facilities (CAM, CAS, fire detection).

The LI/LO process of plutonium nitrate solutions from PR cans in the 234-5Z Building, room 227, has alarms for several parameters. The alarms include, the NO_x monitor, chemical addition tank high level, vacuum trap liquid detection, the glovebox HC-227S sump probe changes in HC-2275 Vacuum (trap liquid detection or sump). The trap and sump liquid levels can be visually boserved by an operator.

Containers of plutonium material are inspected, both visually and with radiation detecting instruments, to ensure proper exterior conditions exist before an NDA can be performed. An NDA of these containers determines the total mass of isotopes by measuring the radioactive emissions and/or the heat output of each package. The NDA Laboratory equipment is discussed in

Section 6.5.1.1.4. Data from this equipment provides the information needed for accountability of SNM.

6.2.5.2 Repackaging. Containers that have either failed or have been damaged are repackaged. Repackaging activities occur primarily in the 2736-ZB Building, room 636, and include the following steps:

- Transfer of the suspect package to the repackaging glovebox
- Opening of the container
- Extraction of the contents
- Disposal of failed containers
- Evaluation of the plutonium material (inspection of contents for signs of moisture, excessive heat, consistency with label), taking corrective actions as necessary
- Placement in new inner containers
- Sealing of inner container and verification of seal
- Bagging of sealed inner container out of the glovebox, and survey
- Addition of final containment (normally two more cans)
- Sealing of outer cans, and verification of seals
- Return of the package to storage, after NDA.

Glovebox 235-B2 in room 235-C is used to repackage large containers that do not fit into the other gloveboxes.

6.2.5.2.1 Plutonium-Bearing Materials. Plutonium-bearing materials are divided into three categories. Stable/Shippable Plutonium-Bearing Materials are plutonium-bearing materials that have well-defined characteristics and are safe for shipment. Reactive Plutonium-Bearing Materials are plutonium-bearing materials that are known to generate gas sufficient to pressurize the packages. Potentially Unstable Plutonium-Bearing Materials are plutonium-bearing materials that are insufficiently characterized to place them in either of the previous two categories.

The plutonium-bearing materials are either generated at the PFP, received from other onsite contractors, or received from offsite generators. They are typically packaged in "lard cans" (shown in Figure 6-6), contained in "A" bird cages (shown in Figure 6-7). These are staged in rooms 192-B and 192-C, and vault 174. Shipments of FFTF fuel arrive at the 234-5Z Building in Radial Reflector Shipping Containers and Model 60 shipping containers (shown in Figure 6-8 and 6-9, respectively). The driver fuel assemblies and fuel pins transported in these shipping containers are stored in their shipping containers in vault 192-A. Liquid plutonium-bearing materials are shipped/received only from onsite facilities in approved containers. The

adequacy of the containers for onsite/offsite shipment, and the shipping requirements, are addressed by specific safety analysis reports for packaging.

Containers (see Figure 6-10) that have failed or have been damaged are repackaged. Only stable/shippable plutonium-bearing materials are repackaged in the 2736-ZB Building. Repackaging/stabilization of potentially unstable plutonium-bearing materials takes place in the 234-5Z Building in rooms 228-C, 230-A,230-B, and 235-B.

Current plutonium-handling operations at the PFP are directed toward shipping and receiving stable/shippable materials and maintaining the inventory of reactive and potentially unstable plutonium-bearing materials in a safe condition until they can be stabilized. The stabilization of reactive plutonium-bearing materials as well as Pu-bearing solution stabilization constitute the primary plutonium-processing operations. The stabilized materials are repackaged for storage or shipment.

Plutonium-bearing material repackaging (recanning) is instituted if there is a gain or loss in gross package weight, a package is damaged, an improper or questionable container is identified, package contents are not well characterized, or management deems it to be appropriate.

Repackaging activities for plutonium-bearing material include prerequisites specified by operating procedures for criticality, radiological, and Safety and Quality Assurance.

6.2.5.2.2 Plutonium-Beryllium Sources. Plutonium-beryllium sources are brought to the repackaging glovebox in room 636 for repackaging. The source containers (type 3-L) are opened and, the sources are withdrawn and the serial number of each source verified using remote handling devices. After repackaging, they are transferred to shipping containers (see Figures 6-11 and 6-12) for radiation survey and shipment.

6.2.5.2.3 Plutonium Metal and Oxide. Packages in storage in the 2736-Z Building are normally in "shippable form." However, the shipping of plutonium metal requires that they be inspected and any loose oxide removed prior to repackaging for shipping. Should this activity be performed, the selected package would be transferred from storage to the 2736-ZB Building, room 636. Repackaging activities would include removing the metal from the old cans, preparing the metal for repackaging, resealing the clean metal in a tuna fish can, verifying the seal, and decontaminating the can. The last three steps would be repeated for the second and third containers (cans). The package would be placed in a shipping cask, inspected, and sealed. The casks would then be moved out of the building to the loading dock (2736-ZC) packed in cargo restraint transporters, placed in a SST, and secured for shipment.

6.2.6 Control Rooms and Control Areas

There are no control rooms or control areas associated with plutonium material shipping/receiving.

6.2.7 Analytical Sampling

Analytical sampling of plutonium-bearing materials may be required for packages with contents that are not well characterized. The sampling of plutonium-bearing material and oxide in gloveboxes is done by following specific steps outlined in an operating procedure. The procedure provides instructions for weighing, bottling, and transporting samples to the laboratories. Instructions for reweighing and/or recanning of the material after sampling are also contained in operating procedures.

6.2.8 Product Handling

Product handling is addressed in Sections 6.2.1 and 6.2.3.

6.2.9 Identification of Items for Safety Analysis

6.2.9.1 Criticality Prevention. The criticality safety evaluation (CSE) analyzes the handling of fissionable materials under normal and credible abnormal conditions, and establishes the limits, controls, and engineered features necessary to ensure that an acceptable margin of subcriticality is maintained. Principal design guidance for the CSE is described in Chapter 4, Section 4.4.4.

Consistent with the requirements of DOE Order 5480.24, *Nuclear Criticality Safety*, the CSC is primarily provided by some combination of: (1) limiting the dimensions of plutonium-containing process components and containers used to transport and store plutonium (geometry controls); (2) limiting the mass of fissionable material per workstation; (3) spacing of fissionable units at workstations, including in-process storage arrays; and (4) limiting moderating materials.

The design of processes and equipment uses the most positive practical method to prevent a criticality accident. The following methods are listed in order of decreasing safety assurance: geometrically safe equipment; geometrically favorable equipment; fixed poisons; nuclear blanks; instrumentation; soluble poisons; and administrative controls. Deviations from this guidance must be justified with clear technical reasoning, particularly if administrative controls are proposed. Criticality safety limits (SLs) for workstations are posted before loading plutonium into the gloveboxes.

6.2.9.1.1 Double Contingency Principle. The process design is analyzed for possible abnormal events to ensure that at least two unlikely, independent and concurrent errors, accidents, or equipment malfunctions would have to occur before a criticality is possible (the double contingency principle). A new process or change to an existing process is analyzed, before startup.

In stating the double contingency principle, "unlikely" means not expected to occur in the lifetime of the facility. For example, a major fire in a process facility is unlikely. While a fire could occur, a major fire is not expected; it is expected that the facility will be decommissioned in a planned and orderly way. Therefore, a major fire meets the definition of an

unlikely event. Events that are unusual or abnormal, but do not meet the test of an "unlikely" event, are not considered contingencies. They are analyzed as part of the base ("normal") condition, or as part of a single contingency based on multiple errors.

The term "independent" means that there is no common mode or common cause for the two events. For example, a fire and the actions of the fire department in response to that fire are interrelated. For criticality safety purposes, the action and reaction are one event.

The term "concurrent" means at the same time and place. For criticality to be possible, the second event must occur before the first event is discovered and corrected. The double contingency principle states that two contingencies must occur "before criticality is possible." This means that no one error, accident, or equipment malfunction will make the system critical. It does not mean that only two controls are applied. To meet the double contingency principle, appropriate controls must be applied to guard against all credible errors, accidents, and equipment malfunctions. The principle also states that the second error, accident, or equipment malfunction must be as serious and as unlikely as the first. The two events must both be unlikely, must independently occur at the same place, and the second must occur before the first is discovered and corrected.

Prevention of "errors, accidents, and equipment malfunctions" is the subject of many safety program elements. Operators receive extensive formal and on-the-job training. Written procedures, reviews, prejob planning meetings, and double or triple checks of work are used to prevent errors. The NDA programs and material balance programs are used to prevent the buildup of fissionable material in an unexpected place. Regular safety meetings are conducted to maintain a high degree of safety awareness. An extensive PM program is used to prevent equipment malfunction. Operators inspect their workstations often to ensure that work is within specified limits. Managers, as well as facility management, the Criticality Safety Representative (CSR), the Nuclear Safety Representative, and multi-disciplinary teams of safety specialists also perform inspections. Representatives of the DOE, from both the U.S. Department of Energy-Richland Operations Office (DOE-RL) and U.S. Department of Energy-Headquarters Office (DOE-HQ) in Washington, D.C., perform inspections of the workplace. In spite of all these efforts, however, the safety program assumes that people make mistakes, accidents occur, and equipment fails. The safety margins have been established so that the system remains subcritical by a comfortable margin for any possible event.

6.2.9.1.2 Criticality Safety Evaluations. The CSEs are performed by criticality safety engineers on all operations involving significant quantities of fissionable material. The criticality safety engineer works with the process engineer and operations to determine the worst possible normal operating conditions, and to identify any accidents that might occur. The accidents are severe enough to meet the description of "unlikely events" given above.

The criticality safety engineer compares normal operations and accident scenarios to known critical systems, based on critical mass experiments performed in critical mass laboratories around the world. The engineer may model normal operations and accident scenarios using computer codes or other

calculational techniques which have been determined to be accurate by comparison to critical mass experiments. Any normal or accident condition must be shown to be subcritical, with a comfortable margin of safety.

The work performed by one criticality safety engineer is documented in Criticality Safety Evaluation Reports and is always verified by at least one other criticality safety engineer. If the work is complicated, the second engineer recalculates some or all of the results using a different method to verify the results.

The engineer then selects operating limits that provide large safety margins between normal operations and any of the accident scenarios that were evaluated. Actual violation of the limits most likely will be less severe than the events defined by the contingency analysis (for example, a partial overbatch instead of a double batch). Therefore, a criticality safety "limit infraction" is distinct from a contingency.

To meet the double contingency principle, it may be necessary to establish limits and controls on any or all of the following, as appropriate:

- Fissile and fissionable material
- Neutron moderation
- Neutron interaction
- Neutron reflection
- Concentration
- Density
- Geometry
- Heterogeneity
- Neutron absorbers.

The proposed operating limits are reviewed by the operations organization to ensure that the limits will be practical to implement. The list of control features above demonstrates that there are many possible control points, and different combinations of limits can be applied to achieve the same safety margin. The criticality engineer works with the operating groups to ensure that the features selected will not only provide the required safety margins, but will be practical to apply. If a limit is not practical, another control feature or set of features can be evaluated, maintaining the margin of safety.

The limits are documented in CPSs, incorporated into operating procedures, and summarized in postings placed in the work area. The CSR provides interpretations of the CPS and reviews procedures and postings as discussed in Chapter 10.0.

Criticality Safety Evaluation for Shipping and Receiving. Analytical methods normally rely extensively on the DOE or Nuclear Regulatory Commission (NRC) COC for the subject shipping container, or the U.S. Department of Transportation (DOT) shipping container approval documents. The DOT limits on materials received require that all shipments be subcritical, even if completely submerged in water.

In addition, mechanical engineering analyses may be requested, or special Monte Carlo criticality calculations performed, to evaluate specific situations to ensure that the double contingency principle will be met.

Qualified contractors selected by PFP perform the criticality calculations. The contractor has personnel which are qualified and documented as having met appropriate DOE and industry standards. The PFP administration manual and training manual contain requirements that ensure those qualified suppliers and personnel are used to perform criticality analysis and manage these activities. The following are examples of situations that may be evaluated:

- Loss of container contents to the ground
- Variation of array size
- Water leakage into the space between the containment vessel and outer package
- Leakage from the containment vessel, where the leakage is moderated by water
- Close water reflection
- Interspersed water moderation
- Density or concentration changes in the fissionable material.

These cases consider undamaged or damaged arrays, as appropriate. Analytical methods include the use of well-referenced data or Monte Carlo calculations.

Implementation of Criticality Safety for Shipping and Receiving. The DOT labeling regulations provide package content identification of items received from offsite. Onsite transfers require equally precise identification. Upon receipt, NDA measurements assist in the confirmation of the fissionable content of these shipments.

Placement into storage is required and verified as part of the administrative control of the facility. Damaged containers are normally returned for repackaging.

Appropriate limits are placed on container content and packaging method, the number of containers that may be shipped, how many may be stacked, and spacing with other fissionable material. Specific safety features of the packaging and shipping process are described in Section 6.2.3.2.1.

During onsite transport, the probability of having an accident severe enough to rearrange the fissionable material are extremely small. However, the following administrative controls are applied, as required, to minimize the possibility of a vehicular accident with criticality safety significance:

- Limiting truck speed
- Use of additional traffic control, preferably convoy operation that requires vehicles ahead and behind the transporting truck. (This has the advantage of having speed controlled by both the lead vehicle and by the transporting truck. In addition, the vehicles ahead and behind provide anti-collision barriers. The lead vehicle

may also be instructed to stop the convoy if an approaching vehicle is sighted at an intersection on the route where the transporting truck would be vulnerable to a side collision. This provides many of the advantages of blocking roads, without the disadvantages.)

- Use of an overpack that meets DOE requirements
- Limiting the number of containers on the truck
- Requiring vehicle inspection to verify that it is in proper operating condition
- Requiring a second employee to accompany the driver, to provide backup traffic warning and emergency response.

Offsite transport control is provided by the DOE.

6.2.9.2 Chemical Safety. Two operators are required when handling hazardous chemicals. Chemical safety showers, sinks, and eyewash stations are available in the event of chemical exposure. Spills/leaks are cleaned up before continuing with chemical transfers, equipment is repaired as necessary, and operating procedures are in place for all chemical handling [e.g., acquisition, use, storage, disposition (see Section 10.4.5)].

6.2.9.2.1 Nitric Acid. Nitric acid (HNO_3) is used in LI/LO of plutonium nitrate solutions. Concentrated HNO_3 (57% HNO_3) was provided from the 7,000-gallon acid storage tank outside and east of the 234-5Z Building. The inventory of HNO_3 in the PFP was reduced by removing excess HNO_3 from the tank during fiscal year 1996. Any future need for concentrated HNO_3 would be met by purchasing HNO_3 in 55-gallon drums. Tank C located in room 336 of the 234-5Z Building stores concentrated HNO_3. Acid from tank C is pumped to tanks G-1 and G-2 (also in room 336) for production of a dilute HNO_3 solution. This dilute HNO_3 is piped by gravity drain to glovebox HC-227S for use as a flush solution. Since it can cause severe burns to the skin and/or eyes, operators are required to wear eye goggles, full-face shields, acid suits, and rubber gloves when transferring the acid. Emergency response materials are provided to neutralize small spills.

6.2.9.2.2 Potassium Hydroxide. Potassium hydroxide (KOH) is used to neutralize spills of acidic solutions. Since it is a strong base and can cause severe burns to the skin, operators are required to use protective equipment in accordance with the work plan and procedures. If the material is spilled, the operators must put on full-face air-purifying respirators. Large spills are pumped into plastic drums (DOT-34) and diatomaceous earth is used to absorb small spills.

6.2.9.3 Process Shutdown Modes. Emergency shutdown of glovebox equipment can be accomplished in several seconds by shutting off power to the gloveboxes. Short-term shutdown (one day to several weeks) of the 2736-Z Support/Storage Complex operation involves placing plutonium in safe storage. This can be accomplished in an hour or less, depending on the number of packages involved and if any contain reactive materials that would need to be moved to gloveboxes in the 234-5Z Building. Normal surveillance would continue, including verification to ensure that proper ventilation of gloveboxes is

maintained with negative pressure at or below -0.5 in. w.g., pressure drop across filters is less than 3 in. w.g., and radiation surveys.

Long-term shutdown (years) is not an option until all of the plutonium has been moved out of the PFP. This option would involve packaging and shipping all plutonium out of the PFP, either offsite or to a new facility at Hanford. It would take months to accomplish a full cleanout. Surveillance requirements would be minimal, primarily ensuring ventilation is adequate for areas containing residual plutonium, and performing area radiation surveys until decontamination and decommissioning (D&D) of the facility is completed. Additional information on facility shutdown and cleanout activities is provided in Section 6.7.

6.2.9.4 Instrumentation. There is no instrumentation associated with SMN shipping/receiving that requires identification for safety analysis purposes.

6.2.9.5 Remote and Contact Maintenance. There is no remote or contact maintenance associated with plutonium material shipping/receiving that requires identification for safety analysis purposes.

6.3 PLUTONIUM MATERIAL STORAGE

6.3.1 Process Description

6.3.1.1 Narrative Description. As discussed in Section 6.2.5.2.1, plutonium-bearing material is categorized as stable/shippable material, reactive material (generates gas), and potentially unstable material. The stable/shippable material category includes plutonium metal, PuO_2, spent nuclear fuel, and unirradiated nuclear fuel. The reactive material includes plutonium nitrate solutions. Potentially unstable material needs additional identification for categorization as either stable or reactive material.

The stable/shippable materials, such as plutonium metal and PuO_2, are stored in the 2736-Z Building vaults (1 through 4). The cans containing plutonium material are stored on pedestals inside cubicles. The concrete walls of the cubicles isolate the plutonium material from neutron interaction with material stored in other cubicles. Thermal loading for the cans of material in storage is limited to 15 W each, at the time of storage. The heat output is determined by calculations based on isotopic analytical data and weight of the material. The amount of plutonium in a can is reduced if it generates more than 15 W.

Spent nuclear fuel and unirradiated fuel are stored at the PFP in a stable/shippable form. Spent nuclear fuel is contained in three Experimental Breeder Reactor (EBR)-II storage casks [as described in WHC-SD-RE-SAP-054, *Safety Analysis Report for Packaging 21PF-1 Overpack/EBR-II Spent Fuels Storage Cask System for Transport* (WHC 1994b)]. The casks are stored in the 2736-ZD facility (refer to Chapter 5.0, Section 5.2.8.5, for a description of the 2736-ZD facility). The EBR-II casks were relocated from a Hanford Site solid waste management burial ground to the 2736-ZD facility to utilize security measures in place at the PFP, and to comply with DOE Order 5632.1C, *Protection and Control of Safeguards and Security Interests*.

The EBR-II containers are constructed of carbon steel and utilize 5 in. of poured lead for shielding. The payloads of irradiated metal fuel are within guide tubes which are doubly encapsulated in 10.2 cm (4 in.) and 12.7 cm (5 in.) diameter, schedule 40, stainless steel pipe which is welded shut and leak tested. These are placed in the 6-inch diameter central cavity of the cask. The cask is closed and sealed with a gasketed cover plate. All necessary shielding and containment is provided by the casks themselves. Details on the cask, including precise dimensions and material specifications for the containment vessels, are found in *Hazard Class and Facility-Use Determination for Irradiated Fuel Storage in EBR-II Casks in the 200 West Area* (Van Fleet 1989). References for analysis of the EBR-II Cask system performed in 1979 and 1980 are provided in *Safety Analysis Report for Packaging 21PF-1 Overpack/EBR-II Spent Fuel Storage Cask System for Transport*, (WHC 1994b).

The material within the EBR-II casks is metallic reactor fuel from the Los Alamos Molten Plutonium Rector Experiment (LAMPRE). It is further described in WHC-SD-SQA-CSA-20381, *CSER 94-014; Storage of Metal-Fuel Loaded EBR-II Casks in Concrete Vault on PFP Grounds* (Hess 1994). No cooling mechanisms are required for the fuel in the casks.

Unirradiated FFTF fuel is temporarily stored in vault 192-A. It consists of Driver Fuel Assemblies (DFAs) stored in Radial Reflector Shipping Containers (RRSCs), and fuel pins stored in Model 60 shipping containers. No cooling mechanisms are required for the fuel stored in these containers.

Each RRSC contains four DFAs. Each DFA contains 217 fuel pins (fuel pin bundle assembly). The fuel composition of each DFA pin is a pelletized and sintered mixture of plutonium and uranium oxide sheathed in stainless steel cladding. A maximum of seven RRSCs can be stored in vault 192-A.

There are 4,997 additional fuel pins that contain fissile material such as plutonium oxide, uranium oxide, plutonium metal, carbide compounds, and thorium oxide. These fuel pins are contained in 68 Model 60 shipping containers. One Model 60 shipping container can hold a maximum of 120 fuel pins. A maximum of 70 Model 60 shipping containers can be stored in vault 192-A. The Model 60 shipping containers have security seals for easy verification that no shipping container has been opened. All 10,205 fuel pins currently being stored are chemically stable and designed for use in high temperature environments.

Unless the fuel pins contained in the Model 60 shipping containers are being inspected for accountability reasons, all fuel pins remain in their shipping containers during storage in vault 192-A. The RRSCs will never be opened while being stored in vault 192-A. The design and analysis of the two shipping containers is provided in *Safety Analysis Report for Packaging, Radial Reflector Shipping Containers* (Carlstrom 1990), and *Model 60 Shipping Container Safety Analysis Report for Packaging* (Ferrell 1990).

The packaging of fissile material and the storage of the material within the seismically qualified restraint system of vault 192-A prevent its release to the environment under all credible accident conditions, including natural hazards. The seismic and design basis wind evaluations of vault 192-A, room 192-B, and room 192-C are given in *Natural Hazards Evaluations (Seismic and Design Basis Wind) for PFP Vaults 192-A, B, and C* (Baxter 1991). *Test Report*

for Modified Compression Test of Model 60 Shipping Container (Barlow 1991) shows that the Model 60 shipping containers are structurally adequate for stacking seven high. The criticality analysis is documented in *Relocation of Fuel Pins and Assemblies from 308 Building to PFP* (Hess 1991). *Calculations for Project C-125, Modification for Storage of FFTF Fuel* (KEH 1991) provides the calculations and design for the restraint structure and devices used to prevent the shipping containers in vault 192-A from moving during a design basis seismic event.

Reactive plutonium-bearing materials are moved to an active glovebox in the 234-5Z Building for interim storage (see Section 6.4.2). The material is confined within a ventilated control barrier until it can be processed to a stable form.

Plutonium nitrate [$Pu(NO_3)_4$] solutions are stored in PR cans, 3 liter polyethylene bottles, and 10 liter polyethylene bottles that are specifically vented to prevent pressurization. The PR, 10-L, L-10, and FL-10-1 containers are shipping containers that are also used for long-term vault storage. The PR container is a stainless steel drum encasing a PR can which can hold 10 liters (controlled to 8.5 liters) of $Pu(NO_3)_4$. The PR can is held in place by a rack inside of the PR container. PR containers are also used as storage containers for 3 liter polyethylene bottles of $Pu(NO_3)_4$. The PR can is removed from the PR container and a 6 inch diameter metal sleeve is inserted to position and support the 3 liter polyethylene bottle. The 10-L, L-10, and FL-10-1 containers consist of pairs of stainless steel drums that have been joined end to end. These drums each encase a cylindrical pipe, which in turn secures a 10 liter polyethylene bottle (controlled to 8.5 liters) of $Pu(NO_3)_4$. The 10-L container has no space-filling material, two holes in the lid for pressure relief (each packed with angel-hair), and a pair of I-beams welded on the base. The L-10 container has vermiculite space filling material, Schedule 80 pipe, a single gasket for sealing the lid, and a needle valve for pressure relief. The FL-10-1 container has molded phenolic foam space filling material, Schedule 40 pipe, two concentric gaskets for sealing the lid, and a needle valve for pressure relief. Other than the differences noted above, the 10-L, L-10, and FL-10-1 containers are identical.

Potentially unstable plutonium-bearing material is inspected in the 2736-ZB Building, and the source data is reviewed to determine whether it should be handled as reactive or stable/shippable material.

6.3.1.2 Flowsheets. The overall schematic flow diagram for dry SNM material handling at the PFP is shown in Figure 6-1.

6.3.2 Process Chemistry and Physical Chemical Principles

The radiolytic decomposition of hydrogenous material generates hydrogen gas. Alpha decay produces helium gas. The decomposition of organic compounds also evolves gas. The pressure of an unvented container will increase as these processes occur. In addition some of the decomposition products are corrosive. If sufficient gas is generated the container will fail.

Energy is released as material undergoes radioactive decay. Plutonium-bearing material which is low in ^{240}Pu (less than 7 weight percent) has a heat

generation rate of 2.5 W/kg. Plutonium-bearing material which is high in ^{240}Pu (more than 16 weight percent) has a heat generation rate of 6 W/kg. Irradiated nuclear fuel continues to generate heat from fission product decay even after the fuel is removed from the reactor. The rate at which energy is released affects the strength of the storage container. If the decay heat generation rate is greater than the rate at which the container can dissipate heat then the temperature of the container will increase. The material properties of the container degrade as the temperature increases. Limits on thermal loadings for storage containers are established to ensure container integrity is maintained.

6.3.3 Mechanical Process Systems

6.3.3.1 Functional Description. Storage specifications for plutonium material require complete identification, packaging information, shipping information, and receiving approvals before placement. The thermal loading of containers when first placed in storage, is limited to 15 W (does not apply the EBR-II or FFTF fuel containers). The decay heat generated by the LAMPRE fuel is conservatively estimated at less than 15 W per cask, well within the limit of 300 W per cask. The 2736-ZD facility can hold up to 7 EBR-II casks. The content of each EBR-II cask is limited to 4,000 g of total dry fissile material. The Model 60 shipping containers are structurally adequate for stacking seven high.

Containers are inspected for corrosion, dents, penetrations, and faulty seams or seals before being placed into storage. Containers holding solid plutonium material (not including the EBR-II casks or the FFTF fuel containers) are inspected monthly for bulging and corrosion. Containers that do not meet any of the above specifications are repackaged.

Extraordinary precautions are taken in the handling and storage of SNM because of its unique properties. Varying quantities of plutonium metal, PuO_2, plutonium compounds, recoverable plutonium-bearing material, salts, and unirradiated reactor fuel are stored in vault and "vault type" rooms at the 234-5Z, 2736-Z, and 2736-ZB Buildings. Also, drums containing TRU waste are temporarily stored. The areas for storage of plutonium material are shown in Table 6-4.

Storage specifications address material not allowed in storage, loss-on-ignition (LOI), enclosure requirements, use of plastics, food pack cans, and thermal loading.

Materials not allowed in storage includes liquid or damp materials of any kind, materials that may easily generate gases, corrosive salts and other materials that react with iron, and plutonium metal pieces with radiolytically sensitive material present (such as fabricating oil).

Materials may be stored or shipped if an LOI analysis of a sample is favorable. The LOI analysis involves heating a sample for a period of time and measuring the change in the mass of the sample. The allowable change in mass, and other specific requirements of the analysis are presented in OSD-Z-184-00013, *Special Nuclear Material Storage* (WHC 1995a).

Materials in storage are contained in a minimum of two (one container sealed inside the other) contamination-free, mechanically sealed containers (food pack cans) (refer to Figure 6-10).

No plastic comes in direct contact with stored SNM except for polystyrene cubes. Polyethylene (6 mil thick) is used to seal inner containers. PVC plastic (12 mil thick) may be used for material with a heat-generation rate of less than 3 W per container.

Specifications for food pack cans require that the can (and lid) be a commercially available, double-seam can of steel construction. The can (and lid) is tin coated on the inside and outside, and the inner surface may be further coated with phenolic or epoxy. Can-sealing gaskets are of synthetic rubber, and side seams, if present, are either welded or soldered.

The thermal loading of containers being stored for the first time does not exceed 15 W decay heat. LOI, process parameter, storage container, wattage, and/or enclosure requirements may be waived, after technical bases demonstrating an acceptable level of risk are prepared by PFP Process Engineering, and approved by appropriate PFP management.

6.3.3.1.1 Reactive Plutonium-Bearing Material Storage. Reactive plutonium-bearing materials are temporarily stored in active gloveboxes in the 234-5Z Building until they can be stabilized. Any active glovebox can be used for temporary storage, including those containing inactive process equipment. In Chapter 5.0, Table 5-5 provides a listing of active and inactive gloveboxes at the time of the preparation of the FSAR. The current listing of active and inactive gloveboxes is provided in WHC-SD-CP-OSR-010, *Plutonium Finishing Plant Operational Safety Requirements*.

Reactive plutonium-bearing materials are placed in polyjars (polypropylene or polyethylene), which serve as primary containers. The quantity of material in each container, and the position of the container in the glovebox, is administratively controlled to ensure criticality safety. Each glovebox is maintained at a negative pressure with respect to the surrounding room, and is equipped with combustion and/or heat-sensing devices and alarms.

6.3.3.1.2 2736-Z Support/Storage Complex. Storage specifications require complete information on material identification, packaging, shipping, and receiving approvals. Containers are inspected for corrosion, rusting, dents, penetrations, and faulty seams or seals before receiving approval for storage in Building 2736-Z. Containers that do not meet specifications are repackaged. During storage, containers are visually inspected on a monthly basis for abnormal conditions such as bulging. A straight edge is placed across the top of each container to check for pressurization.

Vault 3 contains plutonium material which is monitored by the International Atomic Energy Agency (IAEA). IAEA personnel review video tapes from eight video cameras which are located in vault 3, and inspect the security seals on the SNM containers once per month. The containers are randomly sampled (by IAEA personnel) once per year to verify the contents (see Section 6.3.7). The samples are sent to Vienna, Austria, for analysis. Room

642 of Building 2736-ZB is used by the IAEA to support their monitoring activities.

6.3.3.2 Safety Features. The safety features addressed in Section 6.2.3.2 are also applicable to plutonium material storage.

6.3.4 Chemical Process Systems

There are no chemical process systems associated with plutonium material storage.

6.3.5 Instrumentation and Control Systems

This section describes the instrumentation systems supporting plutonium material storage. The primary purpose of the instrumentation systems required for plutonium material storage are to ensure personnel safety, accountability, safe condition of materials, and security. Instrumentation systems for the handling processes are associated with general safety class instruments, which are common to most of the PFP facilities (CAM, CAS, fire detection).

A vault safety and inventory system is installed in vaults 1, 2, 3, and 4 of the 2736-Z Building. This system monitors container temperature, ambient air temperature, dimensional changes of the container, container presence, and container identification number. Data processing equipment located in the 2736-Z Building log and process the information received from the container monitors. Vault inventory system anomalies are annunciated in rooms 104 and 306A of the 234-5Z Building.

Temperature detectors (thermocouples) are provided above each cubicle in the 2736-Z Building vaults. Temperature detectors are also provided in the exhaust plenum for each room. Temperature readout devices for the 2736-Z Building are located in Building 2736-ZA. The maximum temperature difference allowed between the inlet and outlet air temperature of each cubicle is 70 °F. The facility manager is contacted if the temperature difference is greater than 25 °F (per the Operating Specifications), the outlet temperature is higher than 140 °F, or the display flashes (indicating that there is an open circuit).

6.3.6 Control Rooms and Control Areas

There are no control rooms or control areas associated with plutonium material storage.

6.3.7 Analytical Sampling

The IAEA requires preparation of sample-sized quantities of plutonium-bearing powders, which is performed with an approved operating procedure. The procedure provides instructions for sampling, mixing, splitting, weighing, and bottling samples. The loading of sample bottles into air-transportable shipping containers is covered by a separate operating procedure, and

instructions for reweighing and/or recanning of the material after sampling are contained in additional operating procedures.

6.3.8 Product Handling

Product handling is addressed in Sections 6.3.1 and 6.3.3.

6.3.9 Identification of Items for Safety Analysis

6.3.9.1 Criticality Prevention.

6.3.9.1.1 Criticality Safety Evaluation for Storage Facilities. A variety of analytical methods are used to evaluate storage facilities, including Monte Carlo calculations, the Surface Density versus Shape Factor Method, the use of well-referenced data, DOE or NRC COC analyses for shipping containers, and DOT shipping container approval documents.

Often the material is conservatively modeled by assuming that the ^{240}Pu content is zero, that the material is spherically shaped, or that the material is optimally moderated using plastic or water. Reflectors may be concrete, water, steel, or soil, depending on the location of the array. Various densities and hydrogen to fissile material (H/X) ratios are evaluated to determine the most reactive cases.

Abnormal conditions include the following, as they apply to the storage array:

- Water addition from a sprinkler system
- Bunching of units in pairs (organized off-centering)
- Double batching (in a single or two adjacent positions) at the center of a row
- Variations in the size, number, composition, and position of units
- Two units in place of a single unit
- Placing a container on top of a storage rack
- Spilling the contents of a shelf onto the floor
- Overstacking containers, or placing containers in the wrong location
- Filling a single unit with water between the inner package and the outer container
- Inadvertent addition of moderated unit(s) to unmoderated arrays

- Fissile solution leakage with either a dry outer drum or a water-filled outer drum which is not geometrically favorable
- Crushing of containers
- Overconcentration
- Flooding
- Making the array too large
- Units shaken out of their storage positions and scattered or heaped on the floor.

The analysis may require the use of drains, neutron absorbers, or leak-resistant containers. The effect of varying parameters that define the storage array are also explored. These parameters include the following:

- The effect of walls
- The effect of hydrogen (water) in the concrete
- The difference between staggering the storage locations and having the storage locations on the same level
- The interaction between storage locations
- The effect of thick iron around the fissile units
- The effect of opening all storage unit doors
- The effect of interspersed water fog
- The effect of reducing the concrete density by 5% to simulate voids and nonstandard thicknesses.

In addition to the storage area parameters, other parameters dealing with the fissile material itself are also studied. These parameters include the following:

- The difference between equilateral or flattened units
- The effect of ^{240}Pu in the plutonium
- The effect of positioning the units within the storage location from the centered position to the closest spacing to each other
- The effect of the number of layers, units per layer, and can size
- The effect of omitting layers versus decreasing the number per layer
- The effect of material composition on the allowed unit mass
- The effect of intermixing various types of units

- The effect of a uniform versus nonuniform distribution on each layer in tray-style storage locations

- Combinations of several of the above.

6.3.9.1.2 Implementation of Criticality Safety in Storage Facilities. Storage cubicles or locations are designed to be geometrically favorable for criticality safety. In many cases, the geometry is ensured by fixed storage locations providing well-defined reflection and interaction potential. Specific safety features are described in Section 6.2.3.2.1. As appropriate, the following limits are applied:

- Volumes of containers
- Moderation controls
- Individual unit mass limits
- Fixed spacing within the array
- Spacing of units being brought into or out of the array
- Unit density
- Total mass in the array
- Piece count controls
- Limits on the compounds or form.

Administrative controls such as "only one unit may be entered into or removed from the array at one time" may also be applied to ensure that limits are not exceeded.

Plutonium in staging areas is contained within geometrically favorable shipping containers. Reactive scrap is stored in gloveboxes, and the posted limits for the glovebox apply to quantity and spacing between containers.

6.3.9.2 Chemical Safety. There is no chemical safety associated with plutonium material storage that requires identification for safety analysis purposes.

6.3.9.3 Process Shutdown Modes. Process shutdown modes are addressed in Section 6.2.9.3.

6.3.9.4 Instrumentation. There is no instrumentation associated with plutonium material storage that requires identification for safety analysis purposes.

6.3.9.5 Remote and Contact Maintenance. There is no remote or contact maintenance associated with plutonium material storage that requires identification for safety analysis purposes.

6.4 REMOTE MECHANICAL A AND REMOTE MECHANICAL C LINE PROCESSES

6.4.1 Reactive Plutonium-bearing Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC.

Miscellaneous plutonium-bearing materials were produced during previous PFP operations. This inventory of plutonium material is in the form of pure

and mixed oxides, fluorides, oxalates, silicates, and organic-based sludges and residues. Reactive plutonium-bearing materials must be stabilized prior to long-term storage to prevent the formation of excessive hydrogen or nitrated organic compounds. These materials are stabilized in the RMA and RMC Lines using a thermal stabilization process which converts the material to a stable Pu oxide and assures a dry product suitable for long-time storage.

The PFP also contains significant quantities of plutonium-bearing solutions that are in a form considered unsuitable for long-term storage. These solutions primarily consist of the following:

- Product plutonium nitrate solutions
- Concentrated filtrate solutions
- Flush solutions.

As part of the PFP cleanout operations, these solutions are stabilized by conversion to plutonium oxide which is suitable for long term storage. The Production VDC process is used to stabilize the solutions by heating the material to a temperature of 1000 °C. Only the product plutonium nitrate solutions are suitable for direct stabilization using the Production VDC process. The other two solutions require pretreatment prior to processing in the VDC. Therefore, only processing of the plutonium nitrate solutions in the Production VDC are covered by the PFP FSAR. The pretreatment and processing of the other two solutions will be added in a future revision of the FSAR.

Plutonium nitrate solution stabilization operations are also performed with the Laboratory Prototype Calciner in Glovebox 188-1 in the PPSL. The Laboratory Prototype Calciner addendum to this FSAR provides a description of the equipment and processes associated with laboratory calciner operations.

6.4.1.1 Process Description - Reactive Material Stabilization and Solution Stabilization Using the Production VDC.

6.4.1.1.1 Narrative Description - Reactive Material Stabilization. Thermal stabilization of reactive Pu-bearing materials is performed in gloveboxes HC-21C and HA-21I, located in rooms 230A and 235B of Building 234-5Z (see Chapter 5.0, Section 5.2.1.2). These gloveboxes were originally used to support the plutonium conversion processes in the RMA and RMC Lines (see Section 6.4.3). Thermal stabilization consists of converting reactive plutonium-bearing materials into a stable form (Pu oxide) by heating the material to high temperatures in a furnace.

Process Feed. There are five categories of plutonium-bearing material containing less than 10 g of organic per charge which are thermally stabilized in the HC-21C muffle furnaces to meet long term storage requirements: PRF sludges from the last PRF campaign, mixed uranium and plutonium oxides (MOX), floor sweepings, plutonium oxalates, and plutonium oxide. Note that plutonium oxalate [$Pu(C_2O_4)_2$] degrades, from exposure to alpha radiation, to plutonium oxycarbonate ($PuOCO_3 \cdot 2H_2O$) with a reaction half-life of 64 days. Since the RMC Line sweepings have been in storage in excess of four years, essentially all of the plutonium oxalate has degraded to the oxycarbonate form. Plutonium oxide (PuO_2) may also be processed in the furnace with the compound simply being dried with no chemical reactions taking place. These feeds are representative of the materials processed in the furnaces in glovebox HC-21C.

The furnaces in glovebox HA-21I are used to thermally stabilize all of the categories of reactive plutonium-bearing material that are stabilized in Glovebox HC-21C except PRF sludges. Plutonium oxides consist of both "clean" and non-product quality plutonium oxides. "Clean" plutonium oxide is defined as materials containing no organic contaminants, plastic, debris or pyrophoric material whereas non-product quality plutonium oxides may contain some of these contaminants.

Stabilization. Processing operations are initiated with the selection of containers from storage. Only containers meeting the type A or B definitions shown in Figure 6-28 may be selected for processing to minimize the amount of hydrogen potentially available for reaction when opening the container. The containers of plutonium-bearing materials are sealed-in using either glovebox HC-13MD, HC-21A or conveyor glovebox HA-28, unpackaged, and loaded into a previously weighed Hastelloy X™ container referred to as a "boat." When processing "clean" plutonium oxide, the material is run through a sieve as the boat is loaded. This assures that any chunks of contaminants are removed before stabilization in the furnace. The boat is reweighed and the weights are recorded. The charge size is limited to 1.5 in. in depth in the boat and, for items other than "clean" plutonium oxide, to less than 10 g of organic content. The charge size is also limited to 2500 g Pu content for criticality control. A single boat is inspected for contaminants, placed into a furnace, and the covergas flow rate (required for PRF sludges only to limit the buildup of butene gas to less than 25% of the lower flammability limit [WHC 1996a]) and furnace offgas flow rate are adjusted as required (e.g., $\geq$ 30 scfh CO_2, 120 scfh offgas). Covergas flow is required only with PRF sludges, which are processed in glovebox HC-21C exclusively (HA-21I can't be used to process PRF sludges because it does not have cover gas available to its furnaces). For PRF sludges, the covergas is required for the heating period before the furnace reaches 300 °C on ramp-up. Offgas flow is used to ensure oxygen is drawn into the furnace and is available for combustion of impurities and removal of pyrolysis generated gases during the heating cycle. Offgas flow is maintained after the heating cycle is complete to aid in cool-down of the furnace. There are staging areas for an additional boat next to each furnace, but the maximum number of boats allowed in glovebox HC-21C is limited to two and the maximum number of boats allowed in glovebox HA-21I is limited to three.

Heating time and temperature for the furnaces in glovebox HC-21C are controlled by individual microprocessor-based controllers. These controllers are programmed to ramp the temperature to the setpoint, hold the furnace temperature at the setpoint for a specified time period, and then shut off the furnace. The furnaces located in glovebox HA-21I are operated with a Programmable Logic Controller (PLC) rather than individual controllers. Offgases generated during the stabilization process are drawn off and passed through a ceramic filter before entering a vacuum system that feeds into the E-4 ventilation system. High temperature interlocks and alarms are provided to maintain furnace temperatures below 1050 °C and glovebox temperatures below 70 °C.

Following stabilization, the furnace is allowed to cool before the exhaust flow is shut off and the furnace door is opened. The boat is removed from the furnace with a handling tool and positioned in the glovebox to cool further. When the process material reaches approximately room temperature, it

is transferred to glovebox HC-18M via conveyor glovebox HC-2 and glovebox HC-18BS when the material is processed in HC-21C. Material processed in HA-21I also utilizes HC-2/3 airlock, HC-3, HC-4 and HA-2B conveyers.

The processed material is scraped from the boat, sieved, crushed using the mortar and pestle (if necessary), sampled for loss-on-ignition (LOI) testing, and placed in a slip-lid product can for interim storage in Glovebox HC-18BS. Upon confirmation of acceptable LOI results (WHC 1995a), the product can is transferred from Glovebox HC-18BS to Glovebox HC18M or Glovebox HC-13MD and is removed from the glovebox (bagged-out) and packaged for storage. For unacceptable LOI, the product is recycled through the process.

6.4.1.1.1A Narrative Description - Plutonium-bearing Solution Stabilization Using the Production VDC. Plutonium-bearing solution stabilization using the Production VDC is performed in glovebox HC-230C-2 in room 230C of the 234-5Z Building (See Chapter 5.0, Section 5.2.1.2). Solution stabilization consists of converting plutonium nitrate solutions to plutonium oxide by processing the solutions through the Production VDC in glovebox HC-230C-2. The VDC process takes plutonium nitrate solutions, removes the liquids, destroys the nitrates, and oxidizes the solid residues at 1000 °C to render a stable plutonium oxide powder suitable for packaging and long-term storage. A process flowsheet and material balance for the VDC process is shown on Figure 6-24 and a flow diagram is shown in Figure 6-25. The equipment used in the Production VDC process for plutonium-bearing solution stabilization is described in Chapter 5.0, Section 5.2.1.2.

Product plutonium nitrate solutions suitable for calcination in the Production VDC are transferred from glovebox HC-227S through a double encased transfer line to a feed tank located in glovebox HC-230C-2 in room 230C. The nitrate solution is then pumped and mixed with an atomizing air flow into a preheated bed of plutonium oxide (PuO_2) powder in the calciner. The calciner agitates and heats the injected mixture between external and internal heaters to 1000 °C to form PuO_2. The calcination of the plutonium nitrate produces nitrogen oxides (NO_x), nitric acid gas (HNO_3), and steam.

The NO_x, HNO_3, and steam by-products from the production of plutonium oxide flow upward through the bed and out the top of the calciner using the 26-in. Hg process vacuum system as motive source. The offgases are filtered prior to exiting the calciner through ceramic filters and then bubbled through a gas scrubber system filled with caustic solution (sodium hydroxide). The scrubber is designed with an internal cooling coil, which receives chilled water from a chilled water supply unit. The acidic gases are condensed and neutralized with the sodium hydroxide and the water vapor is condensed. Non-condensable gases and partially spent caustic solution flow from the scrubber to a phase separator tank. The treated gas flow is then removed through a vacuum trap into the 26-in. Hg vacuum system. The radioactive offgas stream is filtered through two stages of HEPA filters in the 26-in. Hg vacuum system prior to discharge to the atmosphere.

The scrubber is designed to operate around 1.0 - 1.5 M NaOH. The caustic solution in the scrubber is depleted over time by the reactions with the acidic offgases which consume hydroxide and reduces the pH of the solution. The scrubber solution is continuously removed and circulated through the phase separator tank and returned to the scrubber tank to provide mixing.

Concentrated sodium hydroxide is added directly to the scrubber to maintain the desired concentration. The phase separator tank has a portion of the scrubber solution pumped to the spent scrub solution receiver tank (SSSRT) bank for disposal. The system is designed to have one SSSRT bank filling while the other bank is sampled and analyzed prior to discharge to tank TK-D8 in Building 241-Z via the PFP liquid drain lines. The liquid waste is ultimately transferred to tank farm facilities.

Product from the Production VDC process is PuO_2. The stabilized product from the Production VDC process is subjected to the same sampling, testing and packaging as described in other subsections of Section 6.4.1 for reactive material stabilization operations. The stabilized material is transferred in a slip-lid product can to Glovebox HC-18M and sampled to verify the LOI meets vault storage specifications (WHC 1995a). LOI testing is performed in the PFP Analytical Laboratory. If the LOI sample results are acceptable, the product can is bagged-out of glovebox HC-18M, placed into two more hermetically sealed cans, and the cans are transferred to the Building 2736-Z vaults for storage. If the LOI sample results are unacceptable, the material is processed through thermal stabilization (reactive material stabilization) until the LOI is acceptable and then it is packaged for long term storage.

Feed Preparation. The plutonium nitrate solution used for feed to the vertical denitration calciner is received from PR cans stored within the PFP. The PR cans contain approximately 8 to 9 L per can. The liquid is transferred via hood HC-227T in room 227 into the three batch load-in tanks in glovebox HC-227S designated BT-1, BT-2, and BT-3 (Batch Tank). Each PR can is emptied and rinsed with 2 M nitric acid. The plutonium nitrate is blended with Pu nitrate solutions from other PR cans and sampled for Pu accountability, acidity (H^+), density, organic (phases) and other characteristics as shown in Table 6-6.

Plutonium nitrate solution is then pumped in 9 to 10 L draws to the feed receipt tank in glovebox HC-230C-2 in room 230C. The solution is then gravity transferred to the feed pump tank. The feed receipt tank is refilled from the designated batch tank.

Feed Injection. Plutonium nitrate solution is gravity transferred from the feed receipt tank (FRT) into the feed pump tank (FPT). Plutonium nitrate solution is pumped from the feed pump tank to the vertical denitration calciner at a nominal flow rate of 2 to 4 L per hour at approximately 25 psi. The feed is then mixed and atomized with air from the air bottle rack located in the corridor outside room 230C at a rate of approximately 40 ft^3/h at 50 psi prior to entering the vertical calciner.

Feed Rate Limits. The feed rate to the Production VDC is limited by two operating factors:

- Plutonium throughput is restricted to about 600-700 g-Pu/h so that the product plutonium oxide residence time within the calciner is sufficient to meet the LOI specifications for SNM storage (WHC 1995a)

- To maintain an acceptable pressure drop across the offgas filters, the liquid flow rate is limited to approximately 2-4 L of feed per hour.

Calcination. The Production VDC is loaded or pre-charged with approximately 3 kg of PuO_2 and slowly preheated to approximately 1000 °C with agitation. Atomized plutonium nitrate solution is injected at a nominal rate of 2 to 4 L/h into the vertical calciner through the bottom plate once the calciner has reached 1000 °C. The plutonium oxide product drops from the top of the oxide bed into a collection vessel through an adjustable weir system within the calciner. When the collection vessel is full, the product is placed into a half-liter, lead-lined, slip-lid can. When the slip-lid can is filled, the product is transferred to glovebox HC-18M where it is sampled and weighed. The sample of the product is transferred to the PFP Analytical Laboratory for LOI testing. If the sample is acceptable (WHC 1995a), the product is placed into a slip-lid product can. Oxide product is collected until the production accumulates approximately 5 kg at which point it is transferred to the Building 2736-Z storage vaults. If the sample is unacceptable, it is processed through thermal stabilization furnaces (reactive material stabilization) which are discussed in other subsections in Section 6.4.1.

Offgas Treatment. Plutonium oxide production from the direct calcination of plutonium nitrate generates several acidic gases that must be removed from the offgas stream before it enters the PFP process vacuum system. These offgases include HNO_3, NO_x and water vapor from the decomposition of plutonium nitrate and vaporization of the liquid component of the feed solution.

The 26-in. Hg vacuum system pulls the hot Production VDC offgases at 300 °C from the vertical calciner through a parallel set of ceramic offgas filters mounted in the top of the calciner unit. The filters are periodically back-washed by a pulse of air to remove accumulated particulates and reduce clogging. The offgases flow to a 15 L, 1.5 M sodium hydroxide scrubber tank. Gases entering the tank are aspirated through a sintered stainless steel plate located at the bottom of the tank. The scrubber tank is cooled to 10 °C using an internal cooling coil and external cooling unit (chiller). The cooling reduces the 300 °C offgas temperature to 10 - 25 °C and, at the same time, the sodium hydroxide reacts with the NO_x and HNO_3 to form various amounts of sodium nitrate and sodium nitrite salts in solution.

Sodium hydroxide solution from the Scrubber Tank (ST) is continuously recirculated into the phase separator tank (PST) and back into the ST at 25 L/h with Pump P-230-C. The ST solution is accumulated in the PST until the high liquid level probe is activated. Solution pumped from the PST to the ST is stopped and PST solution is pumped to SSSRT 1 or 2. When the PST low liquid level probe is activated, solution transfer to the SSSRT is terminated and the recirculation of solution from PST to the ST is resumed.

Offgas Scrubber Solution. The offgas scrubber system solution, ie., the sodium hydroxide, is consumed as the reactive NO_x and HNO_3 are mixed into the scrubber tank. The scrubber is initially charged with a sodium hydroxide concentration at 8.0 M from a solution drum station via pump P-230-B. The scrubber unit operates at 1.0 - 1.5 M sodium hydroxide. A pH element is

located in the recirculation pump (P-230-C) discharge line. The pH element starts the caustic addition pump, P-230-B, depending on solution pH.

Process Cycle Time. Process cycle time regulates process support activities required to maintain the process in continuous operation. Below are listed items needed to be maintained to operate the process in a continuous manner.

- Feed Receipt Tank - Tank filling is required every 3-5 hours depending upon a Feed Pump Tank Rate.
- Product Storage - The Production VDC generates approximately 680 gm/h PuO_2. The product can is allowed 5 kg which requires sampling, testing, final canning, and storage every 7 hours.
- Spent Scrub Solution Receiver - The process has two spent scrub solution banks, each containing two tanks. Each 40 L bank will allow approximately 6 hours of calciner operation before sampling is performed and transfer to Tank TK-D8 in Building 241-Z. The sample results must be received prior to transfer.
- Sodium Hydroxide Feed - Sodium hydroxide solution is pumped into the scrubber tank from a 55-gallon drum. At the process flow sheet rate, the drum would need replacement approximately every 30 to 40 hours of system operation.
- Bottled Process Air - Bottled air is injected into the vertical calciner at approximately 40 ft^3/h. At the process flow sheet rate, one bottle containing 250 ft^3 of compressed air is used every six hours. The bottled air rack contains four compressed air bottles.

6.4.1.1.2 Flowsheets - Reactive Material Stabilization. The thermal stabilization of reactive plutonium-bearing materials is a batch process. Containers holding in-process material are staged in glovebox HA-23S or containers of material to be processed may be staged in fixed array wagons in Room 230B. A quantity of plutonium-bearing material is placed into a boat in glovebox HC-21A. The boat is covered and then transferred through the conveyers to glovebox HC-21C or HA-21I. The boat is uncovered and placed into a muffle furnace and the temperature controller is started. The stabilized material is transferred to glovebox HC-18M for sieving, LOI sampling and product can makeup. The cans are stored in Glovebox HC-18BS until the LOI results are obtained. Upon receiving acceptable results (WHC 1995a), the cans are sealed out of glovebox HC-18M or HC-13MD and sealed into two outer cans before being sent to the vaults for storage.

Heat balances are not provided because the amount of heat varies depending on the amount and type of material being processed. The heat input is controlled by automatic temperature controllers. Most of the heat generated is dissipated to the ventilation system, primarily to the E-4 (offgas) system, and discharged to the atmosphere via the 291-Z-1 stack.

6.4.1.1.2A Flow Sheets - Plutonium-Bearing Solution Stabilization Using the Production VDC. The stabilization of plutonium-bearing solution by the Production VDC process is a continuous operation. Solution is continuously

fed from the feed pump tank to the calciner by the feed pump, P-230-A. As the solution is depleted from the feed pump tank, additional solution is gravity transferred from the feed receipt tank to the feed pump tank. Similarly, as solution is depleted from the feed receipt tank, additional solution is pumped from glovebox HC-227S in room 227 to the Production VDC process glovebox, HC-230C-2. A process flow sheet and material balance are shown in Figure 6-24. The plutonium oxide product from the calciner is essentially processed as described in Section 6.4.1.1.2 for reactive material stabilization. The product is transferred to the HC-18M glovebox for sampling. The sample is transferred to the PFP Analytical Laboratory for LOI testing. If acceptable, the product in glovebox HC-18M is packaged and transferred for long term storage in the Building 2736-Z storage vaults. If unacceptable, the product is processed through the thermal stabilization furnaces in the same manner as discussed in Section 6.4.1.1.1 for reactive material stabilization.

6.4.1.2 Process Chemistry and Physical Chemistry Principles - Reactive Material Stabilization. Five categories of plutonium-bearing material are thermally stabilized to meet long term storage requirements: PRF sludges from the last PRF campaign, mixed uranium and plutonium oxides (MOX), floor sweepings, plutonium oxalates, and plutonium oxide. When heated, PRF sludges dry and then oxidize to an impure plutonium oxide powder. The floor sweepings include plutonium oxide, plutonium oxalate, and plutonium oxycarbonate. The plutonium oxide simply dries with no chemical reactions occurring. Plutonium oxalate [$Pu(C_2O_4)_2 \cdot 6H_2O$] degrades from exposure to alpha radiation to plutonium oxycarbonate ($PuOCO_3 \cdot 2H_2O$) with a reaction half-life of 64 days. Since the floor sweepings have been in storage for over four years, essentially all of the Pu oxalate has degraded into the oxycarbonate form. Plutonium oxycarbonate, when heated above 100 °C, forms an intermediate phase. As the temperature rises (or is held at an elevated level), the aqueous portion is driven off and the remaining material is oxidized to plutonium oxide powder. Plutonium oxide is simply dried in the furnace to meet LOI requirements for long term storage. Currently, all five categories of "clean" and non-product plutonium-bearing material mentioned above may be processed in the furnaces in glovebox HC-21C. Four of the five categories of "clean" and non-product plutonium-bearing materials (excluding PRF sludges) may be processed in the furnaces in glovebox HA-21I.

6.4.1.2A Process Chemistry and Physical Chemistry Principles - Plutonium-Bearing Solution Stabilization Using the Production VDC. The objective of the plutonium-bearing solution stabilization program is to convert the plutonium in Pu nitrate solutions to Pu oxide using the Production VDC process. The acidic offgases produced by the conversion process are treated in the scrubber prior to being released to the atmosphere. The process technology is described below.

Plutonium Oxidation. The Pu nitrate, $Pu(NO_3)_4$, at an acid concentration of at least 1.3 M HNO_3 or greater is decomposed to plutonium oxide when heated in the calciner to an overall process temperature of 1000 °C in excess oxygen/air. A reactor residence time of at least 4 hours assists in heating the product further to obtain the desired product which meets LOI requirements.

The decomposition of the Pu nitrate to Pu oxide follows a reaction similar to:

$$Pu(NO_3)_4 \text{ ---------> } PuO_2\downarrow + 0.6\ NO\uparrow + 3.4\ NO_2\uparrow + 1.6\ O_2\uparrow$$

The overall process heat in the Production VDC is achieved through heating the outer portion of the reactor and the inner core to 1000 °C.

Air is injected into the system at 40 ft^3/h at 50 psi from an air bottle rack to atomize the feed solution and provide the excess O_2 required to oxidize the Pu nitrate to the oxide form of the element (Pu) with no valence change. Offgases produced from the reaction are a mixture of oxides of nitrogen (NO_x) compounds with nitric acid vapor and water as steam.

Offgas Treatment. The NO_x compounds discharged from the calciner unit are drawn through the offgas treatment scrubber using the 26-in. Hg vacuum system. The offgas scrubber uses a box constructed of sintered stainless steel plate that disperses the gas into small bubbles. This dispersion increases the reaction area in the scrubber and reduces NO_x emission.

The neutralization of the NO_x compounds follows reactions:

1) $2\ NO_2 + H_2O \text{ ---------> } HNO_3 + HNO_2$

2) $HNO_3 + NaOH \text{ ---------> } NaNO_3 + H_2O$

3) $HNO_2 + NaOH \text{ ---------> } NaNO_2 + H_2O$

4) $3\ HNO_2 \text{ ---------> } HNO_3 + 2\ NO + H_2O$

5) $2\ NO + O_2 \text{ ----------> } 2\ NO_2$

The NO_x compounds are converted to mostly sodium nitrate, per reaction 2, in the liquid phase as determined from the material balance in Figure 6-24. The reaction consumes a portion of the sodium hydroxide and lowers the pH, or sodium hydroxide concentration, as sodium salts of nitrate/nitrite and water are formed.

Offgas Scrubber pH. The scrubber is designed to operate around 1.0 - 1.5 M NaOH. The reactions shown above consume sodium hydroxide which reduces the pH of the scrubber solution. The hydroxide ion is forced to form water to maintain a chemical balance in the system. The scrubber solution is recirculated from the phase separator tank to the scrubber tank to provide mixing. The phase separator tank, at the same time, has a portion of the sodium hydroxide pumped to the SSSRT for disposal. The scrubber tank volume and pH is adjusted by adding 8.0 M fresh sodium hydroxide solution. The sodium hydroxide (NaOH) addition maintains the scrubber at a pH of approximately 14.1 at 1.0 - 1.5 M NaOH. Lower pH values (below 13.5) will permit NO_x in the vacuum system lines and seal water which will cause low pH discharges to the Low Level Waste Treatment Facility, Building 243-Z.

6.4.1.3 Mechanical Process Systems. There are no mechanical process systems associated with the RMA and RMC Line processes involving reactive material stabilization or plutonium-bearing solution stabilization using the Production VDC.

6.4.1.4 Chemical Process Systems - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC. Thermal stabilization of reactive materials is performed in gloveboxes HC-21C and HA-21I, located in rooms 230A and 235B of Building 234-5Z (see Figure 6-27). The thermal stabilization process is supported by charge makeup in glovebox HC-21A. Sampling and product can makeup is conducted in HC-18M. Feed lag storage is in glovebox HA-23S, and product lag storage is in glovebox HC-18BS. LOI analysis is performed in the PFP Analytical Laboratory. Conveyor gloveboxes HC-1, HC-2, HC-3, HC-4, and HA-28 are used to transfer material between gloveboxes.

Plutonium-bearing solution stabilization using the Production VDC process is performed in glovebox HC-230C-2 (see Figure 6-26) located in room 230C of Building 234-5Z (see Figure 6-27). The Production VDC process converts Pu nitrate solutions into Pu oxide. Solution stabilization operations are supported by the following:

- LI/LO hood HC-227T/glovebox HC-227S for Pu nitrate solution LI, blending, sampling and transfer to glovebox HC-230C-2 and LO of solutions from glovebox HC-230C-2
- Gloveboxes HC-18BS and HC-18M for Pu oxide product storage, sieving, grinding, sampling for LOI testing, and initial packaging for long term storage
- Conveyor gloveboxes HC-1, HC-2 and HC-3 for transfer of materials between gloveboxes.

6.4.1.4.1 Functional Description - Reactive Material Stabilization. Thermal stabilization is used to stabilize reactive plutonium-bearing materials. The stabilized plutonium is then packaged for long-term storage.

Thermal stabilization is accomplished by heating the plutonium-bearing materials to high temperatures in furnaces. A pre-programmed controller is used to ramp the temperature to the setpoint, hold the furnace temperature at the setpoint for a specified time period, and then shut off the furnace. Following stabilization, the material is cooled, crushed (if necessary) and sampled to verify compliance with the vault storage criteria (WHC 1995a). The processed material is then packaged for long-term storage.

6.4.1.4.1A Functional Description - Plutonium-bearing Solution Stabilization Using the Production VDC. The Production VDC process (not currently authorized) is used to stabilize plutonium-bearing solutions. The process converts Pu nitrate solutions to Pu oxide for long term storage by heating the solutions to approximately 1000 °C in the calciner. The dried product, Pu oxide, is continuously collected from the calciner which overflows into a collection jar. The product is transferred to other gloveboxes where it is sieved, ground, sampled for LOI testing and packaged for long term storage. The Production VDC process is described in Section 6.4.1.1.1A and the process flow is presented in Section 6.4.1.1.2A.

6.4.1.4.2 Major Components - Reactive Material Stabilization. The major components associated with thermal stabilization of reactive plutonium-bearing materials are identified and described below for each glovebox. These

gloveboxes were originally used to support plutonium conversion operations, as part of RMA or RMC Lines. Additional information can be found in Chapter 5, Section 5.2.1.2.2.

Gloveboxes HC-1, HC-2, HC-3, HC-4, HA-28. These gloveboxes are conveyer gloveboxes and therefore contain no process equipment. Gloveboxes HC-1, HC-2, HC-3, and HA-28 are equipped with 4-1/2-in.-wide electrically powered slat conveyors that travel between 5/8-in.-high guide rails that are separated by a distance of 7-5/8 in. A series of rollers are used for transporting items through glovebox HC-4.

Gloveboxes HC-1 and HC-2 serve as plenums that deliver air to all the adjoining gloveboxes, except for the top and bottom sections of HC-9B and HC-17P (see Figure 6-14). Glovebox HC-2 extends from Glovebox HC-18BS to an airlock in Room 230-B. Glovebox HA-28 also serves as a plenum to deliver air to adjoining gloveboxes. Air is exhausted through HEPA filters located in the gloveboxes and out of the E-4 gas system. At least -0.5 in. w.g. pressure is maintained in the gloveboxes by the exhaust system.

Air enters the system at the top of the glovebox HC-2 conveyor adjacent to glovebox HC-18BS, through a 4-in. self-governing regulating valve rated at 250 std ft^3/min. Flow is regulated between 25 to 250 std ft^3/min. The sensing pressure is applied directly to the diaphragm chamber to control pressure to -0.5 to -1.2 in. w.g., and can cycle from full-open to full-closed within 3 s. Air also enters the system at the west end of glovebox HA-28, through a 4-in. self-governing regulating valve. As pressure increases to greater than -0.5 in. w.g., the supply valves close, avoiding loss of negative pressure, overpressurization, or discharge of air through an open port (see Section 5.2.1.2.2 for more details).

A differential pressure switch connected to an annunciator in the power control room (room 321) monitors the pressure in the gloveboxes, and alarms if it exceeds -0.3 in. w.g. The power operator in room 321 announces the loss of sufficient differential glovebox pressure to the affected area.

Two valves regulate exhaust on an emergency basis. Each parallel 4-in., 200 std ft^3/min valve connects to a common, locally unfiltered 8 in. diameter duct to exhaust a total of 400 std ft^3/min. The valves are closed tight for any upstream pressures less than -0.5 in. w.g. They are set to start opening at -0.45 in. w.g. and be opened fully before upstream pressure becomes positive. The resulting flow of unfiltered air goes to the 12-in.-diameter E-4 header in room 263 (above the RMC Line), and to four primary filterboxes connected in parallel. The increased exhaust flow helps to maintain the glovebox confinement in the event of a glovebox glove failure.

An electrically controlled valve located on the 8-in.-diameter emergency exhaust duct is interlocked with the glovebox heat detectors. If a fire with sufficient heat to activate the heat detectors occurs, the emergency duct valve would close, reducing heat load on the first-stage filters and reducing the flow of air that could feed the fire.

A 12 in. diameter unfiltered duct, equipped with a manual valve, is located on the west end of glovebox HC-2. This valve is used to regulate airflow during glovebox panel changes.

Gloveboxes HC-1, HC-5, and HA-23S are equipped with criticality drains. A criticality drain is a 3 in. diameter bag port attached to the side of the glovebox with the bottom lip of the port just below the maximum allowed depth of liquid accumulation on the glovebox floor. An open-ended plastic bag is attached to the port. The open end is closed for confinement purposes by a precision-finished steel roller balanced on a polished steel plate. Liquid exceeding the maximum slab depth drains out of the glovebox into the plastic bag. The weight of the liquid pressing against the steel roller moves it off of the plate, freeing a path for drainage to the room floor. The resulting contamination is a less severe hazard than a criticality incident.

Glovebox HC-18BS. Glovebox HC-18BS is used as a transfer and product lag storage area. The low, broad glovebox frame is level with glovebox HC-1. There are no panels on the north and south sides, where it connects to the HC-2 and HC-1 conveyor platforms. Glovebox HC-18BS contains 20 storage sites. The storage sites are on a chain-driven slotted belt conveyor, situated horizontally around five large sprockets.

Glovebox HC-18BS was originally used to store and transfer metal buttons using the serpentine conveyor belt during production operations in the RMC Line. The conveyor belt is used during thermal stabilization operations to transfer furnace boats between conveyor Glovebox HC-2 and Glovebox HC-18M for further processing. A new boat holder has been specifically designed to accommodate use of the serpentine conveyor with furnace boats. The conveyor is also used for lag storage of the plutonium oxide product while waiting for LOI analysis results.

Glovebox HC-18M. The glovebox is equipped with gloveports on three sides, and connects with glovebox HC-1 on the north side. The glovebox top is mostly polymethyl methacrylate paneling. The glovebox contains a sieve pan, sieve screen, sieve shaker, mortar & pestle, a weigh scale, electric bag sealer, furnace boats and covers, funnel, and tongs. Beneath the glovebox are the two hydraulic pumps that serve the RMC Line. All of the electric valves (EVs) that control the hydraulic fluid to the equipment in the gloveboxes are housed in a separate compartment beneath the glovebox on the south end. This section is ventilated by room air that is exhausted by a dedicated duct. The electric blower that served the line vacuum cleaner is located beneath the north section of the glovebox. The electric blower, which is no longer in service, exhausted into the E-4 system by a dedicated duct.

There are two levels in the glovebox with the second level floor at 45 in. above the room floor. The lower level is not used for stabilization operations. The upper level houses the sieve, mortar and pestle, and a weigh scale. Glovebox HC-18M is used to sieve the stabilized plutonium oxide material to obtain a particle size of less than 1/4 inch. This ensures that a representative sample is obtained for LOI testing. Larger particles are broken up by use of a mortar and pestle. A sample of material is obtained and bagged-out for LOI testing in the PFP Analytical Laboratory and the remainder of the material is placed in a slip-lid can, taped closed, and transferred for temporary storage in Glovebox HC-18BS. For samples that pass the LOI test, the slip-lid container corresponding to that sample is retrieved from Glovebox HC-18BS, weighed, bagged-out of Glovebox HC-18M, and transferred to storage. Samples that do not pass the LOI test are returned for additional processing through the furnaces.

Glovebox HC-21A. The equipment in glovebox HC-21A is used for sealing-in/out plutonium-bearing materials, opening containers, loading boats, and weighing (See Figure 6-15). Filled boats are covered and transferred to Glovebox HC-21C for thermal stabilization processing in one of the muffle furnaces. The glovebox contains an electronic balance for determining the mass of plutonium-bearing material before and after thermal stabilization. A glass mortar and pestle are available (if needed) for crushing large chunks of thermally stabilized material. Thermally stabilized material is passed through a sieve to uniformly size the material. The sieving is performed to ensure that a representative sample can be taken for LOI analysis. The processed material is placed into slip-lid cans and stored on a storage rack in glovebox HC-21A or in HC-18BS until the LOI results are obtained. For acceptable LOI results, the cans are sealed out of glovebox HC-21A and sealed into two outer cans before being sent to the vaults for storage. Any material that not meeting the LOI limits is resampled and recycled if necessary. Slip-lid cans are used for holding the stabilized material. Note that Glovebox HC-18M is the primary location for processing of thermally stabilized material and sealing out, although the option of using Glovebox HC-21A has been retained for back-up purposes (e.g., Glovebox HC-18M out-of-service). Glovebox HC-21A will require a review/revision of the glovebox posting and associated procedures to provide adequate material control prior to initiating thermally stabilized material processing in glovebox HC-21A.

Glovebox HC-21C. Glovebox HC-21C houses two muffle furnaces that are used for thermal stabilization. The glovebox is linked on the north side with conveyor glovebox HC-2. The furnaces have chamber dimensions of 13 in. in length, by 5.5 in. in width, and 5 in. in height. The 4.1 kW furnaces have an operating temperature range of ambient to 1093 °C. The furnaces are equipped with CO_2 purge systems that are used to dilute butene, which could be generated while processing PRF sludge to $\leq$ 25% of the lower flammability limit (WHC 1996a). The CO_2 is supplied by a station located in room 230A. The station consists of a cabinet that houses two liquid CO_2 cylinders. A manifold automatically switches to the second cylinder when the first one is empty. Each cylinder is equipped with a vent that releases approximately 2 lb of CO_2 per day, to reduce cylinder pressure.

The exhaust line from each furnace in Glovebox HC-21C ties into the 26-in.-Hg process vacuum system. The exhaust air passes through a stainless steel housing with ceramic filter media, to filter out suspended particles greater than 2 microns in diameter. The filter is followed by a needle valve that is used to adjust the exhaust flowrate. The flow rate is indicated on rotameters and differential pressure gauges. Inconel tubing is used between the furnace and filter housing to withstand the high temperatures. Once the exhaust gas passes through the filter housing, the gas has cooled sufficiently so that stainless steel may be used. The stainless steel offers greater resistance to corrosion.

There are two stainless steel desiccators that may be present in the glovebox. The sides and door are made of tempered glass. The desiccator has a positive-latch door with a neoprene gasket. A manual relief valve allows for chamber pressure equilibration. The outside dimensions of the desiccator are 12.5 in. in length by 12.5 in. in width and 12.25 in. in height. The desiccant is a silica gel contained in a small canister that can be regenerated. The current feed types do not require the use of a desiccator

following thermal treatment but the new feed types being tested may require a desiccator.

Glovebox HA-21I. Glovebox HA-21I contains three muffle furnaces used for thermal stabilization (see Figure 6-16). The south end of glovebox HA-21I connects to conveyor glovebox HA-28. The same type of muffle furnace is used as in glovebox HC-21C. The furnaces in HA-21I do not have a CO_2 purge system, therefore, HA-21I is not used to treat PRF sludges. The exhaust line from each furnace in HA-21I ties into a dedicated 5-in. mercury process vacuum system. Similar to the HC-21C system, the exhaust flows through a ceramic filter followed by a needle valve, which is used to adjust the exhaust flowrate. The flow rate is indicated on differential pressure gauges. This glovebox is equipped with a criticality drain.

The HA-21I glovebox is provided with a criticality drain to prevent liquid accumulation and fissionable material from reaching a depth that could result in exceeding an allowable criticality limit.

Glovebox HA-23S. Lag storage of feed material is provided in glovebox HA-23S. The south end of glovebox HA-23S connects to conveyor glovebox HA-28. This glovebox is equipped with a criticality drain.

6.4.1.4.2A Major Components - Plutonium-bearing Solution Stabilization Using the Production VDC. The major components in the Production VDC process used for solution stabilization are the glovebox, calciner, scrubber, process tanks, and process pumps. These components are described in detail in Chapter 5.0, Section 5.2.1.2.2 under the headings "Remote Mechanical C Line Glovebox for Solution Stabilization Using the Production VDC" and "Remote Mechanical C Line Glovebox Equipment for Solution Stabilization Using the Production VDC".

6.4.1.4.3 Design Description - Reactive Material Stabilization. The gloveboxes used for thermal stabilization operations are part of the RMC/RMA Line which was designed for converting plutonium nitrate solutions to plutonium metal. The gloveboxes are fabricated of stainless steel frames with top and side panels of clear plastic or leaded glass with wire mesh. The large windows provide visibility for the operators. The window panels are penetrated by gloveports, glovebox bag-in/bag-out ports and sphincter seals. Most of the gloveboxes are also provided with leaded glass for shielding. Glovebox HA-23S has a water wall for neutron shielding.

6.4.1.4.3A Design Description - Plutonium-Bearing Solution Stabilization Using the Production VDC. The process design for the solution stabilization operations using the Production VDC is provided in Section 6.4.1.1.1A and the equipment design is provided in Chapter 5.0, Section 5.2.1.2.

6.4.1.4.4 Safety Criteria and Assurance - Reactive Material Stabilization and Plutonium-Bearing Solution Stabilization Using the Production VDC. The primary safety concerns associated with the stabilization process are:

- criticality safety
- radiological safety
- process upsets
- industrial safety.

Criticality Safety. The gloveboxes and processes used in the stabilization processes have been analyzed by the methods outlined in Section 6.4.1.9.1 to ensure compliance with the criticality safety criteria presented in Chapter 4, Section 4.4.4. Criticality safety features incorporated into the design of the gloveboxes include the following:

- The process equipment is designed to be geometrically favorable, even if it is filled with plutonium at the maximum credible moderation.
- Process containers such as boats, slip-lid cans and product receiver jars are designed to be subcritical, even if overbatched and moderated.
- Gloveboxes HC-1, HC-5, HA-21I, and HA-23S are each provided with a criticality safety drain to ensure that a critical depth cannot be achieved, even if material is spilled and the gloveboxes are flooded.

Administrative limits are included in the criticality safety programs for stabilization operations. These limits include restrictions on plutonium mass, the number and size of containers, material type, and spacing limits between containers. Specific administrative limits for reactive material stabilization operations are specified in WHC (1995b) and, for solution stabilization operations, are specified in BWHC (1997a). The total dispersible Pu in Glovebox HC-18BS is limited to 50 kg as metal or 20 kg as powder (BWHC 1998). Criticality specification limits for the various process gloveboxes are shown in Chapter 5.0, Table 5-5.

Criticality detection and alarm systems are located in the areas used for stabilization operations. Personnel are required to rapidly evacuate the areas if the alarms sound. Criticality drills are conducted annually. The detection and alarm equipment is checked on a scheduled basis and redundancy is provided. This system must be functional to perform stabilization operations.

Radiological Safety. All gloveboxes are maintained at negative pressure with respect to room pressure (-0.3 to -1.5 in. w.g.), to confine plutonium to the gloveboxes if a small break in the confinement barrier occurred. Three stages of HEPA filtration (one non-testable at the glovebox and two that are testable in the exhaust system) are provided in the E-4 exhaust system before offgases are discharged to the atmosphere via the 291-Z-1 stack.

Strategically located CAMs alarm if airborne plutonium is detected in the work space and prompt evacuation of the affected airspace is required. The CAMs must be functional to perform stabilization operations. Criticality detectors and alarms are also required to be operational. The layout of CAMs and criticality detectors is provided in Chapter 8.0, Figures 8-13 and 8-27, respectively.

Process Upsets. Process upsets can potentially lead to loss of confinement, criticality, equipment damage, or high plutonium losses to waste. These events were considered when developing the process flowsheets, equipment design, and instrument and control (I&C) systems. The stabilization systems

were designed to maintain the process within operating limits (see Section 6.4.1.4.5). Instrumentation and controls are provided to monitor process parameters and alarm abnormal conditions. Interlocks are provided to automatically place equipment in a safe condition in the event of process upsets.

Industrial Safety. High temperatures could melt glovebox gloves. The gloves are pulled out of the glovebox and tied together when the thermal stabilization furnaces or the calciner are in use and work is not being performed.

Fire in a glovebox is a potential hazard that could breach confinement barriers (glovebox panels, gloves) and disperse plutonium powders. The potential sources of fire are primarily ignition of gloves by high temperature equipment, and accumulation of combustibles (gloves, rags, paper, etc.) in a glovebox (particularly during maintenance activities) with subsequent ignition.

Administrative controls require that combustibles in a glovebox be kept to a minimum. Criticality prevention specifications limit the number of rags per glovebox for cleaning purposes. All gloveboxes are administratively limited to control combustible material. Gloves are fabricated of fire-resistant and chemical-resistant Hypalon™ material and are not permitted to accumulate in gloveboxes when removed. Maintenance activities are monitored to ensure that there is no excessive accumulation of combustibles.

Each glovebox has heat detectors that alarm if a fire starts. The Hanford Fire Department also receives an alarm. Some of the glovebox panels are fabricated of Lexan™ (a self-extinguishing material) and the remainder are plexiglass or wire-reinforced glass. Hand-operated dry chemical fire extinguishers with bayonets to penetrate gloves and MgO sand are also available to extinguish fires. An automatic Halon system is provided in thermal stabilization glovebox HC-21C. Thermal stabilization glovebox HA-21I and Production VDC solution stabilization glovebox HC-230C-2 have sensors that are set to activate dry-chemical fire protection systems.

6.4.1.4.5 Operating Limits - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC. The thermal stabilization process for reactive materials has operating limits controlling feed type, furnace operation, offgas and purge flow, fire safety concerns, product specifications, and glovebox plutonium inventory. These limits and their related safety/operational considerations are shown in Table 6-5. The solution stabilization operations using the Production VDC have operating limits on feed materials, process conditions and product quality which are shown in Table 6-6.

6.4.1.5 Instrumentation and Control Systems - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC.

6.4.1.5.1 Functional Description - Reactive Material Stabilization. Reactive plutonium-bearing materials are thermally stabilized in muffle furnaces located in gloveboxes HC-21C (in room 230A) and HA-21I (in room 235B). Most of the instrumentation, controls and alarms for the thermal stabilization process are located on a control panel and on a personal

computer (PC) control station located in room 230A, near the HC-21C glovebox. The control panel is used for operating the muffle furnaces in glovebox HC-21C. The furnaces in HA-21I are controlled with the PC. A CO_2 cabinet is also located in room 230A. Rotameters are located near glovebox HC-21C. Differential pressure gauges are located both in and near gloveboxes HC-21C and HA-21I.

Thermocouples are used to determine furnace and glovebox temperatures. If the furnace temperature exceeds a preset value, an alarm is activated and power to the furnace is automatically shut off. Offgas flow rate and CO_2 purge are manually set at the glovebox (CO_2 purge is only available in glovebox HC-21C). Covergas flow is required only with PRF sludges, which are exclusively processed in glovebox HC-21C. For PRF sludges, the covergas is required for the heating period before the furnace reaches 300 °C on ramp-up. Offgas flow is used to ensure oxygen is drawn into the furnace and is available for combustion of impurities and removal of pyrolysis generated gases during the heating cycle. Offgas flow is maintained after the heating cycle is complete to aid in cool-down of the furnace. Offgas flow is used during the whole operation cycle.

6.4.1.5.1A Functional Description - Plutonium-bearing Solution Stabilization Using the Production VDC. Solution stabilization is performed in glovebox HC-230C-2 in room 230C of the 234-5Z Building. The stabilization operations consist of processing solutions of plutonium nitrate through the Production VDC to convert the solutions to plutonium oxide. Most of the instrumentation and controls for the Production VDC process are located in panels in room 230C and a programmable logic controller (PLC) and modular automation system (MAS) located in room 235B. The panels, PLC, and MAS are summarized in Chapter 5.0, Section 5.2.1.2.2. The Production VDC process is monitored and controlled by the PLC which monitors process parameters and actuates appropriate equipment and controls. The principal process parameters of interest are the glovebox pressure (negative) relative to the room, glovebox temperature, calciner temperatures and pressures, calciner offgas differential pressure, agitator operation, scrubber pH and levels of the various process tanks. Section 6.4.1.5.3A discusses the instrumentation, controls, interlocks and alarms in detail.

6.4.1.5.2 Major Components - Reactive Material Stabilization. Glovebox HC-21C has two muffle furnaces, and three muffle furnaces are located in glovebox HA-21I. Temperature elements are used to measure furnace temperature and provide feedback to the programmable electronic controllers for the furnaces in glovebox HC-21C. The temperature elements in glovebox HA-21I are connected to a PLC. Thermocouples are used to determine glovebox temperature. Orifices with differential pressure gauges are used to control offgas flow rate and, for the furnaces in HC-21C, CO_2 purge. In addition valved rotameter are located near glovebox HC-21C.

6.4.1.5.2A Major Components - Plutonium-bearing Solution Stabilization Using the Production VDC. The major components in the instrumentation and control system for solution stabilization using the Production VDC are those that monitor and control system pressures, temperatures and levels. In addition, power input for the calciner heaters is controlled to provide process temperature control. Pressures are monitored through direct reading gauges and switches for control and/or alarm. Self-contained pressure

regulating valves are generally used for pressure control. Most other process valves are of the open-close type.

Process temperatures of interest are associated with the calciner and are monitored by thermocouples, some of which control the power to the calciner heaters. Process tank levels are monitored by either conductivity probes or weight factor instrumentation. Specific information on significant process instrumentation and control is provided in Section 6.4.1.5.3A.

6.4.1.5.3 Detection Systems and Locations - Reactive Material Stabilization. Each muffle furnace in glovebox HC-21C is equipped with two temperature elements. The temperature elements provide information to the local controllers, which control the power to the furnaces. If the furnace temperature exceeds 1050 °C an alarm is activated and power to the furnace is shut off. Glovebox temperature is measured by three thermocouples placed in representative areas in the glovebox. The measured temperatures are sent to an instrument that digitally displays the temperature in each zone for several seconds. An alarm is activated at 70 °C and the power to each furnace is shut off. An independent detector system is used for the Fire Suppression System. At 93 °C a Halon fire suppression system is activated. A differential pressure gauge measures the negative pressure in the glovebox relative to the room.

Similar to glovebox HC-21C, each muffle furnace in glovebox HA-21I has two temperature elements, and there are three thermocouples placed in HA-21I to monitor glovebox temperature. The information from the temperature elements is sent to the PLC, which controls power to the furnaces. If the furnace temperature exceeds 1050 °C an alarm is activated and power to the furnace is shut off. The measured glovebox temperatures are also sent to the PLC, where the high temperature is selected and displayed on the PC control station. An alarm is activated at 70 °C and the power to all furnaces is shut off. An independent detector system is used for the Fire Suppression System. At 93 °C, a dry chemical fire suppression system is activated. A differential pressure gauge measures the negative pressure in the glovebox relative to the room.

6.4.1.5.3A Detection Systems and Locations - Plutonium-bearing Solution Stabilization Using the Production VDC. The following subsections present information on the major process instrumentation, controls, interlocks and alarms associated with solution stabilization operations using the Production VDC process. A flow diagram for the Production VDC process is provided in Figure 6-25. Operating specification limits for various parameters in the process are provided in Table 6-6.

Calciner Temperature. The calciner has several temperature control and monitoring points. For temperature control, the calciner temperature is measured by a thermocouple which provides temperature information to the PLC system. Temperature controllers control power to the silicon-controlled rectifiers (SCR) which supply power to the calciner heaters. The calciner temperature controller is part of the modular automation system (MAS) with set point programming which receives input from the thermocouple and, based on a comparison with the setpoint, sends output to SCRs. The SCRs control power to the calciner heaters based on the input from the controller. The SCRs use the input from the controller to establish the output current to the heating coils

(dome and shell heaters) on the calciner. A shorted SCR provides full power to the connected heater. On heater A, the SCR provides an alarm contact which is annunciated on the control console. Additionally, an LED on the shorted SCR will indicate the failure at the SCR box located in the control area. The heater B SCR has only an LED which indicates the level of the control signal by its intensity. In addition, heater current readings are provided on the control panel.

Several temperature elements provide temperature information during calciner ramp-up/soak time and control information during calciner operation. One temperature element feeds an interlock to provide high temperature annunciation and calciner operations shutdown. The high temperature alarm annunciates when the calciner outer temperature exceeds 1050 °C and notifies the operators that the Production VDC temperatures are deviating from program parameters and action may be necessary.

Calciner Pressure. The Production VDC uses pressurized air to atomize the feed solution and to provide the oxygen to oxidize the plutonium nitrate at high temperatures. The calciner differential pressure is monitored with a differential pressure transmitter (DPT) installed between the calciner internal compartment and the calciner glovebox. The DPT senses the calciner pressure versus the vacuum of the glovebox within a specified range (<5 inches W.G.) and when activated, annunciates VDC Low Vacuum Alarm. This alarm activates an interlock to shutdown the feed pump, the atomizing air, and the offgas filter blowback air.

Calciner Offgas Filter Differential Pressure. The Production VDC process uses pressurized air to atomize the feed solution and to provide the oxygen to oxidize the plutonium nitrate at high temperatures. The system relies on the 26-in. Hg vacuum system to remove this air to prevent pressurization of the calciner and provide offgas control. The offgas filter differential pressure is monitored with a DPT installed between the vacuum source and calciner internal compartment. The DPT senses the calciner pressure verses the vacuum within a specified range and, when activated, annunciates an alarm. Following an alarm, the operator checks the filter dP on the operator control screen. If the dP is >90 in. W.G., then the feed pump, atomizing air and offgas filter blowback air are stopped (manual response).

Calciner Agitator Stopped. The calciner agitator is monitored for operation and annunciates when not in operation. An agitator stall is detected by a sensor which shuts down the calciner feed pump, P-230-A.

Glovebox Temperature. The glovebox high temperature control system ensures that calciner operations are not allowed to continue if high temperatures in the glovebox are occurring. Discontinuing the calciner operations prevents the Dry Chemical Fire Suppression System from tripping.

The temperature for glovebox HC-230C-2 is measured by one thermocouple in the upper level of the glovebox. When the temperature from the thermocouple reaches a setpoint of 70 °C, a temperature switch actuates an alarm to notify operators that glovebox temperature is high and shuts down the Production VDC operations. An interlock automatically shuts off power to the calciner heaters (dome and shell heaters), the feed pump and the offgas filter blowback air when the glovebox temperature exceeds the limit. The temperature setpoint

of 70 °C is well below the 93 °C automatic trip point for the glovebox dry chemical fire suppression system to prevent inadvertent actuation of the system.

Glovebox Differential Pressure. The differential pressure between glovebox HC-230C-2 and room 230C is monitored to assure that the glovebox is always at a negative pressure relative to the room. This prevents contamination of the room should the glovebox confinement be breached. The differential pressure is read on a local indicator and if negative pressure is lost, the Production VDC operations are manually terminated.

Glovebox Fire Detection System. A heat detection system is provided for the glovebox and automatically activates the dry chemical fire protection system if the temperature exceeds 93 °C.

Calciner Offgas Scrubber Tank pH. The offgas scrubber pH is controlled using a pH sensing element in the discharge line of the phase separator tank pump, P-230-C. The pH probe activates an interlock which starts the sodium hydroxide pump, P-230-B, when the pH drops to $\leq$ 13.0. The probe activates the pump to supply fresh 8.0 M sodium hydroxide to increase the scrubber tank pH to approximately 14.

Phase Separator Tank Level. The phase separator tank (PST) pump, P-230-C is running whenever the offgas scrubber is operating. The PST pump recycles solution from the PST to the scrubber or transfers spent sodium hydroxide solution to the Spent Scrub Solution Receiver Tank (SSSRT) depending on the PST level. The PST level is monitored by conductivity probes. Once the PST level reaches the probe, the transfer to the SSSRT is started. When the level in the PST drops below the level high probe, the recycle to the scrubber is started. Level control in the scrubber is by use of an overflow tube from the scrubber to the PST.

Spent Scrub Solution Receiver Tank Level. Levels in the SSSRTs, SSSRT-1 or -2, are monitored through weight factor transmitters (WFT). The WFTs actuate alarms which warn of high liquid levels in the tanks. The corrective action for an alarm from either tank is to manually switch operations to use the other tank. Corrective actions by operations will prevent liquid spillage to the floor from the tank vents. Tanks overflowing to the glovebox floor will activate the sump level switch which actuates an alarm.

Vacuum Trap Level. Two vacuum trap conductivity probes (a high and a high-high level) actuate an alarm and a solenoid actuated valve on the vacuum trap to isolate the 26-in. Hg vacuum system from the glovebox HC-230C-2 vacuum line when there are high levels of liquid in the trap. One of the conductivity probes detects the presence of liquid in the vacuum trap and actuates an annunciator so corrective action may be taken. The second conductivity probe detects higher levels of liquid in the vacuum trap and, after a time delay, closes a valve to isolate the vacuum trap from the 26-in. Hg vacuum header. The delay before the valve closes allows the feed pump, the feed pump supply isolation valve, the atomizing air, the caustic pump, the PST recirculation pump, and the offgas filter blowback air system to shutdown. The alarm is on the MAS system.

Feed Receipt Tank Level. The FRT level is monitored by a conductivity probe. Upon receiving a high level signal, feed solution transfer from glovebox HC-227S to the FRT is automatically terminated by closing the FRT inlet valve.

Feed Pump Tank Level. The FPT level is monitored by a WFT. Upon receiving a high level signal, feed solution transfer from the FRT to the FPT is automatically terminated by closing the FPT inlet valve.

Emergency Shutdown Switch. An emergency shutdown switch is provided at the local control panel in room 230C. The switch provides for manually terminating the Production VDC process when abnormal conditions arise which require shutting down operations. Actuation of the switch results in shutdown of the following:

- Calciner heaters (dome and external)
- Feed pump, P-230-A
- Caustic (sodium hydroxide) pump, P-230-B
- Phase separator tank pump, P-230-C
- Offgas filter blowback air
- FRT outlet valve closed
- Atomizing air
- Calciner agitator.

Seismic Shutdown Switch. The Production VDC process is interconnected with the existing PFP HVAC supply fan seismic shutdown switch. When actuated, the seismic switch will result in shutdown of the same calciner equipment as described above for the emergency shutdown switch. The seismic shutdown switch also shuts down the normal power to the calciner fire control panel and forces it onto its battery backups.

6.4.1.5.4 Operating Characteristics - Reactive Material Stabilization. Heating time and temperature for the furnaces in glovebox HC-21C are controlled by individual microprocessor-based controllers. These controllers are programmed to ramp the temperature to the setpoint, hold the temperature for a specified time period (soak), and shut off the furnace. Each controller is programmed with six ramp/soak regimes; one for PRF sludges, one for plutonium metal, one for plutonium oxide, and recycled feed, one for regenerating desiccant, and two for restarting the furnaces at elevated temperatures. The controllers can be programmed with additional ramp/soak regimes as new feeds are approved for processing in the furnaces.

The furnaces located in glovebox HA-21I are operated with a PLC rather than individual controllers. The PLC is currently programmed for processing plutonium oxide, and recycled feed, and for restarting the furnaces at elevated temperatures. The PLC can also be programmed with additional ramp/soak regimes.

Because PRF sludges potentially contain organics, the furnaces in Glovebox HC-21C are ramped up to 175 °C and held for 1.5 h. This keeps the rate of butene generation outside of the flammable range. The temperature is then increased to 1000 °C and held for 2 h. The controller then shuts off the furnace. This sequence of operations removes essentially all of the volatiles.

For plutonium metal the furnace is ramped up to 550 C and held for 12 hours. The material in the boat is examined and if all metal is oxidized the material is sieved and returned to the boat. the sieved material is then processed as oxide.

The following are typical process programs for thermal stabilization. The parameters can be changed and programs added for variations in the process feeds.

For plutonium oxalate charges, the furnace is ramped up to 110 °C and held for 1 h. This removes most of the water of hydration, and allows the liquid portion of the charge to evaporate without foaming over the edge of the cake pan. The temperature is then increased to 175 °C and held for 0.5 h to allow separation of the remaining water of hydration from the oxycarbonate (oxalate) and continued evaporation of the free liquids. The temperature is then increased to 1000 °C and held for 1 h. The controller then shuts off the furnace. This removes essentially all of the volatiles.

There are no intermediate temperature hold points required for plutonium oxide and recycled feed charges. The furnace is ramped up to 1000 °C and held for 1 h. The controller then shuts off the furnace. This removes essentially all of the volatiles.

Each furnace door is interlocked to shut off the furnace whenever the door is opened. When the door is closed, a red light on the panel illuminates or an illuminated icon on the PC indicates that a heating cycle can be started.

6.4.1.5.4A Operating Characteristics - Plutonium-bearing Solution Stabilization Using the Production VDC. The principal operating characteristics for solution stabilization using the Production VDC process is to heat the feed solution to approximately 1000 °C to convert the Pu nitrate into Pu oxide. The offgas from the process are run through a scrubber to remove and neutralize undesirable constituents prior to release to the atmosphere. The instrumentation and controls for the Production VDC process are designed to assure that the desired operating conditions are obtained and abnormal process conditions are detected and appropriately mitigated. Section 6.4.1.5.3A provides a discussion of the principal process instrumentation, controls, interlocks, and alarms. Section 6.4.1.1.1A provides a description of the Production VDC process for solution stabilization. Chapter 5.0, Section 5.2.1.2.2, provides a description of the equipment used for solution stabilization operations using the Production VDC.

6.4.1.5.5 Safety Criteria and Assurance - Reactive Material Stabilization. The ramp rates are pre-programmed into the controller for each specific feed type. The furnace is ramped up slowly to avoid damaging the furnace heating coils. If temperature deviates greater than 20 C° from the ramp setpoint, a deviation band controller alarms and the control system alarm interlock shuts off the furnace. This is accompanied by an audible alarm, and an illuminated window on the annunciator panel or a display on the PC.

The high temperature alarm system provides an independent backup to prevent over-heating the furnace if the controller fails. When the furnace temperature exceeds 1050 °C, the alarm is activated, an interlock shuts off

the furnace, an audible alarm sounds, and a window will illuminate on the annunciator panel or display on the PC.

When any one of the three glovebox thermocouples reaches 70 °C, the furnace is shut off, an audible alarm will sound and a window will illuminate on the annunciator panel or display on the PC. The Halon fire suppression system for glovebox HC-21C is activated when the independent detector system associated with the Fire Suppression System detects a temperature of 93 °C. The Halon fire suppression system can be restrained by pressing the Halon ABORT button and holding it constantly, or by pressing it at intervals of less than 30 s. The dry chemical fire suppression system for glovebox HA-21I is activated when the independent detector system associated with the Fire Suppression System detects a temperature of 71 °C.

If the furnace door is opened within a heating cycle, the furnace is shut off. This interlock prevents the furnace from being on while a boat is being put into or removed from the furnace. This interlock also minimizes heat loading to the glovebox during heating cycles.

6.4.1.5.5A Safety Criteria and Assurance - Plutonium-bearing Solution Stabilization Using the Production VDC. Safety criteria and assurance for solution stabilization operations using the Production VDC process is provided by establishing limits for various process parameters and by the use of instrumentation, controls, interlocks and alarms to monitor and warn of parameter deviations. The operating specifications for important variables are shown in Table 6-6. Section 6.4.1.5.3A provides a discussion of the principal detection systems and resultant interlocks and alarms which assure safety in the operations.

6.4.1.6 Control Rooms and Control Areas - Reactive Material Stabilization. Most of the instrumentation, controls and alarms for the thermal stabilization process are located on a control panel, and on a PC that are located in room 230A, near the HC-21C glovebox. A CO_2 cabinet is also located in the room. Differential pressure gauges are located both in and near gloveboxes HC-21C and HA-21I. Valved rotameters are also located near glovebox HC-21C. If the local controls are disabled, power can be shut off at the main electrical breaker box. In general, shutting off power to a glovebox results in an immediate safe-shutdown condition. A longer term safe shutdown requires cleanout of plutonium bearing-materials from the gloveboxes.

6.4.1.6A Control Rooms and Control Areas - Plutonium-bearing Solution Stabilization Using the Production VDC. There is no control room dedicated to the solution stabilization operations using the Production VDC. Control panels and related control devices (MAS and PLC) are located in rooms 230C and 235B. A local panel with an operator display screen is provided in room 230C near the Production VDC process equipment and glovebox. The MAS and PLC, located in room 235B, provide the control components for the operations. Additional discussion of the control panels and associated equipment is provided in Chapter 5.0, Section 5.2.1.2.2. Details of the instrumentation and controls associated with the Production VDC process are provided in Section 6.4.1.5.3A.

6.4.1.7 Analytical Sampling - Reactive Material Stabilization. Feed material originating in the PRF, or material of unknown origin is sampled and analyzed

in accordance with procedures before processing. Charges containing less than 10 g of organic material may be processed through the muffle furnaces in glovebox HC-21C. Feed material is NDA'd for plutonium content to ensure that glovebox mass limits are not exceeded.

Each full can of processed material is sampled in Glovebox HC-18M for LOI analysis. Approximately 11 g of material is removed from a slip-lid can and the can is defined to be full when the processed material is 3/4 inches from the top. The weight of the sample is determined and entered on a data sheet for the sample. The sample is transferred to the Analytical Laboratory for LOI analysis. For transfer to the Analytical Laboratory, a Nuclear Material Item Transfer Form is obtained for each item to be transferred. The sample is sealed out of Glovebox HC-18M or HC-13MD for LOI in accordance with procedures. If the LOI does not meet the storage specification (WHC 1995a), the material is processed per the manager's instructions. If the LOI meets the storage specification, (WHC 1995a) the material is packaged for storage and sent to the vaults.

6.4.1.7A Analytical Sampling - Plutonium-bearing Solution Stabilization Using the Production VDC. The PR cans of plutonium nitrate to be processed for solution stabilization by the Production VDC process have been previously characterized prior to placing them in storage at the PFP. The PR can contents are loaded into glovebox HC-227S through the load-in head in hood HC-227T. The contents of several cans are blended in the glovebox and a sample is removed for testing to assure compatibility with the Production VDC process. The testing assures that the Production VDC process feed solution meets the acid concentration, organic content, solids content and Pu concentration limits shown in Table 6-6. The plutonium nitrate solutions are then transferred by pumping through a double contained line to glovebox HC-230C-2 for stabilization using the Production VDC process.

The Pu oxide product resulting from the VDC process is transferred from glovebox HC-230C-2 via conveyor gloveboxes HC-2 and HC-3, to glovebox HC-18M or HC-21A, where it is accumulated in a slip-lid can. When the can is full, approximately 5 kg, the contents are mixed and sampled. The sample is transferred to the PFP Analytical Laboratory for LOI testing. If the sample meets the LOI requirements of the storage specification (WHC 1995a), the product material is packaged for long term storage. This consists of taping the slip-lid product can closed and bagging-out the can from the glovebox. The unit is then packaged and sealed in two more cans and transported to the nondestructive assay laboratory in Building 2736-ZB. After assaying the contents, the can is transferred to the Building 2736-Z vaults for long term storage.

If the product material does not pass the LOI test, it is considered reactive material and processed through the thermal stabilization furnaces for additional stabilization. It is then transferred to glovebox HC-18M or HC-21A for additional sampling, LOI testing and packaging, and then transferred for assaying and storage.

6.4.1.8 Product Handling - Reactive Material Stabilization. The stabilized plutonium-bearing material generated by thermal stabilization is handled, packaged, and stored in accordance with the process descriptions contained in Sections 6.2, 6.3, and 6.4.1.

6.4.1.8A Product Handling - Plutonium-bearing Solution Stabilization Using the Production VDC. Handling of the plutonium nitrate solutions during the Production VDC stabilization process and after conversion to plutonium oxide is included in the discussion in Section 6.4.1.7A. Additional discussion is also provided in Section 6.4.1.1.1A.

6.4.1.9 Identification of Items for Safety Analysis.

6.4.1.9.1 Criticality Prevention - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC.

Criticality Safety Evaluation. Activities associated with thermal stabilization of reactive materials include inspecting, splitting, weighing, heating, sampling, crushing, mixing and packaging. Thermal stabilization takes place in gloveboxes that were used as "dry gloveboxes" for plutonium metal production. Activities associated with stabilization of plutonium nitrate solutions using the Production VDC include solution transfers, blending, sampling, VDC processing, LOI testing and packaging. The process occurs in a new glovebox (HC-230C-2) added to the RMC Line. Criticality prevention specifications (CPS) based on Criticality Safety Evaluation Reports (CSER) have been prepared for all of the gloveboxes and activities/processes used in the stabilization processes.

Analytical methods used include the use of well-referenced data, Surface Density versus Unit Shape Factor method, Monte Carlo calculations, and all plutonium is assumed to be ^{239}Pu, unless the isotopic content is specifically controlled by analysis and administrative procedures. All moderated mixtures are assumed to be metal-water or oxide-water.

The analyses consider available containers, maximum fissionable material densities, credible moderators, glovebox floor surface area, the presence of criticality safety drains, reflectors near the glovebox (floors, walls, or ceiling), and normal maximum process limits.

Contingencies are developed for each operation in the gloveboxes. These contingencies include the following, as appropriate to the operation analyzed:

- Addition of fissile material in excess of that allowed by the CPS, either as additional units (overloading) or larger units (overbatching or double batching).
- Addition of a moderator
- Intermixing of units of various types
- Violation of spacing rules
- Spills
- Equipment failure
- Equipment volume or depth larger than expected
- Accumulations of fissionable material
- Density of materials increased
- Addition of a reflector.

The controlling (worst-case) contingency for most gloveboxes is the introduction of a moderator (e.g., water used in fire fighting). Specific analyses demonstrate that the operation remains acceptably subcritical even if fully moderated.

Implementation of Criticality Safety. Process equipment and containers used in stabilization gloveboxes are designed to remain subcritical even in the event of accidental flooding. Criticality safety drains are also provided to limit the depth of liquid in a flooding event. Storage gloveboxes are designed to provide spacing between plutonium units. Specific safety features are described in Section 6.4.1.4.4.

Process glovebox limits are established for moderators, liquids in the glovebox, container size, batch or unit mass, spacing and, spills or accumulations of fissionable material. CSERs have been prepared and appropriate CPSs have been established for stabilization gloveboxes. The glovebox inventory limits are shown in Chapter 5.0, Table 5-5.

6.4.1.9.2 Chemical Safety - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC. At elevated temperatures, heavy metal nitrate-tributyl phosphate (TBP) complexes (and associated dibutyl and monobutyl phosphate complexes) decompose exothermically. If the rate of reaction is such that heat is generated faster than it can be removed, the reaction becomes autocatalytic. The accompanying rapid evolution of butane gas may lead to an explosion. Additional details regarding the decomposition of heavy metal nitrate-TBP complexes are provided in Chapter 9.0, Sections 9.2.1.2 and 9.2.9.1.

Tributyl phosphate/nitric acid reactions are possible during stabilization operations. The probability and magnitude of such reactions are reduced to an acceptable level primarily by limiting the organic content of the material being processed and by controlling process temperatures. The probability of a rapid organic reaction during thermal stabilization in glovebox HC-21C is reduced by limiting the feed material to a charge with less than 10 g of total organic content. In addition, when processing organic materials, an inert covergas (CO_2) is introduced into the furnace to ensure flammable gas concentrations (butene) remain $\leq$25% of the lower flammability limit (WHC 1996). Covergas ($\geq$45 scfh) is required for the heating period before the furnace reaches 300 °C on ramp-up. Offgas flow (120 scfh) is used to ensure oxygen is drawn into the furnace and is available for combustion of impurities and removal of pyrolysis generated gases during the heating cycle.

The plutonium nitrate solutions to be stabilized are limited to less than 1% organics. A discussion of reaction potential is provided in Chapter 9.0, Section 9.2.9.1.

6.4.1.9.3 Process Shutdown Modes - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC. The stabilization processes have emergency shutdown switches. For thermal stabilization, a manual switch is located in the control console, and will shut off the furnace in glovebox HC-21C until the manual reset button is pulled out. During an emergency shutdown, the control system will continue to function. A manual switch is located on the exterior of glovebox HA-21I, which shuts off power to all three furnace elements in the glovebox when the button is depressed. The PC station contains an icon for emergency shutdown of the furnaces in glovebox HA-21I from the Control Computer.

For solution stabilization using the Production VDC, a manual shutdown switch is located on a local control panel in room 230C near glovebox

HC-230C-2 which houses the Production VDC equipment. This switch shuts down the Production VDC operations as described in Section 6.4.1.5.3A. The local control panel is described in Chapter 5.0, Section 5.2.1.2.2.

6.4.1.9.4 Instrumentation - Reactive Material Stabilization and Plutonium-bearing Solution Stabilization Using the Production VDC. This section provides an overview of the parameters used to detect process conditions. More details are provided in Section 6.4.1.5.

Process-specific operating parameters that are monitored for thermal stabilization of reactive materials include temperature and flow rate (offgas and CO_2 purge). Each of the five muffle furnaces has two temperature elements to measure the furnace temperature. Glovebox HC-21C and glovebox HA-21I each have three thermocouples to provide representative glovebox temperature measurements. Orifices with differential pressure gauges are used to control the offgas flow rates for glovebox HC-21C and HA-21I. Glovebox HC-21C also has valved rotameters for controlling offgas flow rates and a CO_2 purge system.

Process specific parameters that are monitored for solution stabilization operations using the Production VDC process include calciner and glovebox temperatures, process tank levels, calciner and glovebox pressures, and scrubber pH. A description of specific instrumentation associated with the Production VDC process is provided in Section 6.4.1.5.3A. Important process parameter limits are shown in Table 6-6.

The instrumentation systems provide information to the operators about process or support equipment under their control, to alert them to off-normal conditions. Sensing devices for these parameters are located within the process equipment. They transmit signals to locally situated recorders/controllers. The controller is used to control the process within the limits for the parameter. The recorder displays and records how the equipment is performing with respect to the parameter of concern. Operating procedures outline the specific actions for the operators to take. Typical responses for thermal stabilization operations include adjusting offgas flow rate to maintain required flow, interrupting power to the furnace temporarily if the furnace temperature is higher than the program temperature, interrupting power to the furnace if the furnace temperature fails to rise or minimum required offgas flow cannot be maintained, and pausing the program if the program temperature is higher than the furnace temperature. For solution stabilization operations using the Production VDC, either manual or automatic response to abnormal conditions provide mitigative actions. Responses for abnormal conditions are included in the discussion in Section 6.4.1.5.3A.

Instrumentation is provided wherever plutonium materials are handled to assure personnel safety and material accountability. The NDA Laboratory has special equipment to determine the amount of plutonium being received or shipped. Sampling, mass spectrometer analyses, and weighing of plutonium materials are the primary methods used for accountability.

Radiation monitoring instruments (stack CAMs and CAS instruments) used in the plutonium materials handling facilities are safety class or safety significant instruments (see Chapter 5.0, Section 5.4.10 and Chapter 4.0,

Tables 4-7 and 4-8). They are controlled by engineering personnel and maintained by maintenance personnel under the PFP PM program.

Airborne plutonium concentration is a personnel health and safety concern. Differential pressure gauges, located in all gloveboxes, measure the negative pressure in the gloveboxes relative to the room. A negative pressure must be maintained on the gloveboxes to contain and control airborne radioactive particles.

Stack effluent samplers and monitors provide proportional samples and real-time gross radioactivity monitoring (see Chapter 7.0, Section 7.1.2). Waste water discharges to the Low-Level Waste Treatment Facility (LLWTF) at 243-Z for treatment (see Chapter 7.0, Section 7.2). The treated stream from the LLWTF is monitored in-line (pH, conductivity, and flow rate) and proportionally sampled by an automatic composite grab sampler at the 225-WC Building. The stream is routed to the Treated Effluent Disposal Facility (TEDF) for discharge to the environment. Radioactive liquid waste to the 241-Z underground tanks is sampled before transfer, and manual records of the amount of liquid pumped and its contents are maintained (see Chapter 7.0, Section 7.2).

A listing of all instrumentation is maintained within the PM program. It provides a schedule for calibration and testing of the instrumentation and the maintenance requirements. Instrumentation is tested and calibrated before installation. Radiation detection instrumentation is tested on a scheduled basis. The NDA equipment is also calibrated on a frequent and scheduled basis. The process instrumentation is important to operations personnel safety.

6.4.1.9.5 Remote and Contact Maintenance. Maintenance of equipment in gloveboxes normally involves replacing the equipment, and repairing the failed item in a "hot" maintenance area or discarding it to solid waste. Instruments or small pieces of equipment are replaced using the rubber gloves and viewing panels of the gloveboxes. The new (or repaired) item to be installed, and the tools required (if not already in the glovebox), are introduced through a sphincter seal, bag-in or airlock and moved to the position requiring maintenance. The failed item is replaced with a new unit, and the failed item is removed from the line and bagged-out in plastic bags.

Larger equipment requires open glovebox maintenance. Normally the equipment is replaced with a new or repaired unit. A temporary plastic containment tent known as a "greenhouse" (or glovebag, if the component being replaced is small) is placed around the glovebox and work area for contamination control. The containment is normally fabricated in a rectangular shape from 12-mil fire-retardant sheet plastic. Irregular shapes may be fabricated as the job dictates. For some jobs, portions of containment may be fabricated from clear plastic for increased visibility. A second smaller containment is installed at the entrance to the containment tent, with an opening between the two. The smaller containment is called an annex and is made of same type of material as the primary containment. It serves as a buffer zone between the room and the primary containment, and as an area for personnel clothing removal when exiting the primary containment. Separate ventilation is supplied to the greenhouse, and portable air monitors are used inside the greenhouse and just outside the entrance. Workers are required to

use multiple layers of protective clothing and respirators, as a minimum. A fresh air supply may also be required.

6.4.2 Other Remote Mechanical A and Remote Mechanical C Line Processes

6.4.2.1 Process Description.

6.4.2.1.1 Narrative Description. As previously discussed in Section 6.1, the plutonium conversion process is inactive and operation is not authorized. However, all gloveboxes (except those physically removed or declared inactive) are authorized for interim storage of plutonium-bearing material. A list of active and inactive gloveboxes is provided in Chapter 5.0, Table 5-4. Inactive gloveboxes cannot store or receive containers of plutonium, but residual quantities of material remain in these gloveboxes.

6.4.2.1.2 Flowsheets. There are no flowsheets associated with other RMA and RMC Line processes.

6.4.2.2 Process Chemistry and Physical Chemistry Principles. There is no process chemistry associated with other RMA and RMC Line processes.

6.4.2.3 Mechanical Process Systems.

6.4.2.3.1 Functional Description. Gloveboxes which were once used for the plutonium conversion process are now used for the interim storage of plutonium-bearing material. The containers are sealed in and sealed out of the gloveboxes in accordance with established operating procedures. The material for interim storage also complies with established CPSs.

6.4.2.3.2 Safety Features. Safety features related to criticality, radiological, and industrial safety are discussed in the following sections.

Criticality Safety. Each room, glovebox, and container has been analyzed by the methods outlined in Section 6.4.2.9.1 to ensure compliance with the criticality safety criteria presented in Chapter 4.0, Section 4.4.4, and criticality safety features are incorporated into the design of the RMC Line.

The process equipment is designed to be geometrically favorable, even if filled with plutonium at the maximum credible concentration and optimum moderation. Process containers such as powder pans and pressure vessels are designed to be subcritical, even if overbatched and moderated. Physical spacers are provided in storage gloveboxes to minimize interaction between plutonium batches. Criticality safety drains are provided to ensure that a critical depth cannot be achieved, even if material is spilled and the glovebox is flooded. The stainless steel discs have been placed in the sumps, where appropriate, to prevent the accumulation of large amounts of solution. Raschig rings (neutron absorbers) have been placed in the sump in room 166 for criticality safety in the event of a large spill of solution. Vacuum traps are instrumented to detect liquid. Interlocks shut off the vacuum supply to prevent plutonium solutions from being syphoned to geometrically unfavorable equipment.

Administrative limits are included in the criticality safety program for the RMA and RMC Lines. These limits include restrictions on the number and size of containers, spacing limits between containers where physical restraints are not provided, and restrictions on fire-fighting practices for most gloveboxes.

A criticality detection and alarm system is located in the RMC Line area. Personnel are required to rapidly evacuate the area if the alarm sounds. Evacuation drills are conducted regularly. The detection and alarm equipment is checked on a scheduled basis, and redundancy is provided. This system must be functional to perform work in the gloveboxes in the RMC Line.

Radiological Safety. Exposure to radiation is controlled to ALARA standards. Lead shielding, water walls, or Lexan™ plastic are used to reduce exposure. Shielding is strategically located so that the average exposure rate at workstations is approximately 0.5 mrem/h. See Chapter 8.0, Section 8.3, for more details.

All gloveboxes are maintained at negative pressure (-0.3 to -1.5 in. w.g. relative to the room) to confine plutonium to the gloveboxes if a small break in the confinement barrier occurred. Differential pressure gauges, located in all gloveboxes, measure the negative pressure in the gloveboxes relative to the room. Three stages of filtration (two of which are testable) are provided before offgases are discharged to the atmosphere via the 291-Z-1 stack.

CAMs are provided to monitor workplace breathing air in occupied areas where a person without respiratory protection is likely to be exposed to a concentration of radioactive materials in the air exceeding 1 DAC over a prolonged period of time or where there is a need to alert potentially exposed workers to significant increases in the level of airborne radioactive material levels, which could result in 40 DAC-hours in a typical work shift. Portable CAMs are used when working in a greenhouse or other areas not adequately covered by a CAM. The CAMs alarm locally, with both audible and visual alarms. Personnel are required to immediately evacuate a room when a CAM alarms. Air-purifying respirators are available, if needed.

Industrial Safety. The amount of combustible material in a glovebox is administratively controlled to the minimum required for the operation. Gloveboxes are equipped with combustion and/or heat detectors. The operators are trained to take action to extinguish any small fires. The fire department responds whenever a fire alarm is sounded.

Glovebox panels where fires could occur are fabricated of metal/glass construction or fire-resistant plastics such as Lexan™. Glovebox gloves are made of fire-resistant neoprene. The gloves are normally tied off outside of the glovebox.

6.4.2.4 Chemical Process Systems. There are no chemical process systems associated with other RMA and RMC Line processes.

6.4.2.5 Instrumentation and Control Systems. Functioning I&C systems remain in place to monitor glovebox differential pressures. The RMA and RMC Line gloveboxes are designed to provide confinement of dispersible radioactive materials. The glovebox design requires a operating range of

-0.5 to -0.7 in. w.g. relative to room pressure. Each glovebox has a differential pressure gauge to monitor interior pressure relative to the room. The gauges are oriented to provide easy viewing for operating personnel.

6.4.2.6 Control Rooms and Control Areas. There are no control rooms or control areas associated with other RMA and RMC Line processes.

6.4.2.7 Analytical Sampling. There is no analytical sampling associated with other RMA and RMC Line processes.

6.4.2.8 Product Handling. There is no product handling associated with other RMA and RMC Line processes.

6.4.2.9 Identification of Items for Safety Analysis.

6.4.2.9.1 Criticality Prevention. While plutonium metal is no longer produced in the RMA or RMC Lines, there are residual quantities of fissile material in the gloveboxes. In addition, active gloveboxes may be used for interim storage of plutonium-bearing material. The established CPS limits are still valid for gloveboxes that are not in routine use. Gloveboxes HC-1, HC-2, HC-3, HC-4, HC-13MD, HC-18BS, HC-18M, HC-21A, HC-21C, HA-21I, HA-22B, HA-23S, HA-28, and HC-230C-2 are used for reactive plutonium-bearing material stabilization and plutonium-bearing solution stabilization operations using the Production VDC.

Dry Process Gloveboxes. Analytical methods used include the use of well-referenced data, Surface Density versus Unit Shape Factor method, Monte Carlo calculations, and all plutonium is assumed to be ^{239}Pu unless the isotopic content is specifically controlled by analysis and administrative procedures. All moderated mixtures are assumed to be metal-water or oxide-water. The analysis considers available containers, maximum fissionable material densities, credible moderators, glovebox floor surface area, the presence of criticality safety drains, reflectors near the glovebox (floors, drains, or ceiling), and normal maximum process limits.

Contingencies are developed for each operation in these gloveboxes. These contingencies include the following, as appropriate to the operation analyzed:

- Addition of fissile material in excess of that allowed by the CPS, either as additional units (overloading) or larger units (overbatching or double batching)
- Addition of a moderator
- Intermixing of units of various types
- Violation of spacing rules
- Spills
- Equipment failure
- Equipment volume or depth larger than expected

- Accumulations of fissionable material
- Density of materials increased
- Addition of a reflector.

The controlling (worst-case) contingency for dry gloveboxes is the introduction of a moderator (e.g., water used in fire fighting). Specific analyses demonstrate that the operation will remain acceptably subcritical even if moderated.

Wet Process Gloveboxes. The criticality safety engineer determines which conditions result in exceeding solution depth must be considered as part of the evaluation. Since leaks of plutonium solution and the addition of water to the floor cannot be precluded, the floor and container mixtures are assumed to be ^{239}Pu-water. Reflection from actual materials of construction, such as "Hanford" concrete with 0.68 wt% hydrogen and the 304-L stainless steel floor of the glovebox, are evaluated. Top reflection is assumed to be nominal (1 in.) water. Interacting tanks, containers, and other plutonium-bearing equipment are specially modeled.

In general, when plutonium nitrate is present, it is assumed that there is no excess nitrate ion present. This assumption yields conservative results, tends to overestimate the value of k^{eff}.

The presence of criticality drains, sumps, or sloping glovebox floors are considered. Abnormal conditions evaluated by the criticality safety engineer in establishing margins of safety include exceeding container mass and volume limits, violating spacing between containers and tanks, violating the sludge depth limit in the tanks, substituting plutonium-water for plutonium nitrate in the tanks and containers, and exceeding the solution depth on the hood floor. Examples of abnormal conditions that could be evaluated are described in the following paragraphs.

An operator could introduce solution containing more than 450 g/L of plutonium into a feed line and transfer the solution into the storage tanks. One or both of the storage tanks could receive more than its mass limit of plutonium.

Two containers, each having a maximum volume of 1.5 L and containing a maximum of 400 g plutonium, are permitted inside the glovebox. One of the containers is allowed to be moved within 25 cm of a storage tank for sampling purposes. A single credible operator error could result in both containers being placed against a storage tank.

Activation of the sprinkler system could introduce water into the room. Water mist could be introduced between the storage tanks and could enter the glovebox through a broken window.

If two storage tanks were full and one of the pipes connected to the lower tank cracked or failed, the contents of both tanks could drain to the hood floor. The maximum permissible depth of solid accumulations in the bottom of any tank is established. However, long-term operations involving the tanks might result in a thicker layer of solid accumulations.

Containers in a hood could exceed the allowable volume limit, or mass in a container could exceed the limit. The spacing requirement between tanks and container could be violated, or plutonium solution in one tank might be of higher concentration than allowed (600 g/L of plutonium versus a 450 g/L plutonium limit). Solution on the floor could also exceed depth limits (possibly 2.5 in. deep versus a 0.5-in. limit).

In some cases, incredible conditions may be analyzed to provide additional information, such as addition of spectral reflection equals 1.0 in the +x direction (full-water reflection) along the side of two tanks or material in tanks or containers being more reactive (plutonium-water versus plutonium nitrate).

Support Gloveboxes. Activities evaluated in the support glovebox analyses are decanning, inspecting, weighing, recanning, transport, and maintenance. Other associated activities may be included, but in each case the equipment and process steps are carefully defined in the evaluation document.

Evaluation methods used are Monte Carlo calculations, the Surface Density versus Unit Shape Factor method, or the use of well-referenced data. Other calculational methods may be selected in some cases.

Accident and abnormal conditions considered include addition of fissile material in excess of that allowed with additional units (overloading) or larger units (overbatching or double batching), addition of a moderator, and violation of spacing rules. Plutonium is assumed to be ^{239}Pu, unless otherwise specified, and moderated mixtures are assumed to be plutonium metal-water or PuO_2-water.

Implementation of Criticality Safety in Other RMA and RMC Line Processes. Process equipment and containers used in the dry process gloveboxes are designed to remain subcritical, even in the event of accidental flooding. Criticality safety drains are also provided to limit the depth of liquid in a flooding event. Storage gloveboxes are designed to provide spacing between plutonium units.

Dry process glovebox specification establish limits for moderator limits, liquids in the glovebox, container size, batch or unit mass, spacing, and spills or accumulations of fissionable material.

Wet process glovebox specifications establish limits on equipment size, shape, and location for fissionable material concentration and masses, acid concentration, number, size, and spacing of containers that may be used, and spills or accumulations.

Support gloveboxes specifications establish limits for number of units, size of containers, fissionable content of containers, allowed moderation levels, spacing, spills or accumulations.

6.4.2.9.2 Chemical Safety. The cold chemical preparation areas in the 234-5Z Building (rooms 336 and 337 on the third floor) are no longer used to support plutonium conversion in the RMA and RMC Lines. Dilute nitric acid solutions are prepared for the LI/LO of plutonium nitrate solutions (see

Section 6.2.9.2.1). Potassium hydroxide solution may still be prepared for use in neutralizing spills of acidic solutions (see Section 6.2.9.2.2). The PFP chemical management program is discussed in Section 10.4.5.

6.4.2.9.3 Process Shutdown Modes. Emergency shutdown of glovebox equipment can be accomplished in several seconds by shutting off power to the gloveboxes. Short-term shutdown (one day to several weeks) involves placing plutonium in safe storage. This can be accomplished within one hour or less, depending on the number of packages involved. Normal surveillance would continue. This includes checking to ensure that proper ventilation of gloveboxes is maintained, with negative pressure at or below -0.5 in. w.g., pressure drop across filters less than 3 in. w.g., and radiation surveys.

Long-term shutdown (years) is not an option until all of the plutonium has been moved out of the PFP. This option would involve packaging and shipping all plutonium out of the PFP, either offsite or to a new facility at the Hanford Site. It would take months to accomplish a full cleanout. Surveillance requirements would be minimal, primarily ensuring ventilation is adequate for areas containing residual plutonium, and performing area radiation surveys until D&D of the facility is completed. Additional information on facility shutdown and cleanout activities is provided in Section 6.7.

6.4.2.9.4 Instrumentation. There is no instrumentation associated with other RMA and RMC Line processes that requires identification for safety analysis purposes.

6.4.2.9.5 Remote and Contact Maintenance. Remote and contact maintenance is addressed by Section 6.4.1.9.5.

6.4.3 Previous Remote Mechanical A and Remote Mechanical C Line Processes

The previous RMA and RMC Line processes are inactive and operation is not authorized. Reactivation of any portion these processes would require the performance, documentation, review, and approval of new hazard and accident analyses, with revision as required to this Final Safety Analysis Report (FSAR). However, all gloveboxes (except those physically removed or declared inactive) are authorized for interim storage of plutonium-bearing material. A list of active and inactive gloveboxes at the time of preparation of the FSAR is provided in Chapter 5.0, Table 5-5. A current list of active and inactive is maintained in WHC-SD-CP-OSR-010 (WHC 1994a). Inactive gloveboxes cannot receive containers of plutonium, but residual quantities of material remain in these gloveboxes. Several of the gloveboxes are now used for the thermal stabilization process (see Chapter 6.0, Section 6.4.1).

A historical detailed description of the former processes can be found in Revision 0 of this FSAR. In addition, historical information can be found in previous PFP Safety Analysis Reports (SAR)s which analyzed different facets of operations at the PFP:

- *Plutonium Finishing Plant Safety Analysis Report*, WHC-SD-HS-SAR-007
- *Laboratory Safety Analysis Report*, WHC-SD-HS-SAR-011

- *Safety Analysis Report, Plutonium Handling and Storage, 2736-Z Support Complex*, WHC-SD-HS-SAR-025
- *Z Plant Plutonium Handling Operations SAR*, RHO-CD-1244
- *Operational Safety Requirements (OSRs) - Plutonium Finishing Plant (PFP) Seismic Safety*, WHC-SD-CP-OSR-004-ENG
- *Safety and Risk Assessment Technical Information to Support PFP Restart*, WHC-SD-SQA-TI-013
- *Remote Mechanical A Oxide Line*, Rev 1, Addendum 1 - Appendix G, RHO-CD-1244
- *Plutonium Reclamation Facility*, Rev 1, Addendum 2 - Appendix H, RHO-CD-1244
- *Selective Decontamination and Decommissioning at Plutonium Finishing Plant*, Rev 1, Addendum 3 - Appendix I, RHO-CD-1244
- *Remote Mechanical C Button Line*, Rev 1, Addendum 4 - Appendix J, RHO-CD-1244
- "Safety Analysis of Potassium Hydroxide Scrubber, Glovebox HA-46-234-5Z," Letter Analysis # JJR-12723-86-133
- *Hazard Identification and Evaluation for Dissolution Operations in Glovebox HC-46F, Room 170, Building 234-5Z*, WHC-SD-CP-SAR-010
- *Hazard Identification and Evaluation, Calcination Operations, Glovebox HA-40F, Room 169, Building 234-5Z*, WHC-SD-CP-SAR-011
- *Hazard Identification and Evaluation, Hydroxide Hydrolysis, Glovebox HC-60, Room 169, Building 234-5Z, Nitrated Organics*, WHC-SD-CP-SAR-012
- *Slag and Crucible Dissolver, Hazard Identification and Evaluation*, WHC-SD-CP-SAR-013-ENG
- "Safety Analysis of Button Burning, Glovebox HC-21C," Letter Analysis # JJR-12723-85-241

6.4.3.1 Narrative Description. The nitric acid solutions of plutonium were converted to plutonium metal in the RMA and RMC Lines. The RMA Line was also once used for converting plutonium nitrate to plutonium oxide powder. The plutonium conversion process is inactive and operation is not authorized. The RMA and RMC Lines are located on the first floor (near the center) of the 234-5Z Building.

The plutonium conversion process consisted of preparing plutonium nitrate feed, precipitating plutonium oxalate from the plutonium nitrate solutions (approximately 250 g/L of plutonium), filtering the oxalate, calcining it to PuO_2, and fluorinating the PuO_2 to form PuF_4 (see Figure 6-18). The PuF_4 powder was loaded into a MgO crucible with elemental calcium and iodine,

charged to a pressure vessel, and fired to produce metallic plutonium and a slag containing CaF_2, calcium, iodine, and small amounts of unreacted PuF_4. The slag was removed from the metallic plutonium button and sent to slag and crucible (S&C) dissolvers (along with the remains of the MgO crucible), to recover the residual plutonium. The metal button was cleaned, pickled, sampled, weighed, and placed in metal cans for storage.

The RMA Line operations were conducted in 6 "wet" gloveboxes where plutonium solutions were present, and in 28 "dry" gloveboxes where plutonium powders and metal were present. The process was semi-remotely controlled from the RMA control room 233. The "wet" gloveboxes include the following:

- Glovebox HC-4 - Feed Solution Staging
- Glovebox HC-6 - Feed Solution Staging
- Glovebox H-7A - Solution Treatment
- Glovebox HA-9A - Powder Production
- Glovebox H-14P - Pickling
- Glovebox HA-46 - Potassium Hydroxide Scrubber.

The "dry" gloveboxes include the following:

- Glovebox HC-3 - Conveyer
- Glovebox HC-4 - Conveyer
- Glovebox HC-5 - Conveyer
- Glovebox H-8A - Conveyer
- Glovebox H-9B
- Glovebox H-9C - Powder Weighing
- Glovebox H-9D
- Glovebox H-9E - Product Handling
- Glovebox HA-10 - Conveyer
- Glovebox H-11
- Glovebox H-12S - Pressure Vessel Sanding
- Glovebox H-13MD - Crucible Loading
- Glovebox H-13G - Gasket Installation
- Glovebox H-13ABC - Reduction to Metal
- Glovebox H-14CC - Crucible Cutter
- Glovebox H-14DC - Pressure Vessel Dumper
- Glovebox H-14S - Sampling

- Glovebox H-15B - Weighing
- Glovebox H-15
- Glovebox H-16CS - Conveyor Storage
- Glovebox H-16BS - Button Storage
- Glovebox H-16L
- Glovebox HA-19 - Storage
- Glovebox HA-20MB - Machining
- Glovebox HA-21I - Reactive Material Stabilization (See Section 6.4.1.4.2)
- Glovebox HA-22B - Weighing (now used for seal-in of plutonium material for transfer to Glovebox HA-23S for storage and for staging items into and from glovebox HA-21I)
- Glovebox HA-23S - Reactive Material Stabilization (See Section 6.4.1.4.2)
- Glovebox HA-28 - Conveyor.

The RMC Line operations were conducted in 6 "wet" gloveboxes where plutonium solutions were present, and in 15 "dry" gloveboxes where plutonium powders and metal were present. The process was semi-remotely controlled from the RMA control room 229. The "wet" gloveboxes include the following:

- Glovebox HC-4 - Feed Solution Staging
- Glovebox HC-6 - Feed Solution Staging
- Glovebox HC-7 - Solution Treatment
- Glovebox HC-9B - Powder Production
- Glovebox HC-17P - Pickling
- Glovebox HA-46 - Potassium Hydroxide Scrubber.

The "dry" gloveboxes include the following:

- Glovebox HC-1 - Conveyer
- Glovebox HC-2 - Conveyer
- Glovebox HC-10 - Powder Weighing
- Glovebox HC-11 - Powder Pan Storage
- Glovebox HC-12S - Pressure Vessel Sanding
- Glovebox HC-13MD - Crucible Loading (now used for seal-in/seal-out of plutonium-bearing material for thermal stabilization processes)

- Glovebox HC-15 - Reduction to Metal
- Glovebox HC-16CC - Crucible Cutter
- Glovebox HC-17DC - Pressure Vessel Dumper
- Glovebox HC-17SBB - Sampling/Weighing
- Glovebox HC-18BS - Reactive Material Stabilization (See Section 6.4.1.4.2)
- Glovebox HC-18M - Reactive Material Stabilization (See Section 6.4.1.4.2)
- Glovebox HC-21C - Reactive Material Stabilization (See Section 6.4.1.4.2)
- Glovebox HC-21A - Reactive Material Stabilization (See Section 6.4.1.4.2).

6.5 LABORATORY SUPPORT

6.5.1 Process Description

6.5.1.1 Narrative Description.

6.5.1.1.1 Plutonium Process Support Laboratories. The PPSL are chartered to operate nonradioactive and radioactive chemical process and equipment demonstration laboratories. These laboratories support numerous programs across the Hanford Site and occasionally on other DOE sites. The PPSL facilities include necessary connections to essential building services, including ventilation, drains, vacuum, electricity, water, compressed air, and compressed gas. The PPSL support processing facility flowsheet evaluation, troubleshooting, new technology implementation, and process demonstration. The above activities are performed on bench scale and pilot-plant scale. The PPSL also analyze nonroutine samples for process support, and develop new methods that are transferred to other organizations when the methodology is well established and the need becomes routine. The PPSL also processes plutonium materials to demonstrate processes in cases where they have exclusive expertise.

The PPSL facilities allow several approved, independent projects or experiments to proceed simultaneously. Administrative procedures and controls for PPSL operation are discussed in general in Chapter 10.0. All changes to configuration and design, such as installation of a new piece of equipment are done in accordance with FSP-PFP-5-8, *Plutonium Finishing Plant Administration* Section 2.27, "Senior Supervisory Watch Program." Part of the analysis requires a review of the FSAR to determine if the change or activity is covered in the existing safety analysis. If not, a revision to the FSAR is required before the work can proceed.

The specific laboratory rooms of the PPSL within the PFP, and their capabilities, are described in the following sections.

Room 179. This room contains a particle counter and an inactive TGA instrument. The TGA is located in a dedicated glovebox, with five other gloveboxes and three hoods available for general alpha-radioactive chemistry projects. All three hoods in room 179 are restricted to glovebox air lock access, because the exhaust ventilation no longer meets the airflow requirements. All glovebox drains in the room are connected to the D-4 drain line.

The gloveboxes contain electrically heated furnaces, hot plates, and small rotary mixers. Personnel using the furnaces and hot plates normally remain in the area, so that access to any hot surface by others is impeded. In addition, work in this room seldom requires access to the same work area by personnel working on different projects. Rotary mixers are used only when submerged magnetic stir bars cannot be used.

Room 180. This room contains a thermal analysis system with simultaneous mass spectroscopy (used to identify decomposition products) and one mobile ultraviolet-visible light spectrometer (used to identify unknown materials). The room contains a hood connected to a glovebox, to permit the analysis of radioactive and nonradioactive samples.

Room 182. This room contains a scanning electron microscope (SEM) for examining minute quantities of solids. The SEM includes energy dispersive X-Ray microanalysis capabilities for elemental analyses.

Room 183. This room is currently used for storage of scintillation counting equipment and waste drums.

Room 186. This room is used only for electronics and for the vertical calciner seismic shutdown system.

Room 187. This room contains five hoods for small general radioactive chemistry projects. Two of the hoods are connected to the normally nonradioactive D-3 drain line.

Room 188. This room contains a production-scale prototype vertical denitration calciner that is used to develop direct denitration techniques. The Laboratory Prototype Calciner is also used to evaluate equipment performance and operating parameters. The equipment and process used in laboratory calciner operations are described in detail in the Laboratory Prototype Calciner addendum to this FSAR. The laboratory calciner is not currently authorized for operation.

Room 189. This room contains an ion chromatograph used to examine non-radioactive samples. The room will be upgraded by adding a hood for a radioactive sample cell for the chromatograph.

Room 190. This room is a vault-type room used for storing stable plutonium material that is not currently needed for ongoing projects and demonstrations.

Room 191. This room is a chemistry laboratory used for general, nonradioactive chemistry projects and chemical preparation. The room contains three hoods and two countertop areas. The hoods in this room are connected to the E-3 ventilation system. The drains in this room are also connected to the D-3 drain line.

Room 202. This room is the nonradioactive pilot-plant laboratory, and contains one walk-in hood and two large countertop areas for general chemistry projects. The hood has a dedicated ventilation system that can also be used for tanks or other equipment in room 202. This ventilation system exhausts to the atmosphere through exhaust fan EM-15. The room also contains a small mezzanine area. Most of the room is (or can be) occupied by multiple pilot plants or process demonstrations. The 4.8-m ceiling allows projects to be considerably larger than in other PPSL rooms. Drains in this room are connected to the D-3 drain line.

Furnaces, hot plates, and rotary mixers are used in the open in this room whenever required by a project. Other types of heating are also used occasionally for specific process demonstrations or other needs.

General. Gloveboxes and hoods are connected to the E-4 ventilation system, except where noted above. All gloveboxes (except glovebox 179-1) are served by building water, pressurized air, and vacuum utilities.

Pressurized air is supplied at 90 lb/in^2 (gauge), but can be controlled to lower pressures. Much of the equipment in the PPSL facilities is portable and may be relocated, as required, to support laboratory activities.

The combined sum of all dispersible plutonium in the PPSL, the PFPAL, and the Standards Laboratory is administratively controlled to 12.45 kg by WHC-SD-CP-OSR-010, *Plutonium Finishing Plant Operational Safety Requirements* (WHC 1994a). Although individual room limits do not exist, the CPSs for the gloveboxes and hoods within the rooms restrict the amount of material within any room. Fissionable material is kept in room (vault) 190 except when in use, or in a nonstable form such as solution or moist solids.

Radioactive nonstable materials are stored in gloveboxes. Chemicals are stored in approved containers on shelving in a storage area. Flammable liquids are stored in flammable material storage cabinets.

The PPSL have no equipment receiving emergency power, and no need for backup power is foreseen. Equipment could be connected to backup emergency power in the future, on a case-by-case basis. Emergency lighting is available in room 179, room 183, room 202, corridor 10, and other strategic locations.

6.5.1.1.2 Plutonium Finishing Plant Analytical Laboratory. The PFPAL is located in the east end of the 234-5Z Building and is used to perform analytical and physical test analyses on plutonium samples. The samples come from the PFP operations, the PFP research laboratory, and a few special test samples from other locations.

The PFPAL is located in rooms 131 through 157 of the 234-5Z Building, with quality control standards being formulated and dispensed from rooms 221-C, 221-D, and 221-E. Plant air samples are counted in room 221-G.

The samples received and analyzed represent process control, material accountability, and product analysis. Both chemical analyses and physical tests are performed. The samples may be liquid, solid (metal and oxide), or substrate captured (filter media).

Chemical analyses are performed to determine major and minor element content, isotopic ratios, radiochemical characteristics, and pH. Physical tests to determine LOI and density are also performed.

All laboratory activities are conducted by trained personnel using approved procedures. Laboratory performance is controlled and monitored by a quality control program that includes analysis of standards, compliance overchecks, and audits.

All laboratory open-faced hoods and gloveboxes are exhausted through the E-4 system. The open-faced hoods and gloveboxes are isolated from the environment by two stages of independent and testable HEPA filtration. No uncontained plutonium in dry form is allowed in any of the open-faced hoods, or in the glovebox in room 143. The glovebox in room 144 is limited to less than 0.2 g uncontained plutonium powder or solid form material for PuO_2 and metal sample dissolution only.

All other laboratory gloveboxes, with the exception of gloveboxes 1 through 5 in room 139 and the single glovebox in room 145, contain both inlet and outlet HEPA filtration. Gloveboxes 1 through 5 in room 139 contain only inlet HEPA filters, and the single glovebox in room 145 contains only outlet HEPA filters. Gloveboxes 1 through 5 in room 139 are interconnected. The normal flow of exhaust from these gloveboxes is via a pass-through to glovebox 6. Glovebox 6 contains outlet HEPA filtration. Gloveboxes 1 through 5 are also connected to an emergency exhaust system. A normally closed valve on the emergency exhaust system opens when the gloveboxes start to pressurize. The emergency exhaust is HEPA filtered before connecting to the E-4 exhaust system. The single glovebox in room 145 is also equipped with an emergency exhaust system. A normally closed valve on the emergency exhaust system opens when the glovebox starts to pressurize. The emergency exhaust is HEPA-filtered before connecting to the E-4 exhaust system.

Room 131. Room 131 is used to analyze samples, by weight, for plutonium concentration. It contains one glovebox made up of three sections used for dissolution and analysis of product quality plutonium. Section 1 contains a muffle furnace used for fusing PuO_2 samples. Section 2 provides a working area where samples are dissolved, heated, titrated, and liquid waste is accumulated. Section 3 contains an argon-purged balance used in the titrations.

Room 132--Mass Spectrometer Laboratory. Room 132 contains two thermal ionization spectrometers for the isotopic analysis of extremely small samples of plutonium and uranium.

Room 133--Dark Room. Room 133 contains the grating and camera portions of a 2-m emission spectrograph and equipment for developing the film. It also contains a refrigerator for film storage. No radioactive materials are allowed in the room.

Room 134. Room 134 is used to prepare samples for analysis on the mass spectrometer, and it contains four open-faced hoods. Hood 1 is used to mount plutonium and uranium by electrodeposition, for analysis by thermal ionization mass spectrometry. Hood 2 is used to purify samples for the mass spectrometer via anion exchange resin columns. The anion resin columns are 3 in. long and contain 2 mL of resin. Hoods 3 and 4 are laminar downflow open-faced hoods with exhaust HEPA filtration. These hoods are used for single filament mounting of nanogram quantities of plutonium, for analysis by thermal ionization mass spectrometry.

Room 135. Room 135 is used to store and mount samples in support of the mass spectrometer laboratory, and it contains four hoods. Hood 1 is used to mount plutonium and uranium by electrodeposition, for analysis by thermal ionization mass spectrometry. Hood 2 provides temporary storage of samples to be analyzed throughout the laboratory. Hoods 3 and 4 are not in use at this time.

Rooms 136 and 137. Room 136 contains an emission spectrophotometer and a quantometer. Room 137 contains the arc stand for the 2-m film spectrograph. These instruments are used in trace element analyses of plutonium and uranium product. Each room contains a glovebox made up of three sections. Section 1 contains equipment for sample preparation. The plutonium metal, nitrate, and oxide samples are heated to 950 °C in a muffle furnace. Samples are then moved to Section 2, which contains equipment for the preparation and weighing of sample electrodes. The samples are moved to Section 3, which contains the arc stand where the sample electrodes are shot in a moist argon/oxygen atmosphere.

Room 139. Room 139 contains six interconnected gloveboxes. It is used to process and store all PuO_2 and plutonium metal received by the laboratory for analysis. The gloveboxes are as follows. Glovebox 1 contains a balance and the airlock for the entire system. Samples are weighed, and equipment and samples may be entered into the glovebox through the airlock. Glovebox 2 contains a balance and is used to weigh plutonium metal and oxide for analysis. Glovebox 3 is used for storage, and glovebox 4 contains the V-blender. The PuO_2 samples are blended in this hood before the start of analysis. Glovebox 5 is a storage hood containing 50 racks, each capable of holding up to 42 25-mL to 35-mL glass or plastic sample bottles per tray. Glovebox 6 contains two balances and a programmable furnace used for LOI analysis. There is a hygrometer located in glovebox 6 which is no longer functioning. Samples for other analyses are weighed in this hood.

The room contains a storage rack with three storage positions (each storage position may contain up to 400 g Pu), and a bench with three can sealers (one manual, two electric) for 7-in. food pack and soup cans.

Room 141--Cold Laboratory. Room 141 is used to analyze cold samples that support the building process such aqueous makeup samples and elevator oil viscosity. It contains a cold hood partitioned into two sections, a sink, and a water purifier. Additional equipment (a hot plate and muffle furnace) is located in the hood. The room also contains additional furnaces. No radioactive material is allowed in the room. Part of this room is set up as a satellite area for chemicals that have not been introduced into the controlled areas.

Room 142. Room 142 consists of four vented storage cabinets. The first two shelves in each cabinet are used to store standards for the radiochemical standards laboratory, and the other two store standards for the PFPAL. The four cabinets store approximately 250 g plutonium (oxide, metal, and nitrate) and/or ^{233}U per shelf. All standards or samples are double contained. Each storage cabinet is equipped with built-in spacers to comply with the CPS. The storage cabinets are 1/8-in. stainless steel. All four cabinets exhaust through the E-4 system, and do not contain HEPA filters.

Room 143. Room 143 is used for the handling of liquid waste that is not compatible with the waste recovery system and disposal of LLW to tank D-8 in 241-Z. Room 143 contains four hoods and one glovebox (glovebox 4). Hoods 1 and 2 are used by PFPAL waste handling personnel and are open-faced (ported hoods). Hood 3 and glovebox 4 were used to treat plutonium solutions with $C_2H_2O_4$ to form a plutonium oxalate cake. This solution was filtered, and the cake was disposed of as reactive scrap. The scrap was counted on the Segmented Gamma Scan Assay System (SGSAS) and transferred to operations for processing. The hood and glovebox are currently used for storage. Hood 5 was used to dispose of LLW via a drain system to the D-8 tank in the 241-Z Building, for transfer to tank farms. The hood contained a waste aspirator to transfer the waste from the 4-L bottles to the sink drain. This hood is no longer used to dispose of LLW. The hood is usable, but it is not being utilized. The sink in the hood is inoperable.

These are standard laboratory open-faced hoods with ports, to which gloves could be attached (if needed) for additional radiological safety. The single glovebox does not provide total containment since it is directly connected to an open-faced hood. For this reason, the glovebox is controlled by radiological posting consistent with open-faced hoods (0 g uncontained plutonium powder or solid-form material). There are no HEPA filters provided at the hoods or glovebox. The exhaust ducting from the hoods and glovebox leads to a filterbox in the E-4 ventilation system.

Room 144. Room 144 contains eight hoods and one glovebox. The work performed in this room provides the primary support for PFP and PPSL plutonium samples. Analyses that are performed include plutonium concentration, visual percent solids, americium concentration, and acid/base determination. Both aqueous and organic samples of high-level and low-level sample concentrations are analyzed. This room also has facilities to dissolve plutonium metal and PuO_2.

Hood 1 is used to package/repackage samples for shipment, hood 2 is used for temporary storage, and hood 3 is used for sample storage. Hood 3 contains one 4-L waste bottle and one 500-mL trap bottle connected to a 26-in. Hg vacuum. One-liter polybottles containing process organic may also be present. During peak operations the samples are disposed of every 24 h. At the beginning of every day shift, the waste recovery technician checks and removes all full bottles to room 152.

Glovebox 4 is used to break down samples received from customers, and to dissolve PuO_2, plutonium metal samples, and solids contained in process samples. All high-level solutions (>60 g/L plutonium) are disposed of in a 500-mL glass bottle. All low-level samples (<60 g/L plutonium) are disposed of in a 4 L bottle.

Hoods 5 and 6 are used for uranium analysis by kinetic phosphorescence. Hood 5 contains reagents, while hood 6 contains the uranium analyzer.

Hood 7 is used for temporary storage, and hood 8 is used for storage of high-level waste samples (>60 g/L plutonium). Samples are segregated plutonium density for criticality control.

Hood 9 contains two 4-L waste bottles and is connected to a 26-in. mercury vacuum and electrical outlets. This hood also has an organic waste bottle. Various analyses, or sample preparations, are performed in hood 9. For high-level (greater than 60 g/L plutonium) and low-level (less than 60 g/L plutonium) radioassay, the sample is placed in a vial, the vial is sealed, and taken to the counting room for analysis. Analyses are performed by the solution counter method.

For americium analysis, the sample is placed in a vial, the vial is sealed, and taken to counting room for analysis. Acid and base titration and low-level plutonium extraction are also performed. For plutonium extraction, the sample is contacted with tributyl phosphate/normal paraffin hydrocarbon and aqueous solutions are sent to the 222-S Laboratory for inductively coupled plasma emission spectroscopy/Dionex. A specific gravity densitometer is also used, where a sample is taken into the chamber of the instrument, measured, and discarded to waste.

Room 145. Room 145 contains a glovebox that was used to analyze sinterability, bulk and tap density of PuO_2, and for the preparation of PuO_2 standards for the emission spectrometer. The glovebox contains two sections. The top section contains a programmable furnace with a normal operating temperature 1600 °C, a balance, a sintering press, bulk and tap density equipment, a mortar and pestle, and screens. The bottom section was formerly used to prepare plutonium standards for emission spectrograph analysis.

This is an older laboratory glovebox, constructed in the early 1970's. It is no longer in use, and the plutonium inventory in this glovebox is 0 g.

Room 145-A. Room 145-A is used to store supplies routinely used in the laboratory. There are no special alarms, protective features, or services provided for this room.

Room 146. Room 146 has four open-faced hoods and a glovebox. The hoods are used for percent organic analysis and storage. The glovebox is used for waste repackaging. All laboratory hood waste goes through this glovebox before being placed in 55-gal drums.

Room 147. Room 147 is used as an office and is not discussed further.

Room 148. Room 148 has two hoods that are cleaned out. The remainder of this room is used as the laboratory chemical satellite area.

Room 149. Room 149 contains an open-faced hood and a hood converted into a glovebox. Since relatively large amounts of plutonium compounds were to be dissolved in the glovebox, the exhaust passes through a scrubber. The converted glovebox is also equipped with inlet HEPA filtration. The glovebox

was not used for dissolving plutonium compounds, and the room is currently used for packing and unpacking shipping containers.

Rooms 150 and 151--Counting Room/Shift Office. Room 150 serves as the counting room and room 151 as the shift office. Room 150 contains six counting systems. There are four hyper-pure germanium detector systems that are used for gamma ray spectroscopy. These detectors are continuously stored at a reduced temperature through the use of liquid nitrogen dewars. The dewars are refilled from cart-portable liquid nitrogen tanks. Room 150 contains a liquid scintillation counting system used for counting samples with very low activities. A gas flow proportional counting system is used for alpha and beta radiation. This detector utilizes a fill gas of 90% argon and 10% methane, known as P-10 gas. The fill gas is available from gas lines in room 150.

Room 152--Waste Laboratory. Room 152 contains a load-in hood and a glovebox. It was used to reprocess liquid laboratory wastes. The open-faced hood (551) initially received the waste container. The waste was sampled for H+ and plutonium analysis before being returned to the process. Currently this hood is only used for storage of high-level wastes.

Glovebox 552 consists of three storage tanks, a distillate tank (sent to D-8), vacuum trap, steam concentrator, caustic scrubber, water condenser, and a LO tank. This glovebox is out of service.

These are standard laboratory hoods and gloveboxes and are exhausted via the E-4 system.

Room 153. Room 153 consists of four open-faced hoods and one glovebox, which are used to support PPSL projects. Hood 1 is used to analyze samples in support of the PPSL, and the hood can have up to 150 g plutonium present. Hood 2 is used to analyze total inorganic carbon (CO_3). Hood 3 is used to analyze total organic carbon samples. The samples are injected through the hood and into the system with a syringe and needle. There is a CO_2 coulometer and printer outside the hood. Hood 4 is used for storage of plutonium oxalate waste. Glovebox 5 contains equipment necessary to perform the surface area analysis. The instrumentation is located on a bench outside the hood and the line runs into the hood. This glovebox may contain approximately 250 g plutonium, and liquid nitrogen was used inside of the glovebox during the analysis. This glovebox is no longer in use.

Room 154. Room 154 contains one glovebox partitioned into three sections, and is used for analysis of both PuO_2 and metal samples. At one time, carbon, sulfur, and nitrogen were analyzed in this glovebox. The glovebox contains two carbon, sulfur, and nitrogen analyzers with furnaces. The glovebox can contain up to 400 g plutonium.

Room 155. Room 155 contains four hoods and associated equipment that were used to support sludge work. Hood 1 contains an ultraviolet spectrometer for measuring trace quantities of nitrite. Hood 2 contains electrodes connected to a pH meter external to the hood, and a hot plate. These are used to measure nitrate. Hoods 3 and 4 are used to analyze for percent organic in sludge samples.

Room 156. Room 156 contains one glovebox divided into two sections and two hoods. The glovebox is no longer in service, and hoods 3 and 4 are used to analyze PPSL samples for F^- and Cl^- ion concentration.

Room 157. Room 157 consists of four gloveboxes (with furnaces) and a sample cell, which were used to support PuO_2 work. Gloveboxes 1 and 2 have been sealed and are no longer in service. Gloveboxes 3 and 4 are new and have never been used. They contain equipment for particle determination, and future use of these gloveboxes would be for temporary storage.

Room 221-G. Room 221-G contains an air filter analyzer.

6.5.1.1.3 Radiochemical Standards Laboratory. The radiochemical standards support that is provided in rooms 221-C, 221-D, and 221-E is devoted to the formulation, verification, packaging, and distribution of the plutonium-containing standards needed in the PFPAL.

Room 221-C. Room 221-C contains a glovebox used for the preparation of ultra-pure PuO_2 standards for the PFPAL. The glovebox is equipped with a balance and an oscillating blender which has been dismantled for disposal. Various materials are blended with PuO_2 to produce quality control standards. Initial preparation of oxide material also occurs in this box. The glovebox is equipped with both inlet and outlet HEPA filters. The glovebox is exhausted via the building E-4 exhaust system. A hygrometer is also located in the glovebox to measure the dew point of the dry air. The hygrometer is not working since there is no dry air supply. Room 221-C also contains two hoods and a vented storage cabinet which is no longer in use. Hood 1 is used for storage. Hood 2 is used for "cold work" with HNO_3 or millicurie level quantities of plutonium dilutions, and for decontamination of glassware. Hood 2 is also used for sheet standard (fiberous papers with mounted plutonium nitrate) preparation. Both hoods contain sinks. The vented storage cabinet is used to store radioactive materials.

Room 221-D. Room 221-D contains equipment used for makeup of plutonium sheet standards and for performing plutonium nitrate characterization. It contains four hoods and a glovebox. Hoods 1 and 2, located on the southwest wall of 221-D, are used as open-faced hoods for the pipetting of plutonium solutions. Hoods 3 and 4 located on the southeast wall of 221-D, are used for plutonium nitrate characterization. The glovebox is used for plutonium nitrate storage, but is not currently being used. This is a standard laboratory glovebox equipped with both inlet and outlet HEPA filters.

Room 221-E. Room 221-E contains equipment for the preparation of thorium and uranium standards. This room is used in conjunction with rooms 221-C and 221-D to support actinide standards used in all 200 Area analytical laboratories. The work done in this room is nonradioactive or has a low-radioactivity level. The room contains bench tops and three open-faced hoods. One hood contains a sink and an ultrasonic cleaner which is no longer used. The second hood contains an electric Bunsen burner for flaming counting disks. The torch is no longer in use and the gas bottles have been removed. A third hood contains heat lamps for drying low-level sheet standards used in NDA techniques. Additional items in the room include the q-water system (an ion exchange resin water purification system to provide low conductivity/high purity water), and an analytical balance on a balance table.

6.5.1.1.4 Nondestructive Analysis Laboratory. The NDA of containers of plutonium material indicates the total mass of isotopes by measuring the radioactive emissions and/or the heat output of plutonium-bearing material in the package. Several NDA systems are available for package evaluation. The NDA Laboratory is located in room 637 of the 2736-ZB Building.

Isotopic Counters. Material in cans (recoverable, metal, or oxide) and drums of waste may be assayed in any one of four isotopic counters in the NDA Laboratory. The isotopic counters detect and measure spontaneously emitted gamma radiation, which allows identification of TRU isotopes and the mass fractions of each isotope. Each assay requires approximately 2.5 h of counting time. The detectors are chilled with liquid nitrogen, and 15-L dewars of liquid nitrogen are kept in the laboratory for each counter.

Pre-Equilibration Bath. Before it is measured by calorimeter, a plutonium-bearing item is placed inside of a calorimeter adapter, which is then brought to a uniform temperature by immersion in the pre-equilibration bath. This temperature adjustment allows the calorimeter to measure container heat output more rapidly and accurately. The demineralized water heat sink in the bath is continually agitated by two electric mixers to ensure uniform temperature throughout the bath.

Calorimeter. The plutonium material container, following temperature adjustment, is placed in a calorimeter for the determination of container heat output. A container may be in the calorimeter from 2.5 to 4.0 h before a heat output can be assigned to the container. The performance and accuracy of the calorimeters are affected by air-space insulation around the heaters, room temperatures, and humidity. Six calorimeters are in use, each measuring a single container at a time.

Neutron Well Coincidence Counter. The Neutron Well Coincidence Counter (NWCC) may be used to determine total plutonium content of a plutonium material container instead of the calorimeter. The counter consists of a large-volume polyethylene moderator, into which the container is placed. Detectors in the polyethylene are positioned radially around the container, and measure the coincident spontaneous-fission neutrons emitted by even-numbered isotopes of plutonium. The NWCC is especially useful when large numbers of containers of similar chemical makeup require assay. Counting time is much shorter than with a calorimeter, and temperature pre-equilibration is not required.

Segmented Gamma Scan Assay System. The SGSAS counts containers of waste or recoverable material on rotating tables. Tables are sized to accommodate containers from 0.5 L polyjars to 55-gal drums. Counting time is 10 to 15 min, depending on the container. The assay system uses a germanium detector cooled with liquid nitrogen. A small ^{75}Se source is associated with the system for determining gamma ray attenuation corrections (adjusting for gamma ray attenuation due to changing matrix density). There are two small-table SGSASs in the 234-5Z Building, and one large-table and one small-table SGSAS in the 2736-ZB Building.

NaI Gamma Package Counter. The NaI package counter detects TRU holdup in waste. The counter is designed and calibrated specifically for large waste packages occasionally weighing over 300 lb, combustibles, or low-density

noncombustibles. The counter is normally used for the assay of room and glovebox waste drums, empty polyethylene bottles, and used HEPA filters. The counter is calibrated against a 300-g plutonium source before counting each item. If a waste package contains 10 g plutonium or more, it is held for recount on an SGSAS (for greater accuracy).

Portable NaI and germanium counters are used primarily for in-situ measurement of plutonium in duct work, HEPA filters, and tanks, and occasionally, for counting packages. They are calibrated by a sheet standard of dried plutonium on filter paper, triply encapsulated.

6.5.1.2 Flowsheets. The majority of laboratory support functions are batch processes. Flowsheet documents are not used in the PFPAL, Radiochemical Standards Laboratory, or the NDA Laboratory.

Flowsheets are seldom required in the PPSL. Most of the projects are small chemistry demonstrations done in batch steps. Many of the processing steps are not determined until the results of the previous step are known. Larger continuous experiments (pilot plants) frequently demonstrate process flowsheets planned for use in production facilities. These planned flowsheets can be either used full-scale for the PPSL demonstration or scaled down, as appropriate. Flowsheets are incorporated into test plan documents unless the flowsheet is so large or complex that a separate flowsheet document is required.

The flowsheet for the Laboratory Prototype Calciner using the vertical direct denitration calciner process, located in room 188 of the PPSL, is incorporated into WHC-SD-CP-TP-088, *Test Plan for Radioactive testing of a Vertical Direct Denitration Calciner* (WHC 1994c). The flowsheet for this process as well as the related equipment and process descriptions are provided in the Laboratory Prototype Calciner addendum to this FSAR.

6.5.2 Process Chemistry and Physical Chemistry Principles

A variety of chemical reactions take place in the PPSL, PFPAL, and the Radiochemical Standards Laboratory. Chemicals that are handling hazards include, but are not limited to, HNO_3, HF, H_2SO_4, NH_2NH_2, NaOH, KOH, and $KMnO_4$. The NDA Laboratory does not conduct chemical processes.

The Laboratory Prototype Calciner located in room 188 of the PPSL is used to convert plutonium nitrate solution into a stable, storable plutonium dioxide powder. The process chemistry involved in operation of the laboratory calciner is described in the Laboratory Prototype Calciner addendum to this FSAR.

6.5.3 Mechanical Process Systems

The NDA Laboratory operations are essentially mechanical in nature as described earlier.

6.5.4 Chemical Process Systems

A variety of laboratory processes involving chemical reactions take place in the PPSL, PFPAL, and the Radiochemical Standards Laboratory. Descriptions of the rooms and equipment where these processes occur are given in Sections 6.5.1.1.1, 6.5.1.1.2, and 6.5.1.1.3. One of these processes is testing the direct denitration of plutonium-bearing solutions in a production-scale prototype vertical denitration calciner. The Laboratory Prototype Calciner is used to evaluate equipment performance and process parameters for operation of the calciner. The direct denitration of plutonium-bearing solutions using the Laboratory Prototype Calciner takes place in glovebox 188-1, located in room 188 of the 234-5Z Building. The Laboratory Prototype Calciner addendum to this FSAR provides a description of the equipment and process for the laboratory calciner. The addendum includes a hazard evaluation of the process, appropriate accident analysis, designation of safety equipment and specification of controls for laboratory calciner operations.

6.5.5 Instrumentation and Control Systems

Instrumentation systems for laboratory support processes are associated with safety significant instruments which are common to most of the PFP facilities (e.g., CAM and CAS). Other instrumentation systems may be added or used per the needs described in the applicable test plan. See the Laboratory Prototype Calciner addendum for information on instrumentation and controls associated with operation of the laboratory calciner.

6.5.6 Control Rooms and Control Areas

The equipment used in the PPSL, PFPAL, Radiochemical Standards Laboratory, and the NDA Laboratory is locally controlled. It can be switched off to ensure a safe shutdown. The equipment used for the Laboratory Prototype Calciner is described in the Laboratory Prototype Calciner addendum to this FSAR.

6.5.7 Analytical Sampling

Product produced by laboratory testing is sampled in the glovebox or hood where produced. The samples are sent to the PFPAL for the desired analyses. Any stabilized product is later sent to 2736-ZB for calorimetry and storage. The plutonium content of the laboratory calciner product is determined by calorimetric measurements in the 2736-ZB Building. A sample of the product is LOI tested in the PFPAL. Additional information regarding the laboratory calciner is provided in the Laboratory Prototype Calciner addendum to this FSAR.

6.5.8 Product Handling

The product destined for storage is transferred from product receiver vessels into slip-lid cans. The stabilized plutonium-bearing material

generated by direct denitration is handled, packaged, and stored in accordance with the process descriptions provided in the *Laboratory Prototype Calciner* addendum to this FSAR.

6.5.9 Identification of Items for Safety Analysis

6.5.9.1 Criticality Prevention.

Criticality Safety Evaluation for Laboratories. The PPSL, PFPAL, Radiochemical Standards Laboratory, and the NDA Laboratory handle fissionable material on a routine basis. The laboratory CPSs establish sets of allowable limits for gloveboxes and hoods, and state where each set may be applied. Design restrictions are not always practical in laboratory gloveboxes, and criticality safety must be achieved by conservative restrictions on plutonium mass, volume, and spacing.

Abnormal conditions considered in the criticality safety evaluation are addressed in the following sections. These conditions can occur individually or as a combination of events.

Mass Limit--Mass limits are imposed in two ways. A glovebox or hood may have a single mass limit for all fissionable material stored inside, or a separate mass limit may apply to more than one unit mass of fissionable material inside the glovebox (a glovebox may have a limit of 4 unit masses with 400 g plutonium per unit mass). Violations of mass limits could occur if a worker introduced a single mass of plutonium that (by itself) exceeded the mass limit for the glovebox, hood or unit mass. A violation could also occur if a mass of plutonium was introduced to existing plutonium in the glovebox, hood, or unit mass such that the total amount of plutonium exceeded the mass limit. These violations could occur by failure to record the introduction of a package of fissionable material to the glovebox, failure to remove a package of plutonium from a glovebox after removing its record from the glovebox inventory, incorrect labeling of the amount of plutonium on a package before placing it in the glovebox, or incorrect calculation of the new total before introducing a new package with plutonium.

Volume Limit--Volume limits are imposed in three ways. There may be a limit to the allowable volume of a single container, the allowable volume of the collection of containers within a glovebox, hood or unit mass, or both. Violations of the volume limits could occur in the same manner as mass limit violations.

Introduction of Water--The presence (or use) of water may not be allowed due to the amount and form of plutonium present in a glovebox. Violations could occur if workers failed to lock out any water supply lines correctly. The potential activation of a fire extinguishing system is considered in CSEs. Water could also be introduced by firefighters using water on a fire inside the glovebox.

Spacing--Spacing limits are imposed in two ways. A glovebox may have a limit on how closely another mass of fissionable material may approach the glovebox, or there may be minimum spacing requirements between separate unit masses within a glovebox. Violations could occur if workers moved containers

of fissionable material without verifying the distance between the package being moved and any adjacent packages or unit masses.

Material--The type of material may also be limited within a glovebox, hood, or unit mass. The limits restrict the introduction of moderating materials and neutron reflectors, the use of plastics in operations, and the use of organic liquids. Violation could occur if workers introduced such materials in excess of the limits. Neutron reflectors must be controlled both outside and inside of the glovebox or hood enclosure. The unapproved installation of radiation shielding material could represent a violation, if its proximity to the fissile accumulations, or if the type of shielding used could increase neutron reflection. Another type of material violation that could occur is the addition of a plutonium container with an unacceptably high ratio of hydrogen to plutonium (H/Pu > 2).

Implementation of Criticality Safety in the Laboratories. Criticality safety is implemented in the laboratories by posting and complying with the specific limits in effect on a glovebox or hood. A CPS containing a uniform set of eight posting limits has been approved for use in the laboratories. Laboratory management and the CSR determine the necessary postings for a glovebox or hood, depending on the type(s) of work to be done and the amount of plutonium necessary to accomplish the task(s). The appropriate limits are posted on the glovebox or hood after ensuring that the current plutonium masses, spacing, and container volumes, etc., are in compliance with both the old and new set of limits.

Plutonium mass and container volume inventories are posted on the glovebox for tracking as material is moved, added, or removed. The inventory is compared with the criticality posting before work begins in any hood or glovebox. These inventories are verified and adjusted before adding and after removing plutonium or containers. The inventories and the condition of glovebox criticality drains are also verified monthly by laboratory personnel, and the results are reported to the CSR. The CSR and the laboratory management also inspect the laboratory areas quarterly for compliance with criticality safety limits.

Design features for criticality safety, such as geometrically favorable equipment, are used to the maximum extent possible. Specific safety features are described in Section 6.3.9.1.

6.5.9.2 Chemical Safety. Significant amounts of chemicals, with a variety of hazards to personnel are used in the PPSL, PFPAL, and the Radiochemical Standards Laboratory. the chemicals used that are handling hazards include, but are not limited to, HNO_3, HF, H_2SO_4, NH_2NH_2, KOH, and $KMnO_4$. Chemical safety is ensured by strict compliance with *Chemical Management* (HNF-PRO-2258) and safety requirements contained in ZAP-000-010, "PFP Chemical Hygiene Plan" (see Section 10.4.5). Safety requirements for chemicals are contained in the Material Safety Data Sheet (MSDS) provided by the chemical manufacturer and the HEHF. Complete listings of applicable MSDSs are maintained by the laboratories and copies are readily available to laboratory personnel. New or unique handling requirements are listed and discussed in all new procedures. These are approved by the appropriate safety organizations before implementation.

Nonradioactive dry chemicals received at the PFPAL from the Radiochemical Standards Laboratory are stored in room 141 for technical staff use. When one of these chemicals is used for a procedure, it is placed in the hood or glovebox where the procedure is performed. Chemicals received from the Radiochemical Standards Laboratory are clearly labeled and are in containers appropriate for the chemical mixture. The label indicates the name(s) of the person(s) preparing the chemical, the date the chemical was placed into the container, and the expiration date for the chemical. Chemical work is not allowed unless at least one other person is in the laboratory, or is aware that chemical work is underway.

Flammable and combustible liquids are stored in cabinets dedicated to flammable materials. Concentrated acid solutions and other hazardous liquids are stored separately from the flammable materials in dedicated cabinets. Spill kits are located in the laboratories.

Radioactive chemicals are handled in accordance with the applicable RWPs. The RCTs are frequently in the laboratories and ensure compliance with the RWPs.

Exposure rate varies with the amount and type of material being handled. The gloveboxes in room 139 of the PFPAL range from 10 to 80 mrem/h. The other hoods and gloveboxes of the PFPAL range from 0 to 40 mrem/h. The higher dose rates are permitted only where intermittent occupancy is required. See Chapter 8.0 for specifics on radiation protection.

Disposal of waste chemicals after testing is guided by (HNF-PRO-455), *Solid Waste Management*. Radioactive waste solutions are sent to the Tank Farms via the tanks at 241-Z. Waste that could not be sent the tanks at 241-Z was run through the waste concentrator in room 152, or converted to an oxalate in room 143. These high-level plutonium-bearing materials were then sent back to operations via tank 227 or as oxalate cake. Radioactive and nonradioactive solid wastes are packaged and disposed of in accordance with *Hanford Site Solid Waste Acceptance Criteria*, (Willis 1994).

Most chemical operations for the Laboratory Prototype Calciner occur inside the glovebox, which shields workers from chemical hazards. The Laboratory Prototype Calciner addendum to this FSAR provides information on chemical and process hazards and protective features related to laboratory calciner operation.

6.5.9.3 Process Shutdown Modes. The laboratory support projects are normally small and localized, allowing power requirements to be met with standard 110-Vac electrical outlets. Special shutdown systems are not required for these projects, with the exception of the SEM and the Laboratory Prototype Calciner. Because the SEM must operate under a high vacuum it contains an interlock built-in by the manufacturer to protect the equipment. If the vacuum is lost or is inadequate for any reason, the electron source automatically shuts down. Emergency shutdown features for the laboratory calciner are discussed in the Laboratory Prototype Calciner addendum to this FSAR.

Normal shutdown for the SEM is in accordance with the operating manual provided with the unit, and no safety hazards are involved. Normal shutdown

of the Laboratory Prototype Calciner is in accordance with PPSL operating instructions.

Larger projects may also require emergency shutdown systems. However, most projects can be shut down completely by deenergizing the process at one or two standard electrical switches or plug-ins. Special instructions for shutdown including locations of circuit breakers and essential valves outside of the laboratory area, are supplied whenever other groups provide overnight or weekend surveillance of PPSL projects.

6.5.9.4 Instrumentation. Instrument needs for laboratory support projects are determined on a case-by-case basis. Most chemistry projects require little or no instrumentation. Larger projects may require thermocouples, pH meters, gas monitors, or similar small equipment that is available from vendors for direct use. Small amounts of chemicals are normally used so that effluent monitors are not required, and nonradioactive waste solutions are collected, sampled, and analyzed by the PFPAL before disposal under PFP Environmental Compliance guidance. Radioactive effluents are disposed of through the building radioactive waste drain system under the guidance of both PFP Environmental Compliance and PFP Process Engineering.

Instruments that are required for laboratory support projects are maintained and calibrated according to the building PM&S system and/or manufacturer instruction manuals. General building instruments used in the PPSL facilities (CAMs, survey instruments, the CAS, security alarms) are controlled by Engineering Administration and calibrated by maintenance personnel under the PM&S and PM programs.

Process specific operating parameters that are monitored for the Laboratory Prototype Calciner are discussed in the Laboratory Prototype Calciner addendum to this FSAR.

6.5.9.5 Remote and Contact Maintenance. There is no remote or contact maintenance associated with laboratory processes that requires identification for accident analysis purposes.

6.6 MISCELLANEOUS PROCESSES

6.6.1 236-Z Plutonium Reclamation Facility Process Systems

The PRF process systems are inactive and operation is not authorized. Active electrical power to the PRF is limited to the 17 inch mercury vacuum system, criticality alarm system, normal lighting/receptacle panels, elevator, security systems, building support systems (e.g., HVAC), and emergency lighting/receptacle panels. A total restoration of PRF electrical power is not planned. Power to PRF process systems and equipment will remain deactivated except when required for PRF facility clean out and deactivation.

Reactivation of any portion of these process systems would require the performance, documentation, review, and approval of new hazard and accident analyses, with associated modifications (as required) to this FSAR. However, all gloveboxes (except those physically removed or declared inactive) are

authorized for interim storage of plutonium-bearing material. A list of active and inactive gloveboxes is located in Chapter 5.0, Table 5-5. Inactive gloveboxes cannot receive containers of plutonium, but residual quantities of material remain in the gloveboxes.

A historical detailed description of the former processes can be found in Revision 0 of this FSAR. In addition, historical information can be found in the previous PFP SARs, which analyzed different facets of operations at the PFP (see Section 6.4.3).

6.6.1.1 Narrative Description. The plutonium recovery process converted various plutonium-bearing materials and aqueous feeds to a purified plutonium nitrate product suitable for conversion to plutonium metal or PuO_2 (see Figure 6-22). This plutonium recovery process is inactive and operation is not authorized.

The process included recoverable material dissolution and scrap stabilization, and plutonium purification. Recoverable material dissolution and scrap stabilization [miscellaneous treatment (MT)] included hydrolysis, clarification, and calcination. Plutonium purification involved feed preparation, solvent extraction (SX) and stripping, and organic cleanup. The process also involved concentration and clarification of the aqueous product and waste streams.

Most of these process steps were located in the PRF in the 236-Z Building (see Figure 6-23). Some of the miscellaneous processing took place within the 234-5Z Building of the PFP.

6.6.1.1.1 Recoverable Material Dissolution and Stabilization. Recoverable plutonium-bearing materials (PuO_2 powders, incinerator ashes, sludge, and miscellaneous solutions) were converted to aqueous plutonium solutions in gloveboxes in the PRF and in the 234-5Z Building.

Several processes, collectively known as MT, were conducted within a complex of five gloveboxes in Room 41 of the PRF. The gloveboxes in Room 41 are numbered one through six (glovebox MT-2 has been removed). MT consisted of inspecting, weighing, sampling, splitting, burning, repacking, dissolving, precipitating, and storing operations. The glovebox operations involved batch lots of different types of materials.

Additional capacity and capabilities were provided by four gloveboxes located in the 234-5Z Building. Glovebox HC-60, located in Room 230, was used for hydrolysis of scrap containing greater than 20% organic. Glovebox HA-40F, located in Room 169, is equipped with two furnaces that were used to calcine miscellaneous solids, primarily ash from the incinerator at the Rocky Flats Plant (RFP) in Colorado. Glovebox HC-46F, located in Room 170, contains dissolver pots and support equipment that were installed (but never used) for dissolving plutonium-bearing solids. Glovebox HA-21I once contained furnaces that were used for calcining hydrolyzed plutonium-bearing materials.

Two continuous refluxing dissolver/condensers installed in the 236-Z Building process canyon were used for dissolving crushed sand and S&C from the RMC Line in the 234-5Z Building. The dissolvers were supported by three systems: acid feed, product treatment, and offgas treatment. Three

interconnected gloveboxes in room 43 of the 236-Z Building also supported dissolver operations. Cans of feed material were dropped into the dissolvers from the charging glovebox. The dissolvers contained hot nitric acid provided by the acid feed system. Gases evolved during dissolution passed through a reflux condenser and scrubber before being vented into the 236-Z process cell. The product solution flowed to a settling tank, where large entrained solids were removed. The product then flowed to a centrifuge, where the remaining solids were removed. The product solution was used as feed to the SX system.

6.6.1.1.2 Plutonium Purification. Plutonium purification was accomplished by feed preparation, solvent extraction and stripping, and organic cleanup. The first step was to prepare and sample feed from such sources as the MT dissolvers, the S&C dissolvers, the filtrate from the RMC Line, and the aqueous waste concentrator.

The plutonium extraction and stripping function took place in the process cell and the upper sections (extending up through gloveboxes on the fourth, fifth, and sixth floors) of the 236-Z Building.

An organic stream composed of 20% TBP and 80% CCl_4 was used to complex, or chemically combine, with plutonium. Because the solvent density was greater than the density of aqueous feed, the organic solvent flowed downward through the aqueous solution. As the liquids passed each other, plutonium in the aqueous feed transferred to the organic extractant. After passing through the organic phase, the aqueous solution flowed out of the top of the column and was sent to Aqueous Waste Processing. The organic phase containing the extracted plutonium continued to move downward and met with an aqueous solution that had been recycled from the stripper column. Finally, near the bottom of the column, the organic met a dilute stream of HNO_3, which removed chemical impurities from the organic.

The plutonium-bearing organic was then pumped to the top of the plutonium stripping (CC) column and flowed downward. As it flowed downward, the organic passed through a dilute aqueous solution of HNO_3 and hyrdoxlamine nitrate (HN) that entered the bottom of the column. This aqueous solution removed ("stripped") the plutonium from the organic, and was recycled back to the plutonium extraction (CA) column.

The organic, which contained impurities, went to Organic Cleanup. The organic from the CC column flowed continuously through three columns to remove trace plutonium, impurities, and organic degradation products, and a fourth column reacidified the organic before being recycled back to the CA column.

6.6.1.1.3 Aqueous Solution Concentration. There are two steam evaporators in the PRF, which are the product concentrator and the filtrate/waste concentrator.

The product concentrator is a "falling film" evaporator. Internal "stripping steam" was used to heat the product solution as it passed through a bed of Raschig rings. Steam was also supplied to a steam jacket, which surrounded the concentrator. Any organic contained in the solution was vaporized as it contacted the hot surface of the Raschig rings. The product solution was then centrifuged to remove any suspended solids, and returned to the 234-5Z Building storage to await metal conversion.

The waste concentrator is also steam-jacketed, and the solution was boiled to reduce its volume. The filtrate from the RMC Line, the organic cleanup column aqueous waste solutions, and miscellaneous solutions were pumped to the evaporator, where antifoam agents and HNO_3 were added if necessary. The concentrated aqueous waste was drained to holding tanks (TK-23 or TK-24) and transferred back to the SX feed preparation.

6.6.1.2 Design Description. The PRF was designed to confine plutonium, and meet commercial and industrial safety criteria. The design of operating area compartments (nuclear and chemical) and critical safety structures has been reanalyzed and upgraded a number of times since the facility was built.

The 236-Z process cell is constructed of noncombustible materials (concrete walls, floors and ceiling, with a stainless steel floor liner capable of holding spills from leaking piping or vessels). The process cell uses limited or controlled air in-leakage to prevent loss of containment. The cell walls and the ceiling are 2 ft thick, providing limited radiation protection in the event of a criticality. The process equipment was designed to be geometrically favorable for criticality safety. Personnel exposures were limited by minimizing "hands on" operation through extensive use of mechanical equipment. Valving and pumps are located outside of the process cell but inside gloveboxes. Major components can be replaced and repaired in the hot maintenance shop, which is located just outside of the process cell.

The process vessels and piping were designed to contain contaminated (plutonium-bearing) solutions. Generally, these streams were operated at atmospheric pressure and relatively low temperatures. Specific equipment items were designed to meet the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* and the American Society for Testing and Materials (ASTM) Code for pressure piping.

The MT gloveboxes were designed to confine plutonium and provide for inlet and outlet air ventilation through HEPA filter systems. The process equipment was designed to provide confinement during normal feed preparation and stabilization. The spacing and size of the equipment, in conjunction with administrative controls on mass and concentration, provide criticality control. The glovebox, ventilation system, and process equipment were designed to minimize the amount of contamination in the event of a fire or explosion, by maintaining airflows and pressure drops.

6.6.1.3 Safety Criteria and Assurance. When in operation, the primary safety concerns associated with plutonium recovery operations were criticality safety, radiological safety, process upsets, and industrial safety. Because of the presence of residual radioactive materials in the process cell and in plutonium-recovery gloveboxes and process equipment, in addition to the use of plutonium-recovery facilities for the temporary storage of in-process material, criticality prevention and radiological hazards continue to be safety concerns. In addition, there are some chemical safety concerns. As discussed below, the PFP has committed to removing all remaining chemicals to alleviate these concerns by December 31, 1997.

6.6.1.3.1 Criticality Safety. The process cell and each glovebox have been analyzed to ensure compliance with the criticality safety criteria presented in Chapter 4, Section 4.3.4. The established CPS limits are still

valid for gloveboxes that are not in routine use. Criticality safety features incorporated into the design of the plutonium recovery operations include the following.

- The process equipment is designed to be geometrically favorable even if operated with plutonium at the maximum credible concentration (if the plutonium precipitates during a process upset) and optimum moderation.
- Spacing between major pieces of process equipment is fixed to reduce neutron interaction.
- Process cell tanks are spaced from the walls, floor, and ceiling to reduce neutron reflection from the concrete.
- Process containers, such as cans or polybottles, are designed to be subcritical even if overbatched and moderated.
- Liquid level on the east and west glovebox floors is physically controlled by weirs. each floor weir discharges to a lower level, and the lowest level discharges to the process cell floor bays.
- The depth of liquid in the process cell floor bays is physically controlled by weirs that direct flow of solutions from bay sections near the east and west walls to the center of the cell. The process cell floor bays can hold all the tank contents of the cell without exceeding the maximum safe depth.
- Process waste is collected in geometrically favorable tanks that are physically isolated from sources of concentrated plutonium. These tanks are connected to waste storage systems through lines operated by supervisor-controlled valves. Transfers are made only after an acceptable plutonium content in the waste is verified by sampling.
- Cooling water systems are designed to ensure that any leakage would flow into the process system and would not discharge into the waste storage system.

Operating procedures incorporate administrative criticality safety requirements. These requirements include plutonium mass limits, limits on the number and size of containers, spacing limits between containers, concentration limits, and limits on the depth of solution spills.

The PFP is equipped with an integrated criticality detector system. The detector system covers all areas where the occurrence of a criticality is considered possible. Periodic operability checks of detectors and alarms are made, and personnel response to criticality alarms is verified by drill exercises.

6.6.1.3.2 Radiological Safety. Although plutonium conversion is no longer being performed, the associated gloveboxes and process cells contain residual radioactive material and may be used for the storage of in-process material. The gloveboxes and cells provide the primary confinement barrier to the release of radioactivity. Gloveboxes are maintained at negative pressure

(-0.3 to -1.5 in. w.g.) to ensure plutonium is confined if a small break in the confinement barrier should occur. Airflow is through a nontestable HEPA filter at the glovebox exit, and at least two testable HEPA filter stages, in series, in the E-4 offgas treatment system. Pressure drop across filters is indicated by Magnahelic gauges and is periodically monitored to detect filter plugging.

The process cell tanks are shielded by a 24-in. concrete wall. Individual gloveboxes, such as at the maintenance cell, have provisions to add lead glass shielding as necessary. Leaded gloves are used in most positions to reduce gamma ray exposure to the hands and arms. Surveys are taken frequently to assess radiation levels at workstations.

The CAMs are provided to monitor workplace breathing air in occupied areas where a person without respiratory protection is likely to be exposed to a concentration of radioactive materials in the air exceeding 1 DAC over a prolonged period of time or where there is a need to alert potentially exposed workers to significant increases in the level of airborne radioactive material levels, which could result in 40 DAC-hours in a typical work shift. Portable CAMs are used when performing nonroutine maintenance activities. Air-purifying respirators and fresh-air-supplied masks are available, if necessary.

CAMs and their associated alarm function also mitigate some potential facility worker hazards at PFP. In general, during stabilization activities, the primary boundary to release of radionuclides to occupied rooms are gloveboxes, process systems, or sealed plutonium storage containers. The primary boundaries to plutonium release inside PFP can fail through several potential mechanisms, such as improper maintenance, equipment degradation, or abnormal glovebox pressurizing events. In many cases, there is no obvious indication that a plutonium release has occurred. The CAMs serve to validate the satisfactory performance of the barriers to plutonium release. If one of these primary barriers fail and plutonium is released into PFP, then alarms will be actuated when the alarm setpoint is reached. Upon actuation of the alarm, facility workers are trained to promptly evacuate the affected air space. These actions in combination serve to reduce the potential plutonium inhalation dose received by the affected facility workers. The public and onsite workers are not significantly affected by these potential plutonium releases inside PFP because the exhaust air flow is filtered by the applicable exhaust ventilation system prior to release outside of PFP.

6.6.1.3.3 Chemical Safety. The cold chemical preparation area in the 236-Z Building (room 40 on the fourth floor) is no longer used to support PRF process systems. The small quantities of chemicals remaining in the PRF tanks and process lines will be managed and dispositioned in accordance with HNF-2977, *Plutonium Reclamation Facility (PRF, Building 236-Z) Layup Plan* (BWHC 1998b).

The excess chemicals (a few hundred pounds) consist primarily of B-acid, sodium nitrate, sodium carbonate, antifoam, and TBP which are currently stored at the PRF. These chemicals have no near-term use in the PRF and present a potential chemical release hazard to facility workers should a tank or storage container leak. Certain chemicals may pose a reactivity or flammability hazard. Therefore, the PFP facility has performed a hazard assessment (BWHC

1997b) relative to chemicals within the plant and identified those items requiring mitigation. Accordingly, plans have been developed to track, monitor and remediate the hazards identified in the assessment.

6.6.2 232-Z Waste Incinerator Facility

The 232-Z Waste Incinerator Facility housed an enclosed system of gloveboxes and hoods that were used for sorting solid waste contaminated with plutonium, leaching noncombustible wastes, chopping waste for size reduction, and incinerating combustible wastes. Solutions and ash from this facility were processed for plutonium recovery in the PRF. The 232-Z Building has undergone bulk plutonium removal from the gloveboxes, hoods, and associated ventilation exhaust piping, in preparation for D&D activities. The fire alarm service in the 232-Z Building remains in operation to alert the necessary personnel, although the automatic sprinklers have been temporarily deactivated.

6.6.3 241-Z Liquid Waste Treatment Facility

The 241-Z Complex (or Liquid Waste Treatment Facility) consists of five structures: the 241-Z Building, 241-ZA Sampling Building, 241-ZB Caustic Tank (now inactive and scheduled for removal), 241-Z-RB Retention Basin (scheduled for removal), and 241-ZG Changeroom. This complex adjusts and temporarily stores PFP radioactive liquid waste (RLW) before transfer to the 244-TX Receiver Facility. The operation of the 241-Z Complex is described in Chapter 7.0.

6.6.4 242-Z Waste Treatment Facility

The 242-Z Waste Treatment Facility was used to treat PRF waste and to extract americium from the waste. On August 30, 1976, an incident occurred that involved the explosion of an ion-exchange column containing approximately 100 g of ^{241}Am. The routine use of the facility was discontinued following this incident and minimal cleanup efforts have been undertaken. In 1977, a testable HEPA filter was added to the E-3 exhaust system for the building. In 1981, the glovebox ports were sealed, nonessential services were disconnected, and contaminated surfaces were treated with a strippable coating. Entry into this building is nonroutine and strictly controlled.

6.6.5 243-Z Complex Low-Level Waste Treatment Facility

The 243-Z Complex (or LLWTF) is a low hazard process facility. It provides the best available technology for treatment of low-level contamination, both chemical and radiological, for the PFP waste that once was disposed to the 216-Z-20 crib. The facility is comprised of two buildings: the 243-ZA Building sump (containing the influent sump tank), and the 243-Z Building (containing the remainder of the equipment for the facility). The functions of the 243-Z Complex are controlled by the MICON™ operator station (see Chapter 5.0, Section 5.4.2, for more details of the MICON™ System). The operation of the 243-Z Complex is described in Chapter 7.0.

6.7 FACILITY CLEANOUT ACTIVITIES

Since startup, the PFP complex has played a historic role in ensuring that defense production needs were achieved. The history of the PFP complex has been one of continuous upgrading, renovation, replacement, and expansion of functions, processes, and buildings, to meet the changing plutonium-production and recycle requirements. The evolving regulations for nuclear operations and the improving technology for plutonium material processing, have been and will continue to be the cause for renovation. As a result, the PFP facilities occasionally have been shut down and placed in inactive status, awaiting further action (refer to HNF-PRO-1794, *Facility Shutdown, Standby, and Transfer*). Often they were restarted for a new mission. The consideration of D&D criteria for plant design was introduced to the nuclear industry after most of the PFP buildings were constructed.

Shutdown facilities first undergo terminal cleanout operations (TCO). This is intended to recover any residual plutonium-bearing material in the equipment, gloveboxes, and offgas system, and leave the area in a stable condition requiring minimum surveillance pending D&D or reactivation. The activities associated with TCO must be evaluated to determine if they are covered by the facility authorization basis. If the activities directly or indirectly affect the facility authorization basis, then the activity must be reviewed in accordance with the Unreviewed Safety Question (USQ) process specified by DOE Order 5480.21, *Unreviewed Safety Questions*. Changes to the authorization basis are incorporated into the PFP FSAR during the annual update.

Following TCO, a facility will eventually undergo D&D activities. This involves removal and disposal of the equipment, decontamination of the room or building and removal of the building if it has no alternative use. A preliminary hazard analysis and a safety analysis report, if necessary, is required before initiating D&D activities.

Shutdown facilities remain on ventilation control as long as dispersible radioactive materials are present. The CAMs are also maintained active, or portable units are used if infrequent entry is required. Fire protection and alarm systems are also maintained active. Criticality incident detection is maintained active until fissile material quantities, forms, or configurations ensure criticality prevention. Power to equipment is shut off, but room lighting is maintained.

Surveillance of the shutdown facilities ranges from once per shift to infrequently. The 242-Z facilities have been stabilized and (except for the ventilation system, wet-pipe sprinkler system, and room lighting) isolated. Surveillance of the 242-Z facilities is conducted approximately once every 6 months. Surveillance is conducted in 232-Z on a weekly basis. Surveillance of the remaining facilities within 234-5Z ranges from daily to once per shift.

Surveillance is performed to verify that conditions within the facility have not changed. The condition of gloveboxes and equipment is noted. Particular emphasis is placed on noting if water is present. Ventilation is checked to determine if it is operational. Radiological surveys are conducted at a frequency dependent on the facility. As required in FSP-PFP-5-8,

Volume 1, Section 7.1, "Hazardous Material Management Plan/EPCRA 312 and 313" (see Section 10.4.5) systems or storage locations with "hold-up" or legacy chemicals are inspected to verify system or container integrity.

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Table 6-1. Plutonium Finishing Plant Operating Procedures.

Series	Topic
ZO-060-XXX	Power and Ventilation
ZO-070-XXX	Steam System
ZO-100-XXX	Facility Operations
ZO-101-XXX	241-Z Process
ZO-102-XXX	Effluent Operations
ZO-106-XXX	Low Level Waste Treatment Facility
ZO-120-XXX	Chemical Storage and Make-up
ZO-160-XXX	Stabilization Procedures
ZO-170-XXX	Operations Standards
ZO-180-XXX	Plutonium Recovery Facility Procedures
ZO-188-XXX	Nitrate Load-In/Load-Out
ZO-190-XXX	Vertical Calciner Operations
ZO-200-XXX	Product Handling
ZO-300-XXX	Special Nuclear Materials
ZAR-XXX	Alarm Response

Table 6-2. Receipt of Nuclear Material Requirements.

A. Nuclear Information Required for Material Receipt		
1.	Material identification	Unique identity number given to material item.
2.	ANSI Class	The ANSI classification (of unirradiated plutonium-bearing material).
3.	Material description	Chemical and physical makeup of material; presence of any radiolytic gas producing components (water, organics); and LOI. The material description should be as complete and accurate as possible.
4.	Gross weight	Weight of container, seals, and labels plus contents in grams.
5.	Net weight	Weight of contents only, in grams.
6.	Element weights	Actual weight of nuclear materials (plutonium, uranium, americium, etc.) in grams.
7.	Isotopic distribution	Weight percentages of isotopes including date determined.
8.	H/X Ratio	Categorize H/X as $\leq$2, $\leq$10, $\leq$20, or fully moderated ($\leq$20).
9.	Decay heat	Thermal energy released by decay of isotopes expressed in watts.
B. Shipper Information Required for Material Receipt		
1.	Station and location	Name and address of shipping organization.
2.	Shipper's contact (particularly necessary if information in A and B is incomplete)	Name of person knowledgeable about shipment and its contents, with telephone number.
C. Receiving Approvals Required for Material Receipt		
1.	Material scheduled to be shipped to PFP from offsite, shall be reviewed by the SNM Evaluation Team. A shipping, receiving, and storage plan shall be developed and approved prior to receipt of the material at PFP	

Table 6-3. Not Used

Table 6-4. Special Nuclear Material Storage Locations.

234-5Z		2736-Z	2736-ZB
Room 174	Room 192-B	Vault 1	Room 637
Room 175	Room 192-C	Vault 2	Room 638
Room 190	Room 225	Vault 3	Room 641
Vault 192-A	Room 236	Vault 4	Room 642

Table 6-5. Reactive Plutonium-Bearing Material Stabilization Operating Limits.

Variables	Operating Limit	Safety/Operations Considerations
Feed Specifications		
Feeds Permitted	PRF Sludge, Plutonium oxide, Plutonium metal, (oxycarbonate), Incinerator Ash. Exception. Additional feed type items may be processed with the written concurrence of Process Engineering as long as they fall within the defined safety boundary.	Off-gas production
Feed NOT Permitted: PRF Sludges in HA-21I	Plutonium bearing materials with ≥ 10 grams or more of organic in charge.	Excessive butene production
Controller Specifications		
Furnace Ramp Rate Settings	Ramp rates controlled to prevent equipment damage.	Heating coil damage; Efficiency
Heating Cycle PRF Sludge Settings	Minimum Times: 1st Soak - 1.5 hr at 175 °C 2nd Soak - 2 hr at 1000 °C	Excessive butene production; Material stability
High Furnace Temperature Setting	Controlled to prevent equipment damage.	Heating coil damage
Off-Gas System		
Off-Gas Flow Rate for PRF Sludge Material (no flow rate required for other materials)	120 std. ft^3/hr. minimum until furnace temperature reaches 300 °C on ramp-up.	Off-gas accumulation
Purge System		
Purge Flow Rate: Purge flow rate applies only to Glovebox HC-21C	≥ 45 std. ft^3/hr. CO_2 Used only for charges with a potential for containing TBP.	Flammable gas concentration
Fire Safety		
Fire Suppression System Activation Temperature	93 °C	Fire
Combustible Materials	Kept to a minimum.	Fire
Product Specifications		
LOI	Must Meet WHC (1995a) Vault Storage Criteria	Gas generation
Glovebox Specifications		
Plutonium Limit in Glovebox HC-21C	5,000 g	Administrative Control
HA-21I, with operating limit of 8,000 g, as an administrative control		

Table 6-6. Operating Specifications for Plutonium-bearing Solution Stabilization Using the Production VDC

Variable	Specification Limit	Basis
Nitric Acid Concentration	≥ 1.6M(H^+)	Lower acid concentrations may cause Pu polymer formation which may create a criticality concern.
Organic in Feed	< 1%	Organic could provide a fire hazard.
Solids in Feed	< 1% total solids	Solids may plug calciner or other equipment.
Pu Concentration	> 30 g/l; < 450 g/l	Lower limit assures efficient calciner operation; upper limit based on criticality prevention.
Pu Nitrate Feed Rate	< 3.5 l/hr	High flow rate could cause vaporized liquids to overwhelm off-gas system.
Calciner Operating Temperature	> 950 °C	Long term storage criteria requires heating materials to ≥ 950 °C which also reduces absorptivity of the Pu Oxide.
Calciner High Temperature	1050 °C	Lower temperatures assures integrity of calciner materials of construction and increases heater life.
Calciner Vacuum	< 5 inches W.G.	Prevents overpressurization of calciner and potential release of material to glovebox. (instrumentation provides indication only)
Calciner Filter High Differential Pressure	< 100 inches W.G.	Limit pressure drop across filters to prevent calciner pressurization and release of material to glovebox.
Glovebox High Temperature	70 °C	Provides sufficient warning of impending conditions which could activate fire suppression system at 93 °C.
Vacuum Trap Level	< 6 inches	Vacuum trap prevents liquids from entering vacuum system which is not criticality safe.
Glovebox HC-230C-2 Sump Probes	Operational when handling Pu Solutions	Prevent Pu solutions on floor in excess of crit. spec.; prevent overflow through crit. drain to room 230C floor.
PuO_2 Loss-on-Ignition	< 0.5 % wt. LOI at ≥ 950 °C for 2 hours	To meet interim storage criteria to prevent pressurization of stored items.
PuO_2 Density	< 6.2 g/ml	To meet crit. spec. requirements.

Figure 6-1. 2736-Z Support/Storage Complex-Solid Fissile Material Handling Flow Diagram.

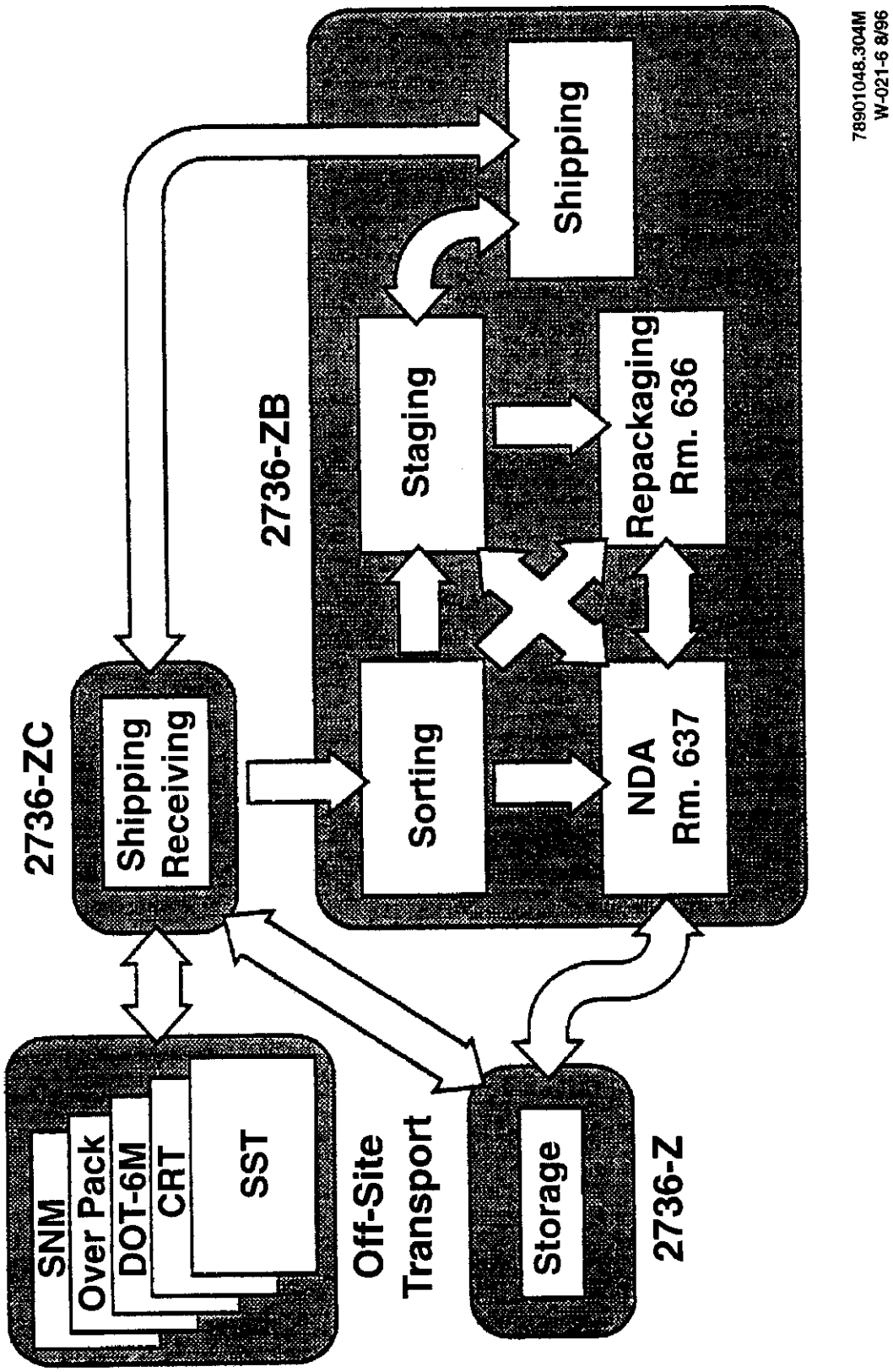


Figure 6-2. Cutaway View of the 2736-ZB Building.

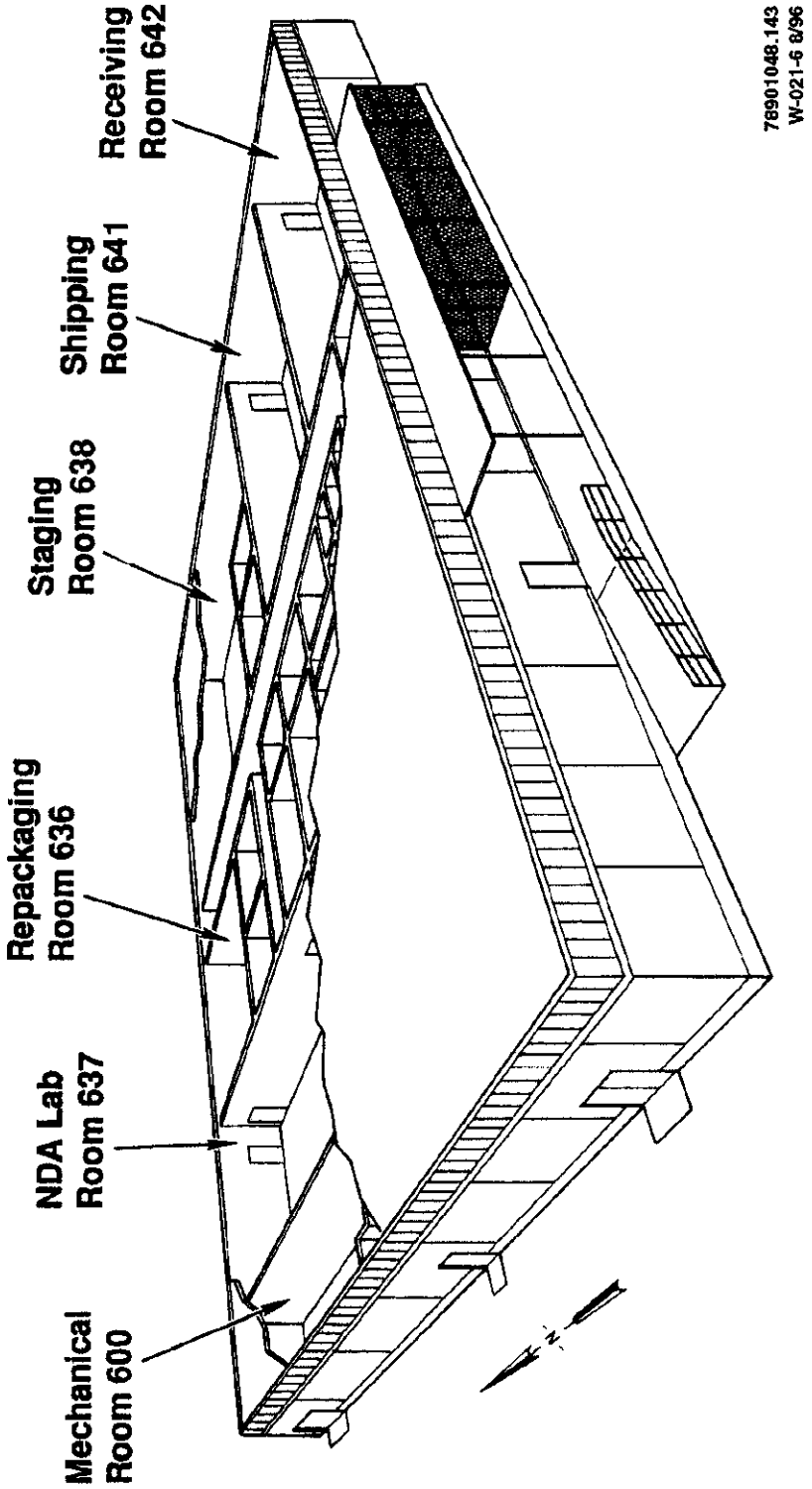


Figure 6-3. Mark IV/V Product Receiver Can Assembly.

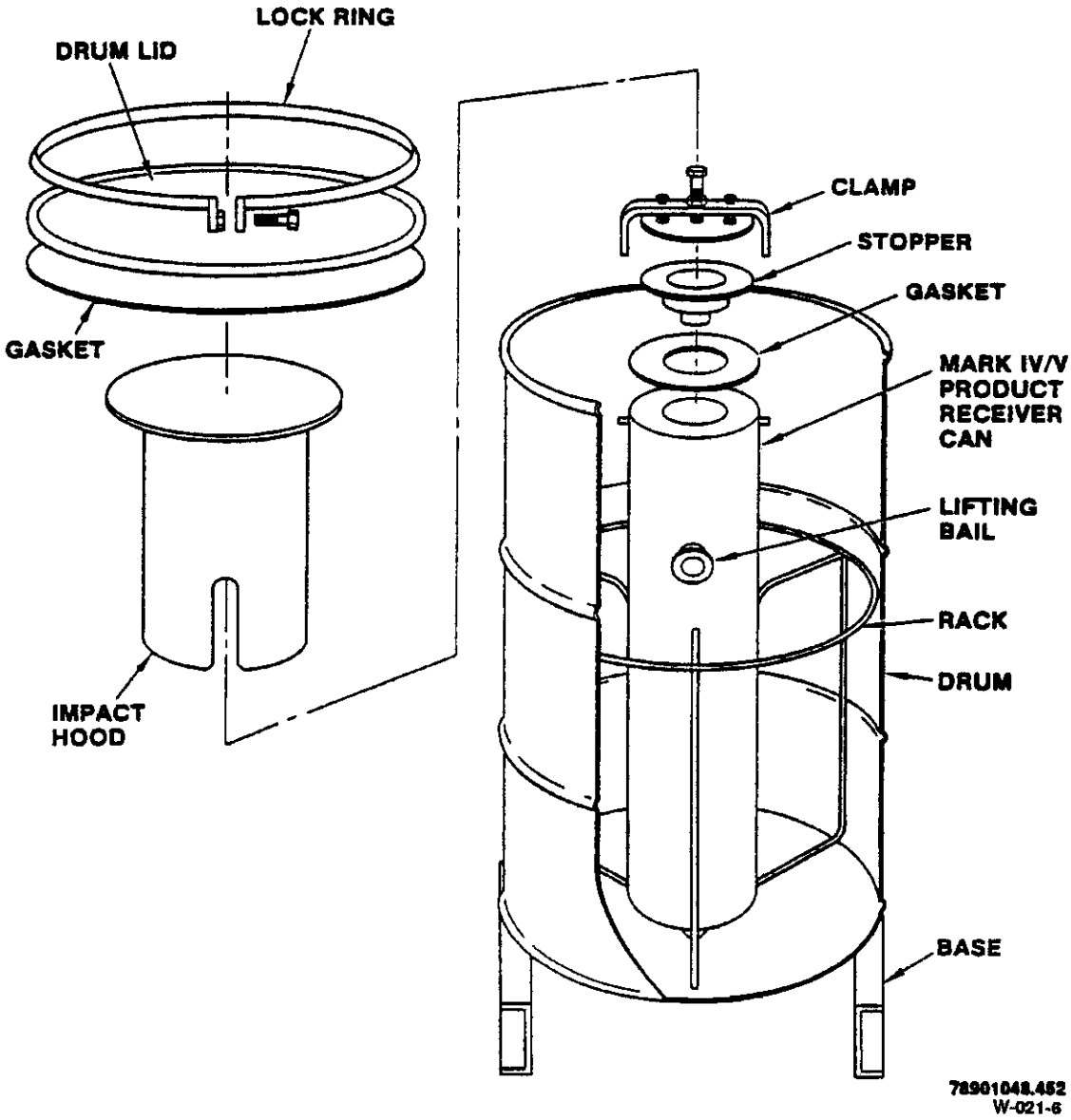


Figure 6-4. Emergency Product Receiver Can Assembly.

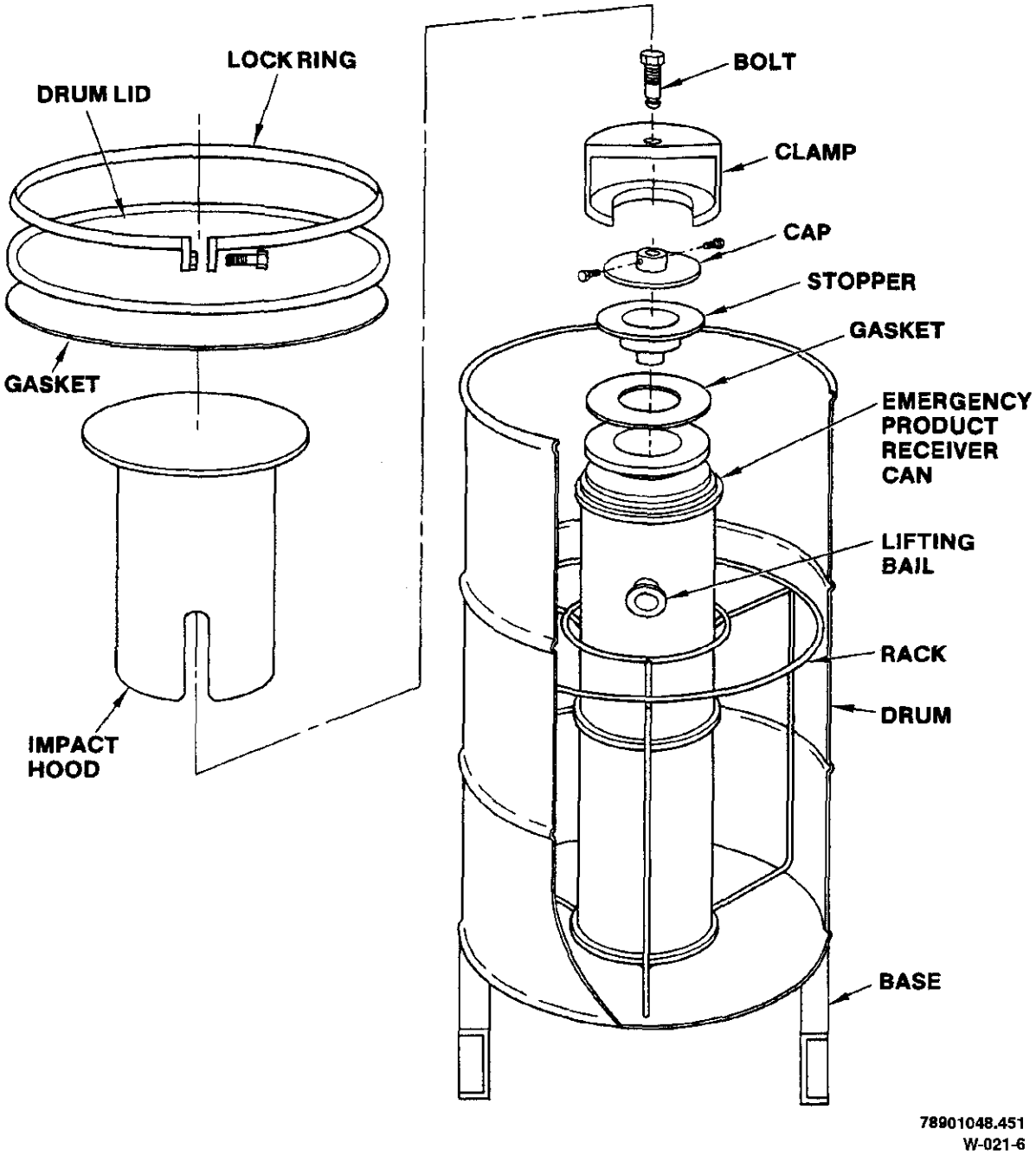


Figure 6-5. Hood HC-227T.

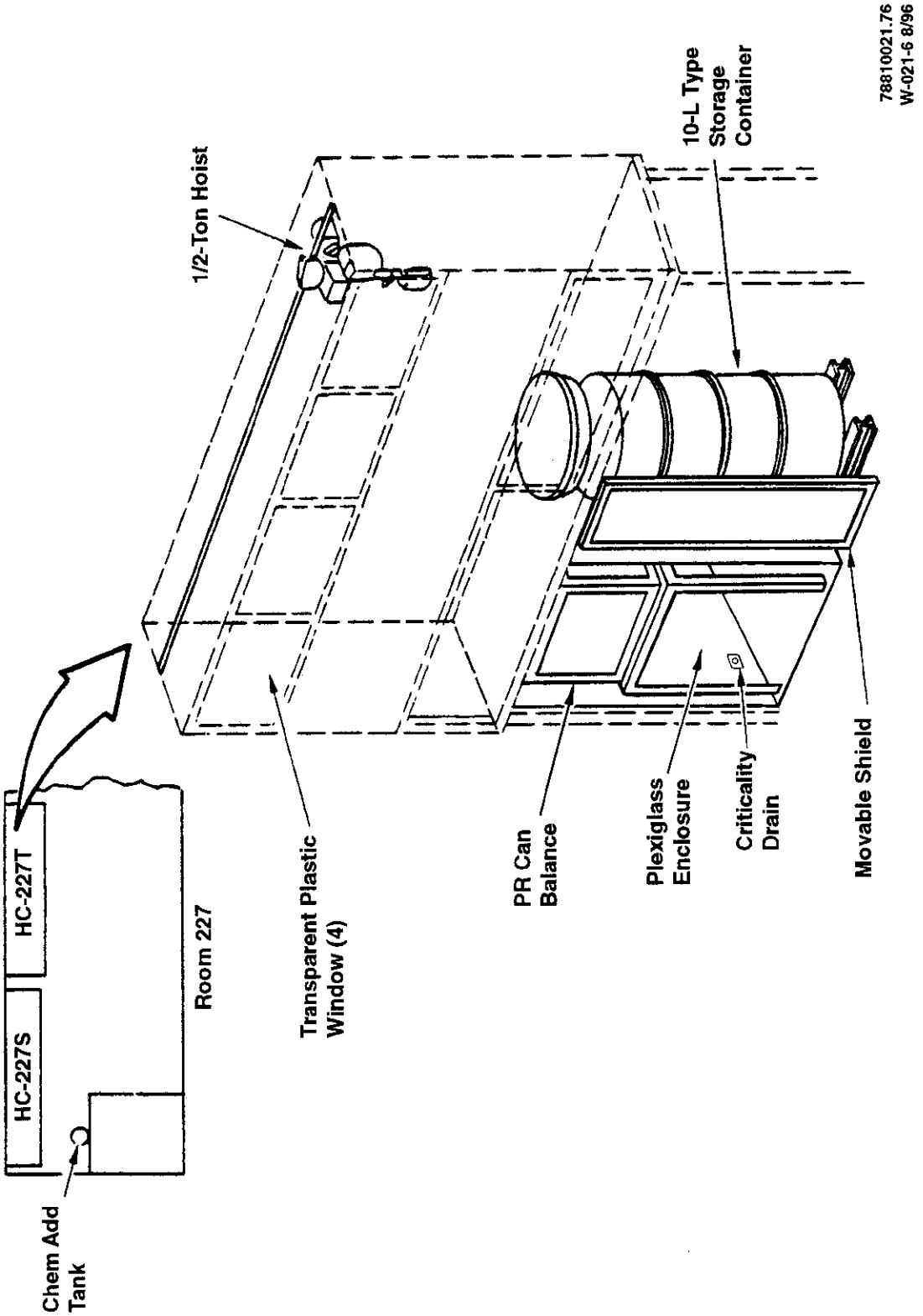


Figure 6-6. Lard Can.

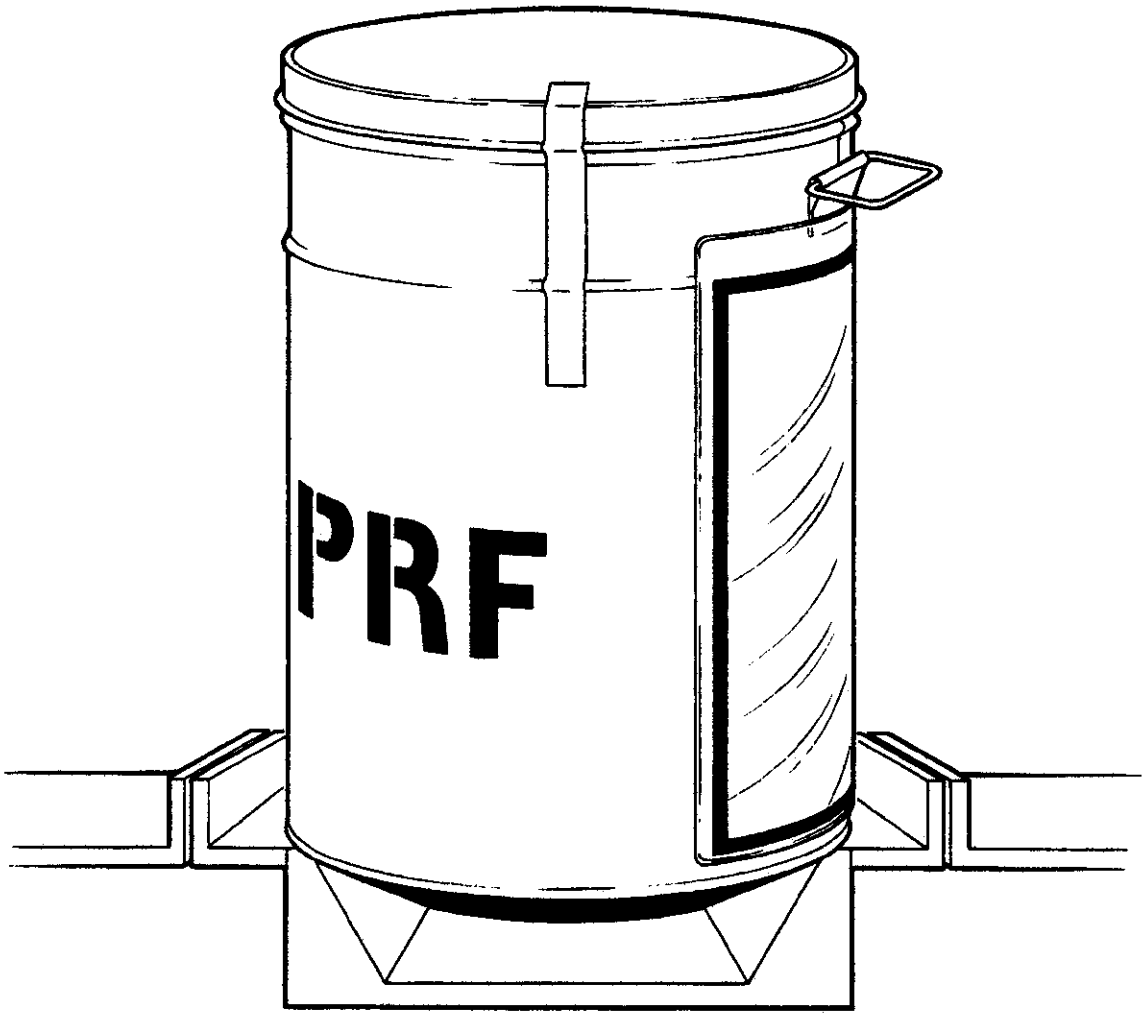
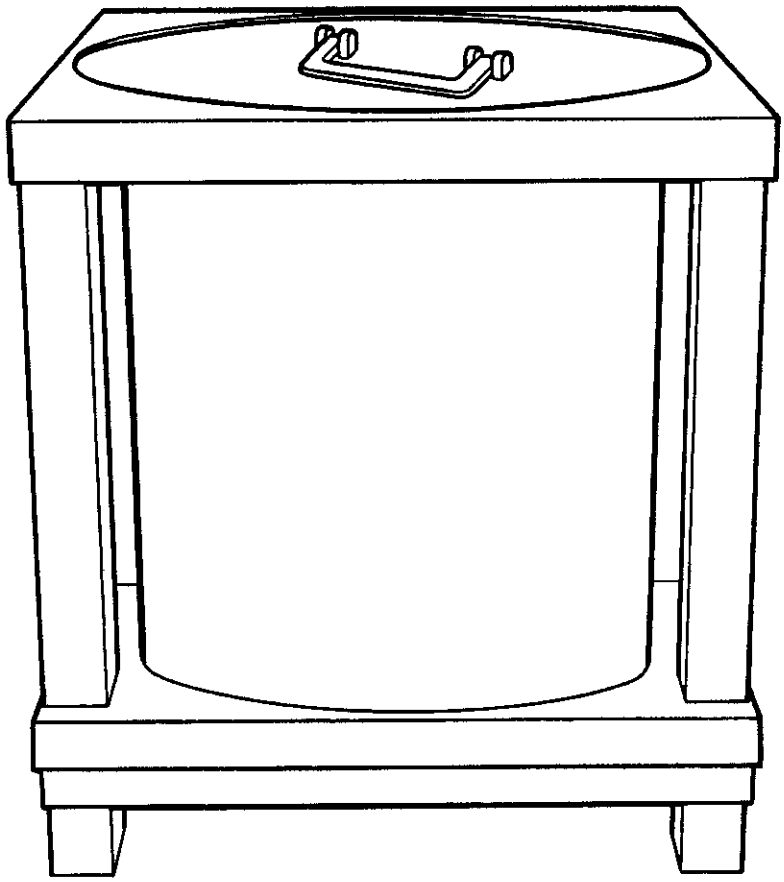


Figure 6-7. "A" Bird Cage.



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Figure 6-8. Radial Reflector Shipping Container.

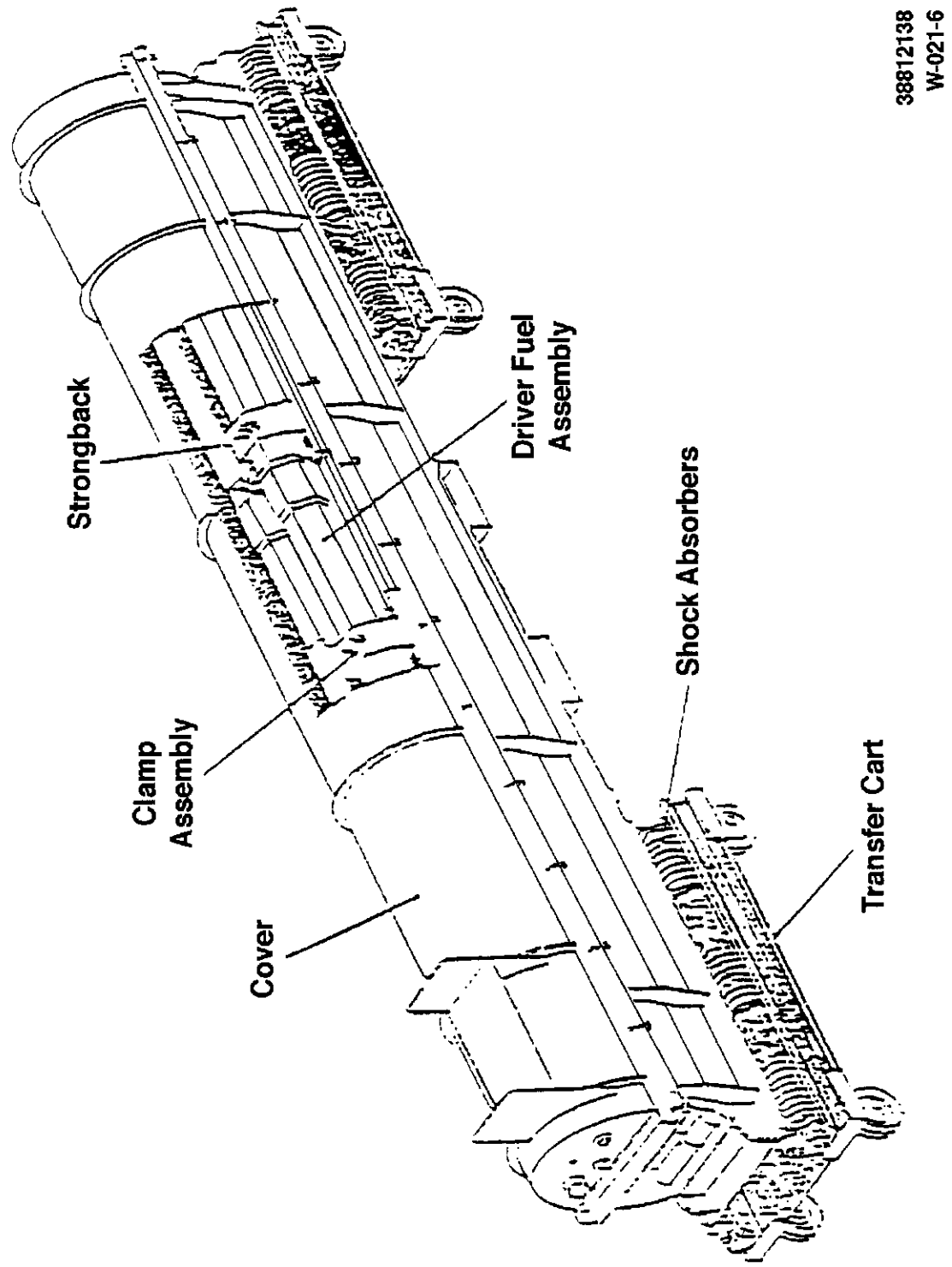


Figure 6-9. Model 60 Shipping Container.

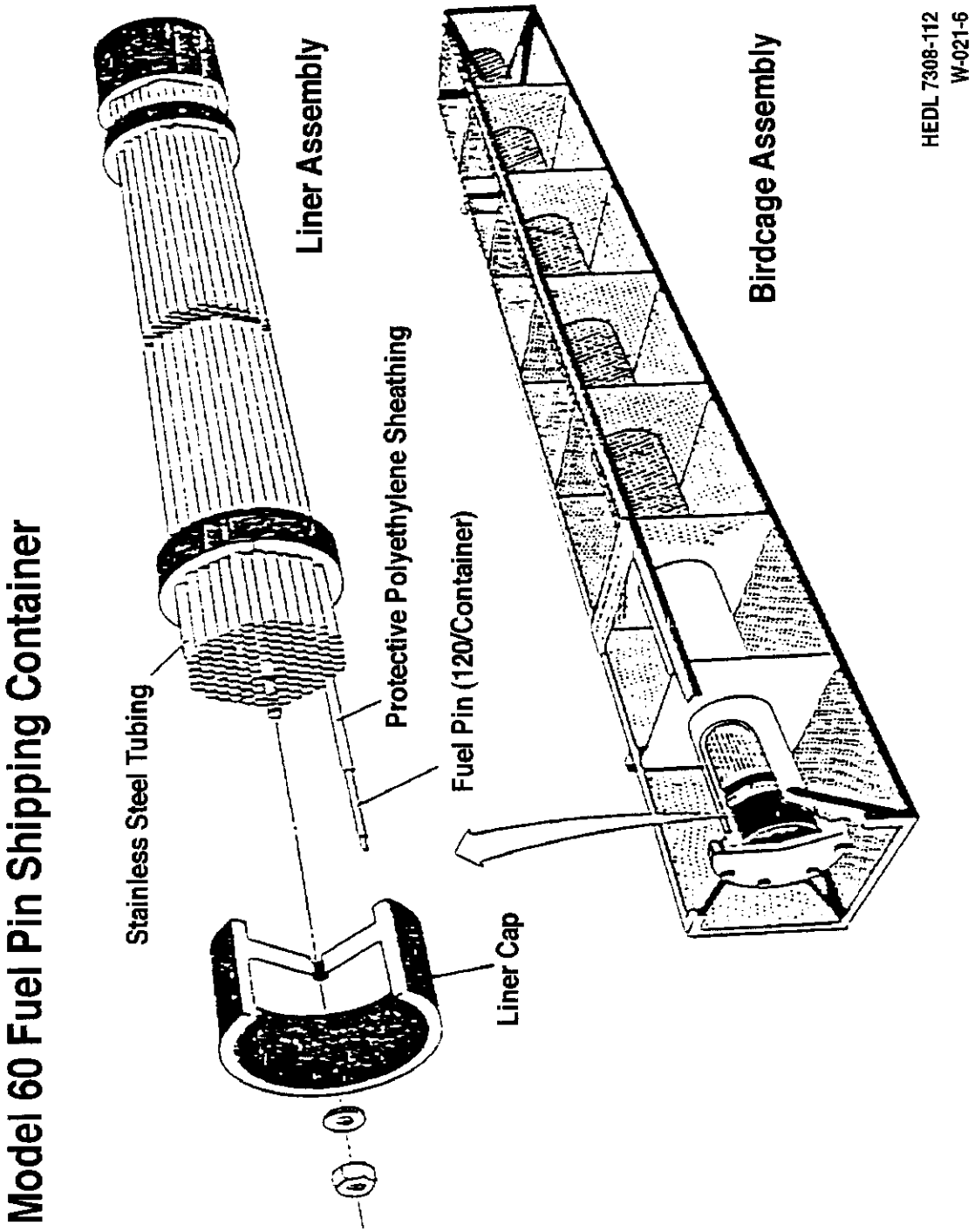


Figure 6-10. Containers for Packaging Plutonium.

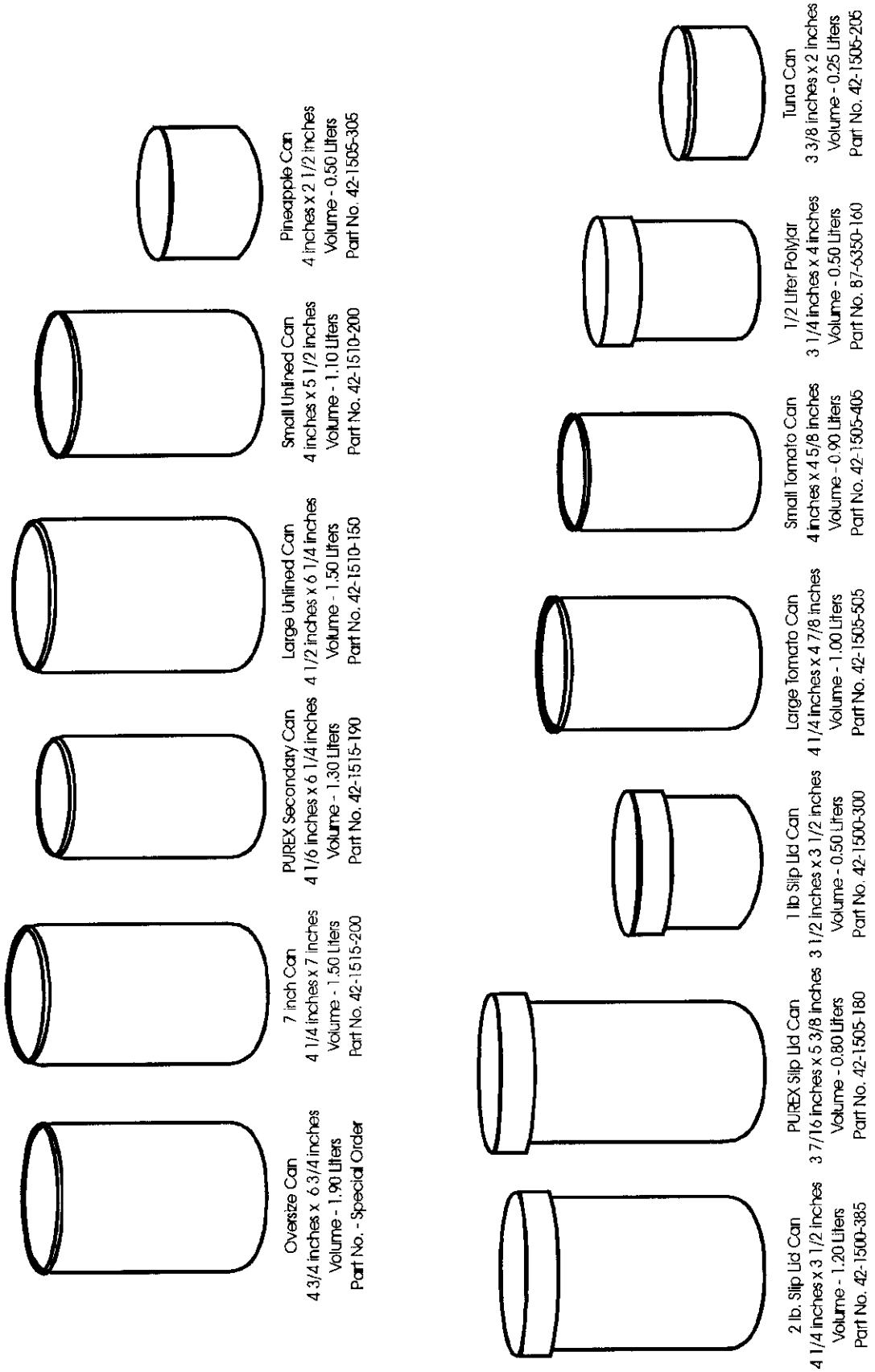


Figure 6-11. U.S. Department of Transportation Shipping Container 6M.

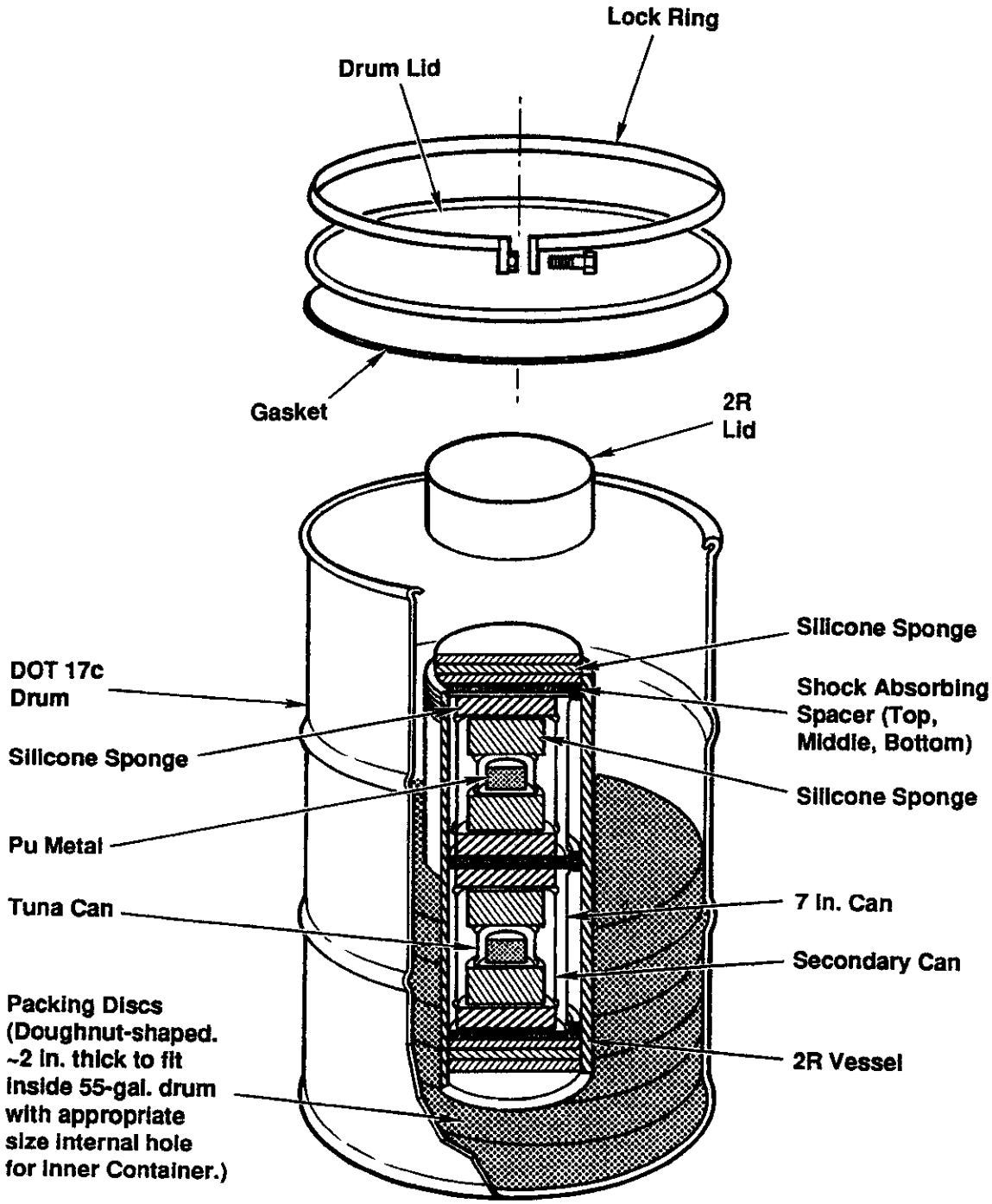
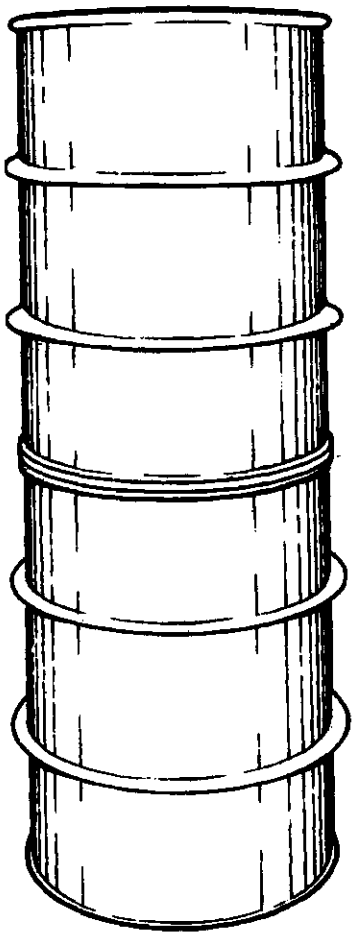


Figure 6-12. Shipping Container FL-10-1.



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Figure 6-13. Not Used

Figure 6-14. Remote Mechanical C Line Ventilation.
(Requires updating re: FB-9A, FB-9B, and FB-9AB)

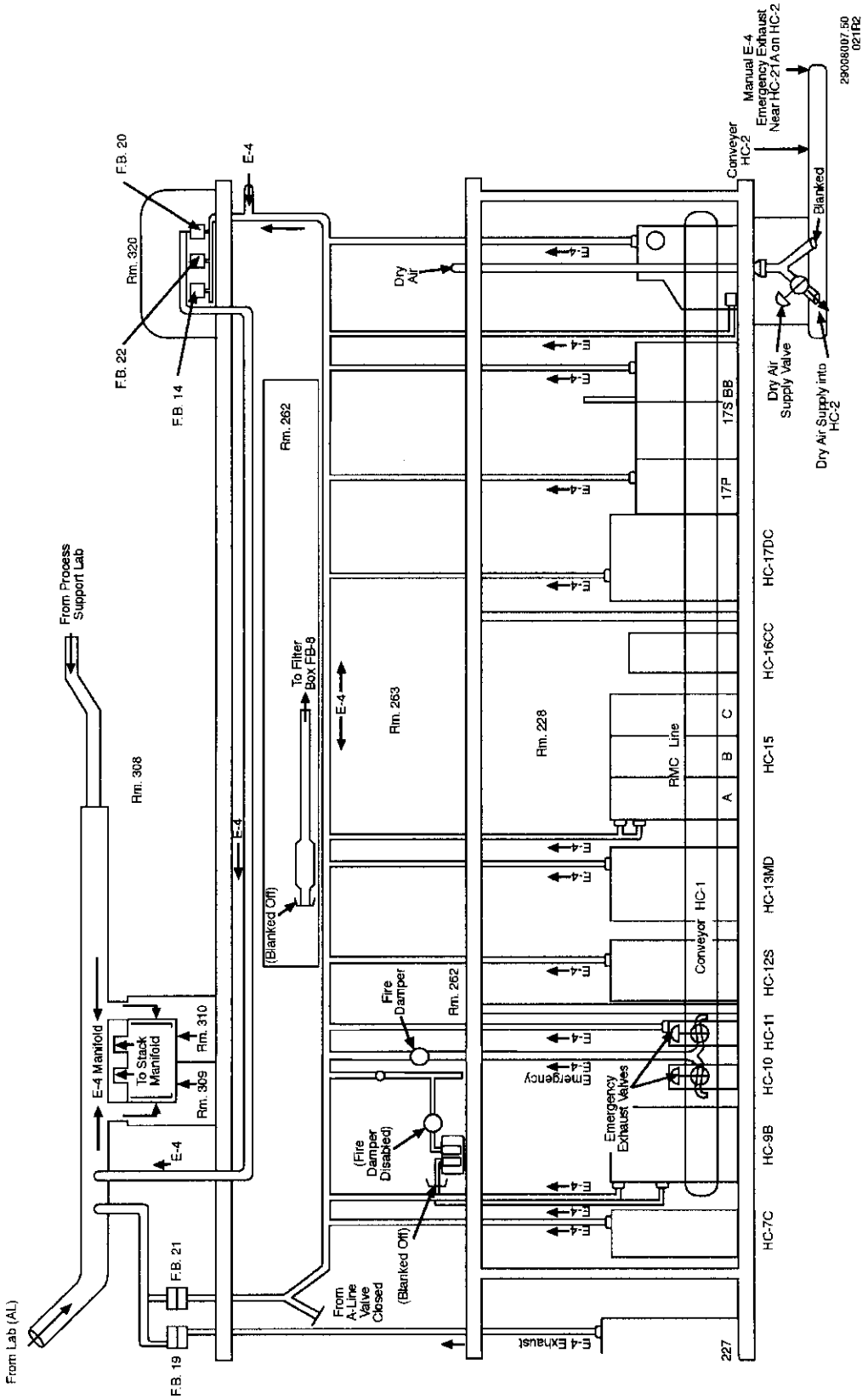


Figure 6-15. Glovebox HC-21A.
(Ref. Dwg. H-2-19669, Sheet 3)

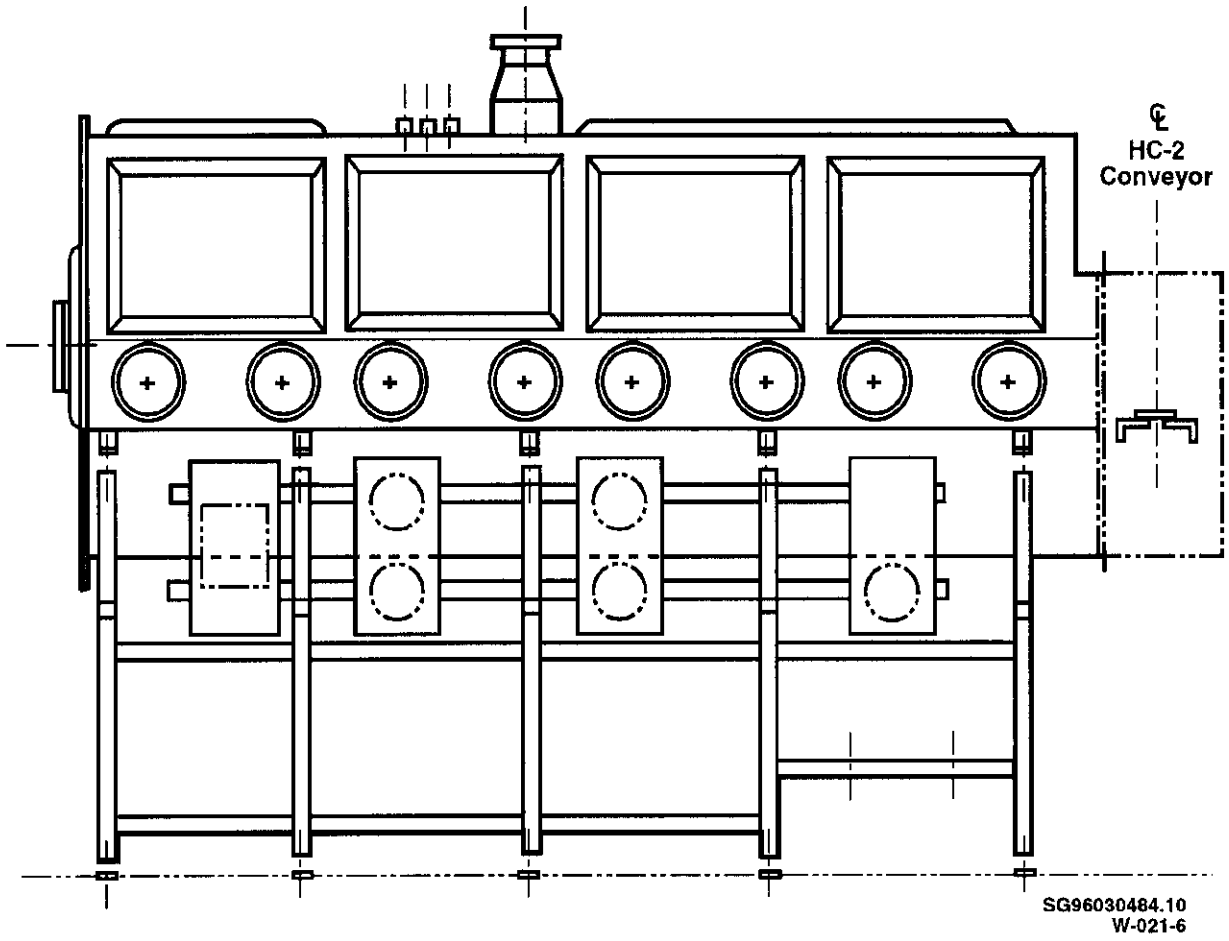
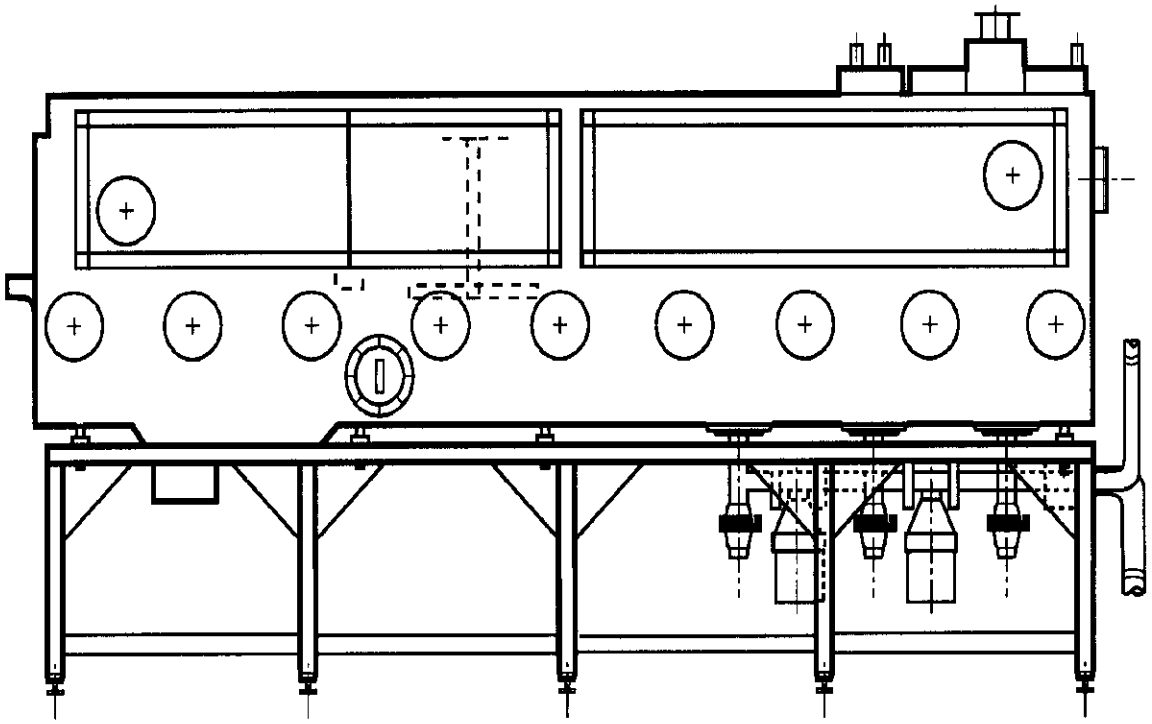


Figure 6-16. Glovebox HA-21I.
(Ref. Dwg. H-2-29109, Sheet 1)



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Figure 6-17. Not Used

Figure 6-18. Remote Mechanical C Line Functional Schematic (Inactive).

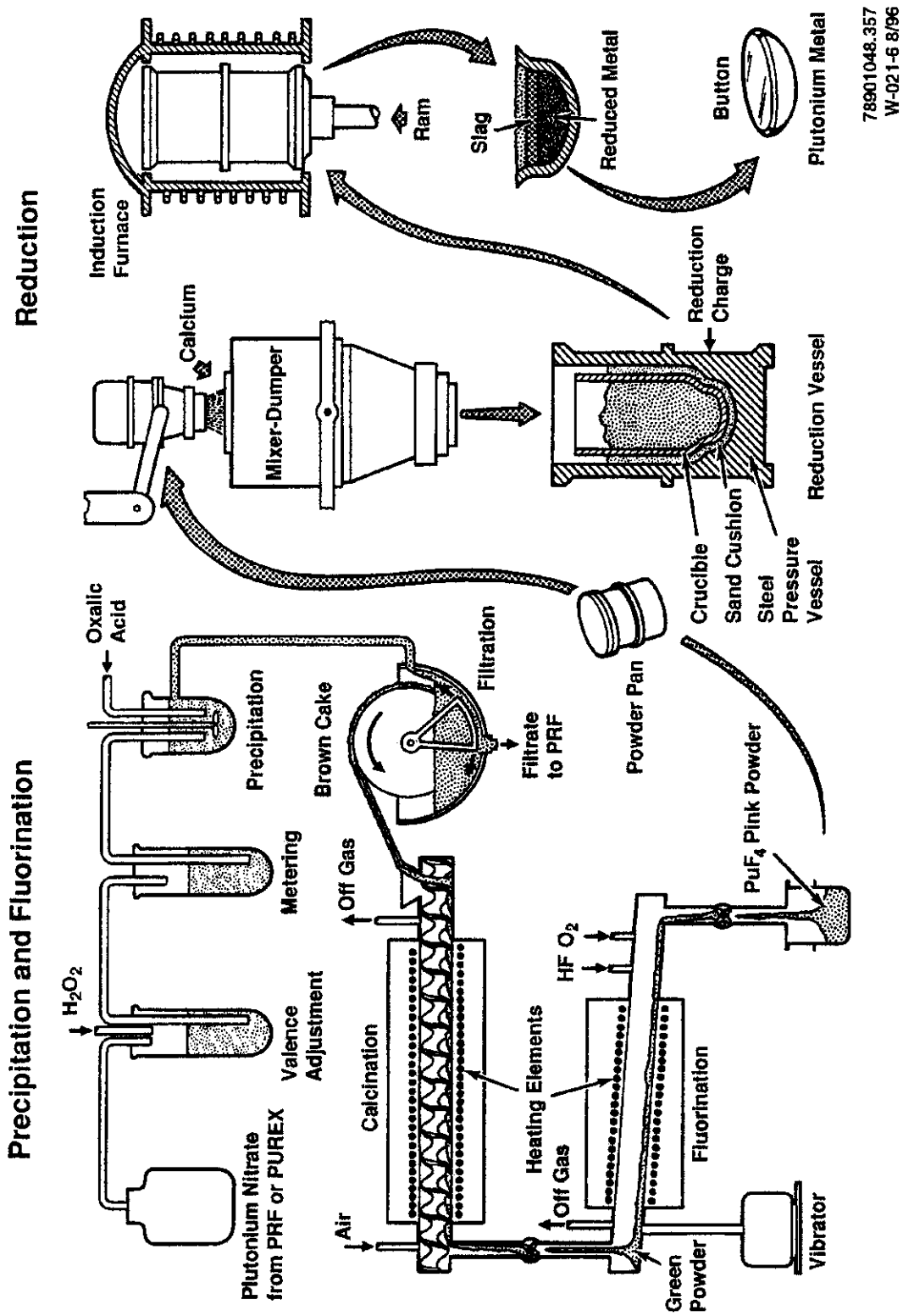


Figure 6-19. Not Used.

Figure 6-20. Not Used.

Figure 6-21. Not Used.

Figure 6-22. Plutonium Reclamation Process (Inactive).

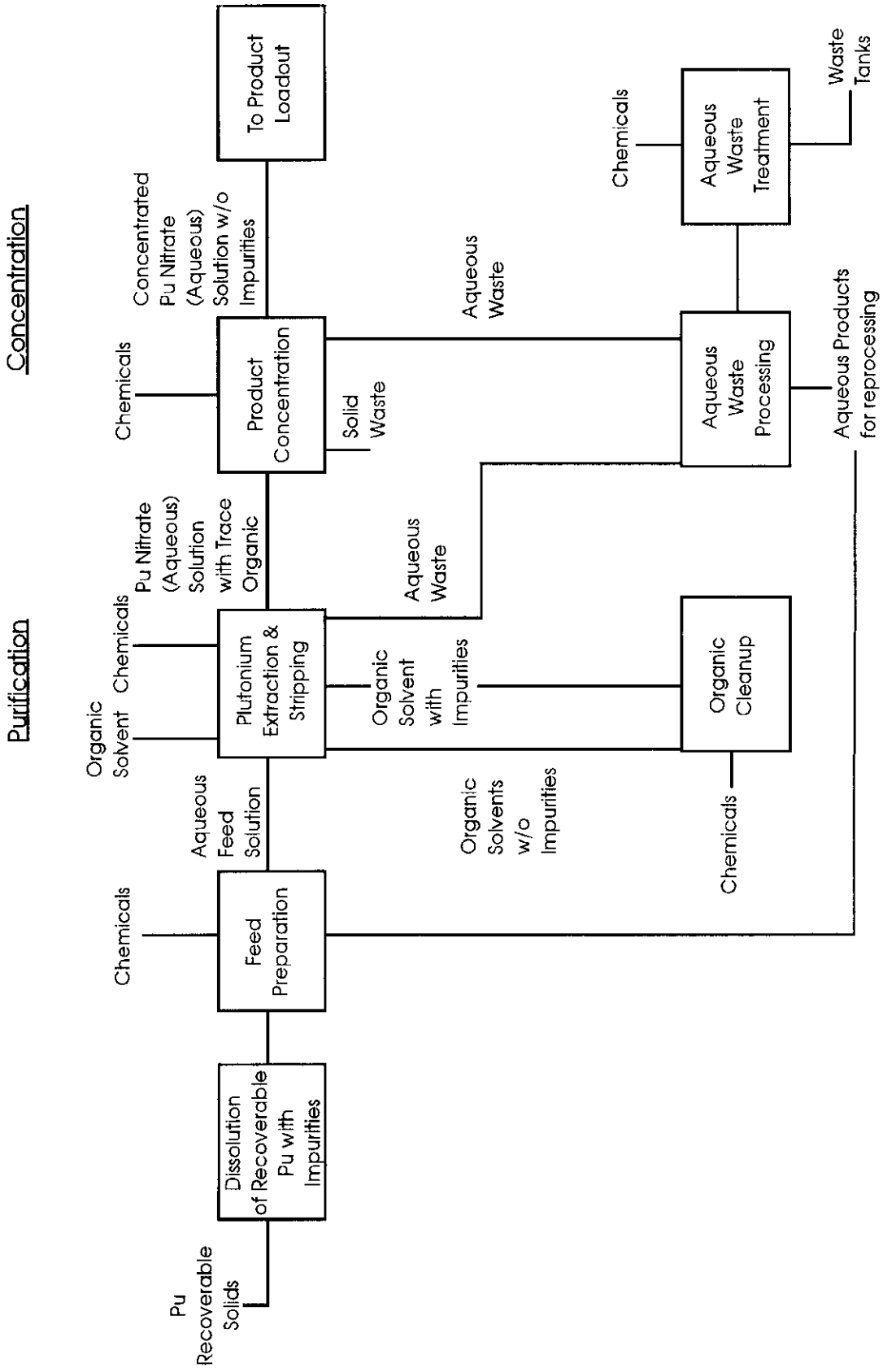


Figure 6-23. Plutonium Reclamation Facility.

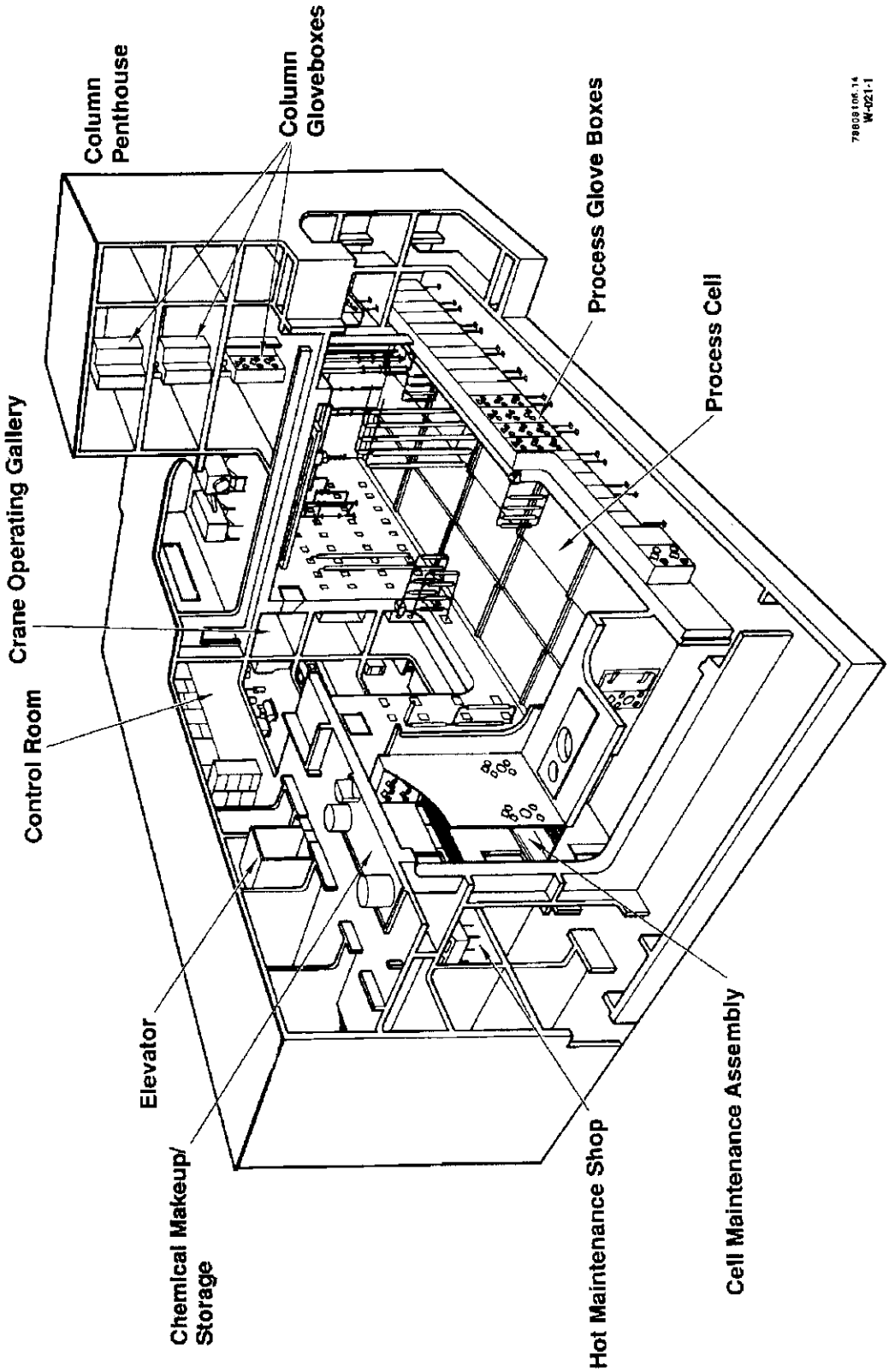


Figure 6-24. Production Vertical Denitration Calciner Process Flowsheet - Glovebox HC-230C-2.

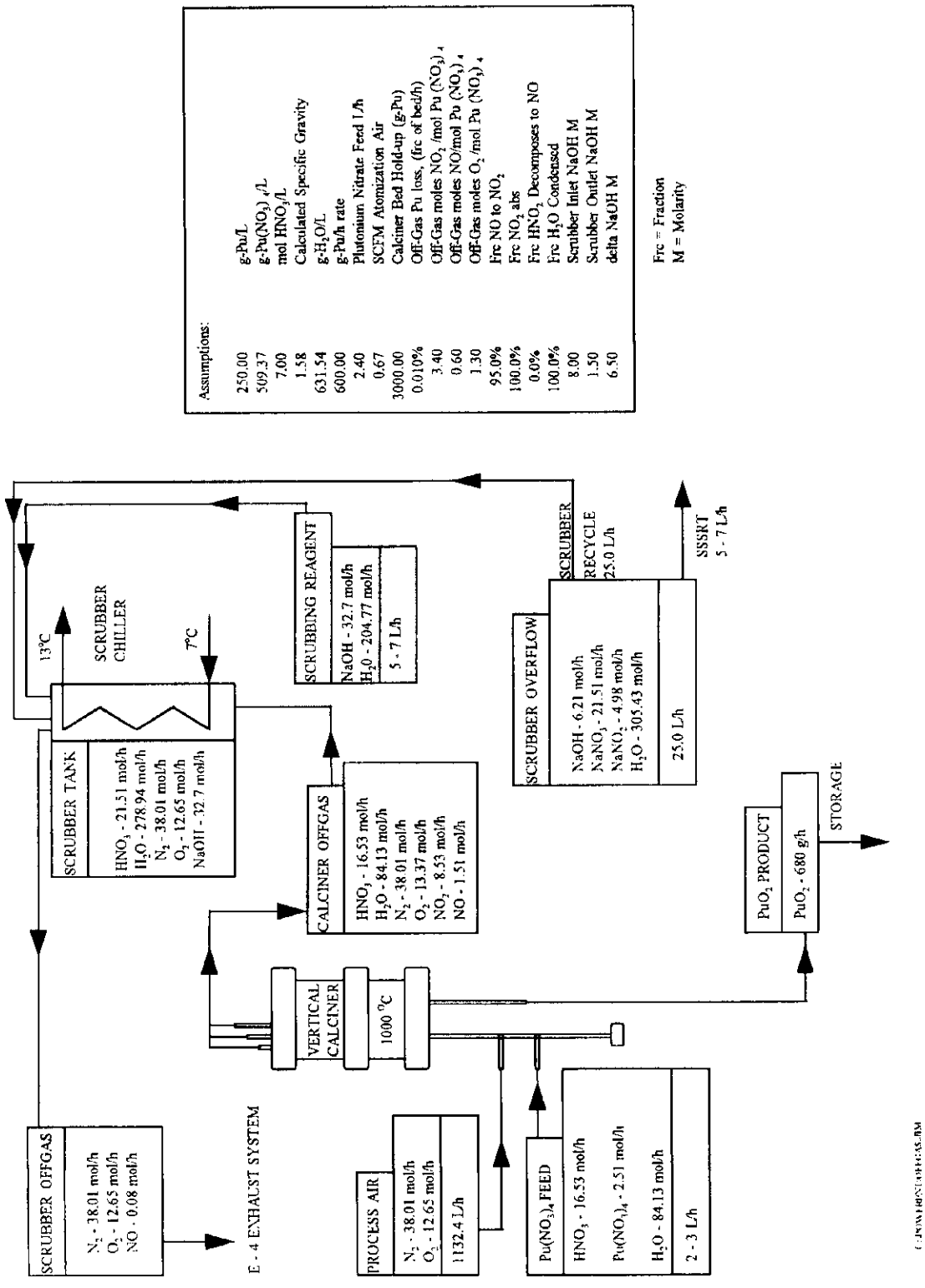


Figure 6-25. Glovebox HC-230C-2 - Production Vertical Denitration Calciner Flow Diagram.

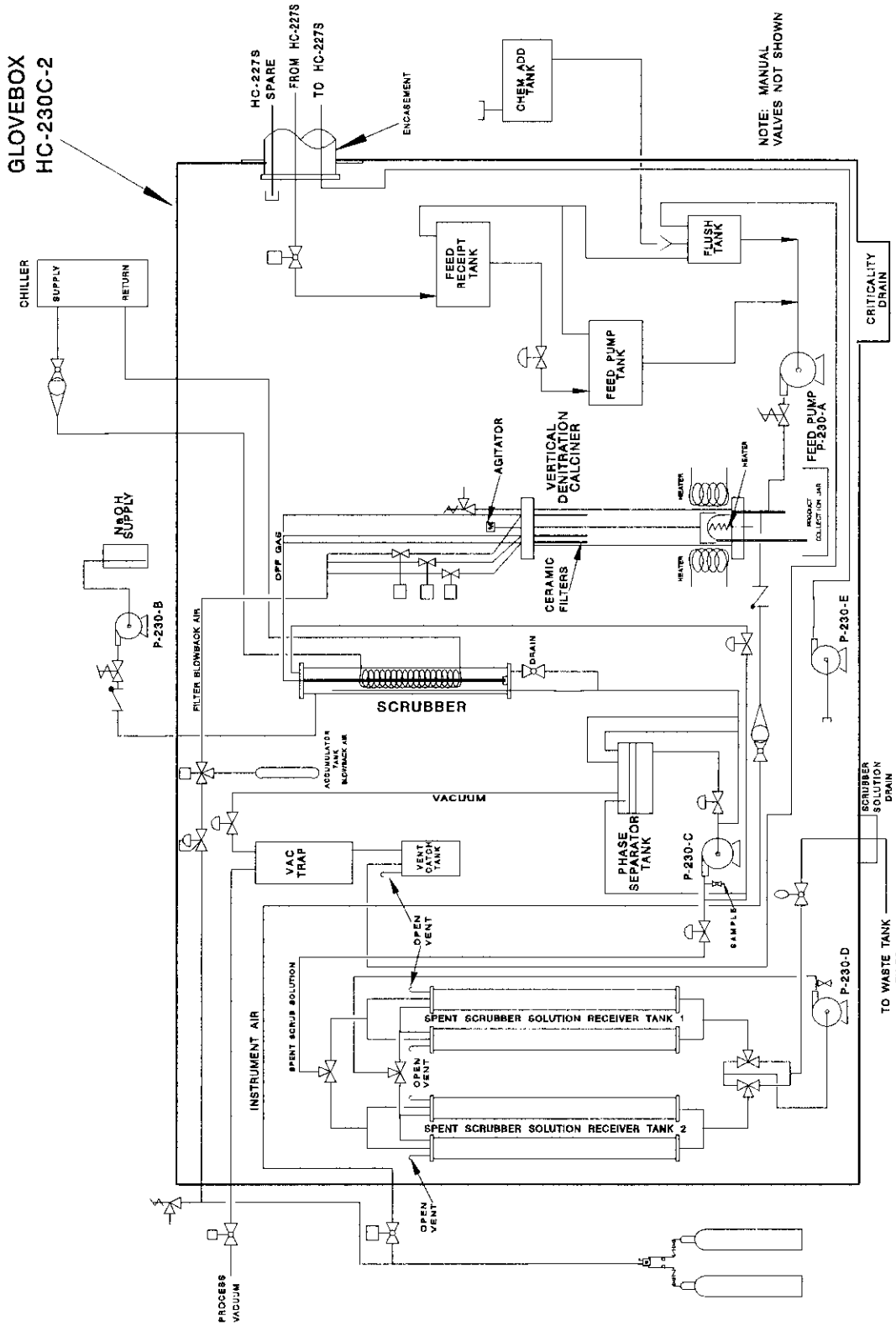


Figure 6-26. Glovebox HC-230C-2.

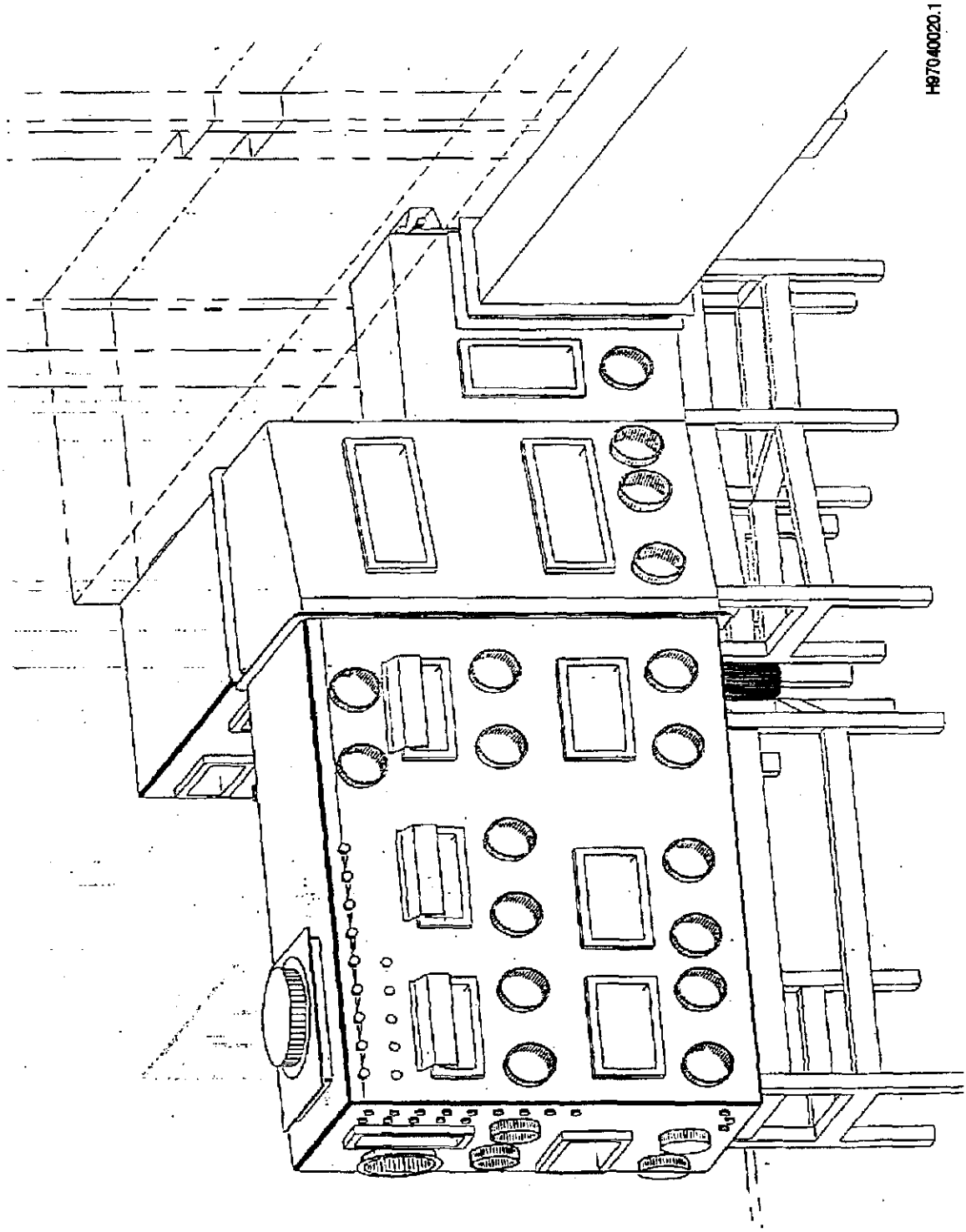


Figure 6-27. Reactive Material Stabilization Glovebox and Plutonium-Bearing Solution Stabilization Using the Production VDC Glovebox Locations.

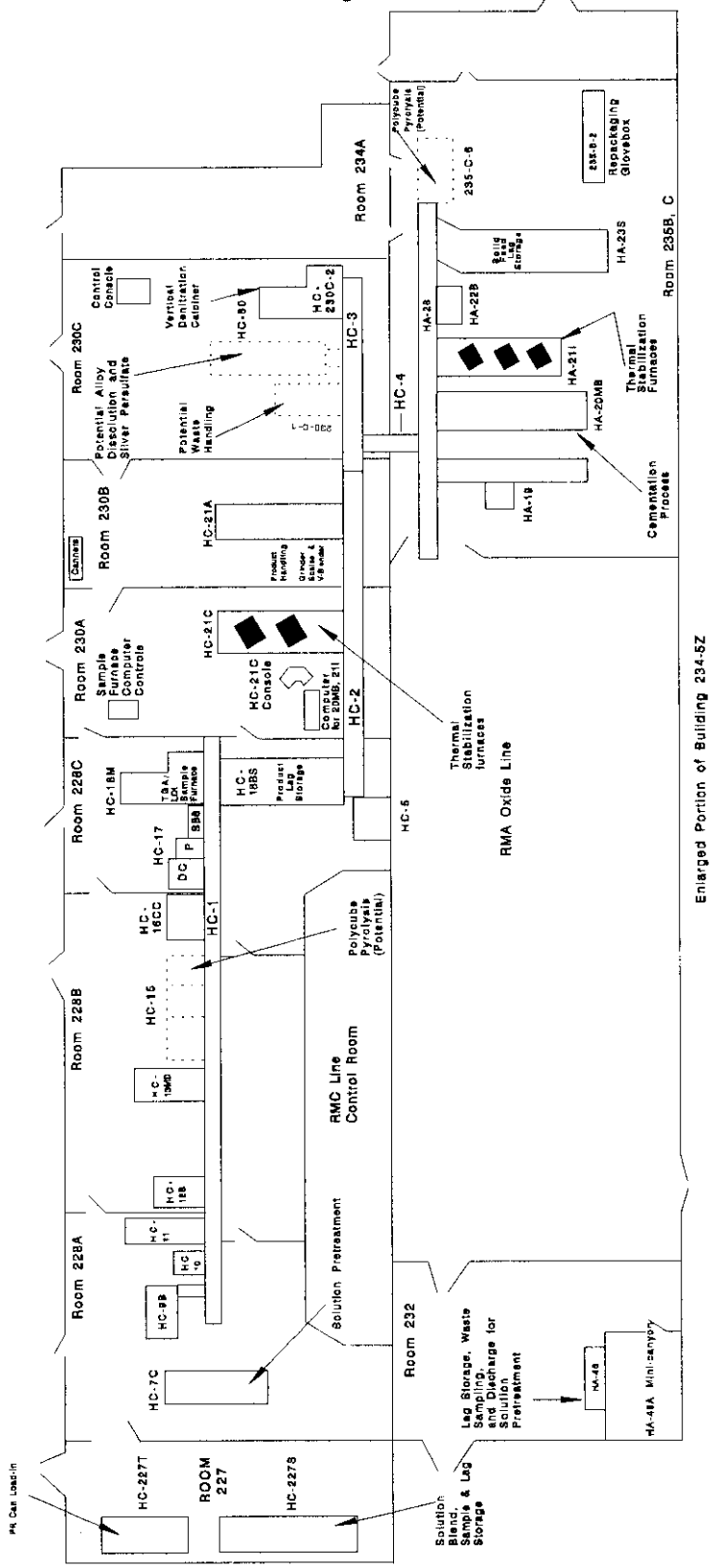
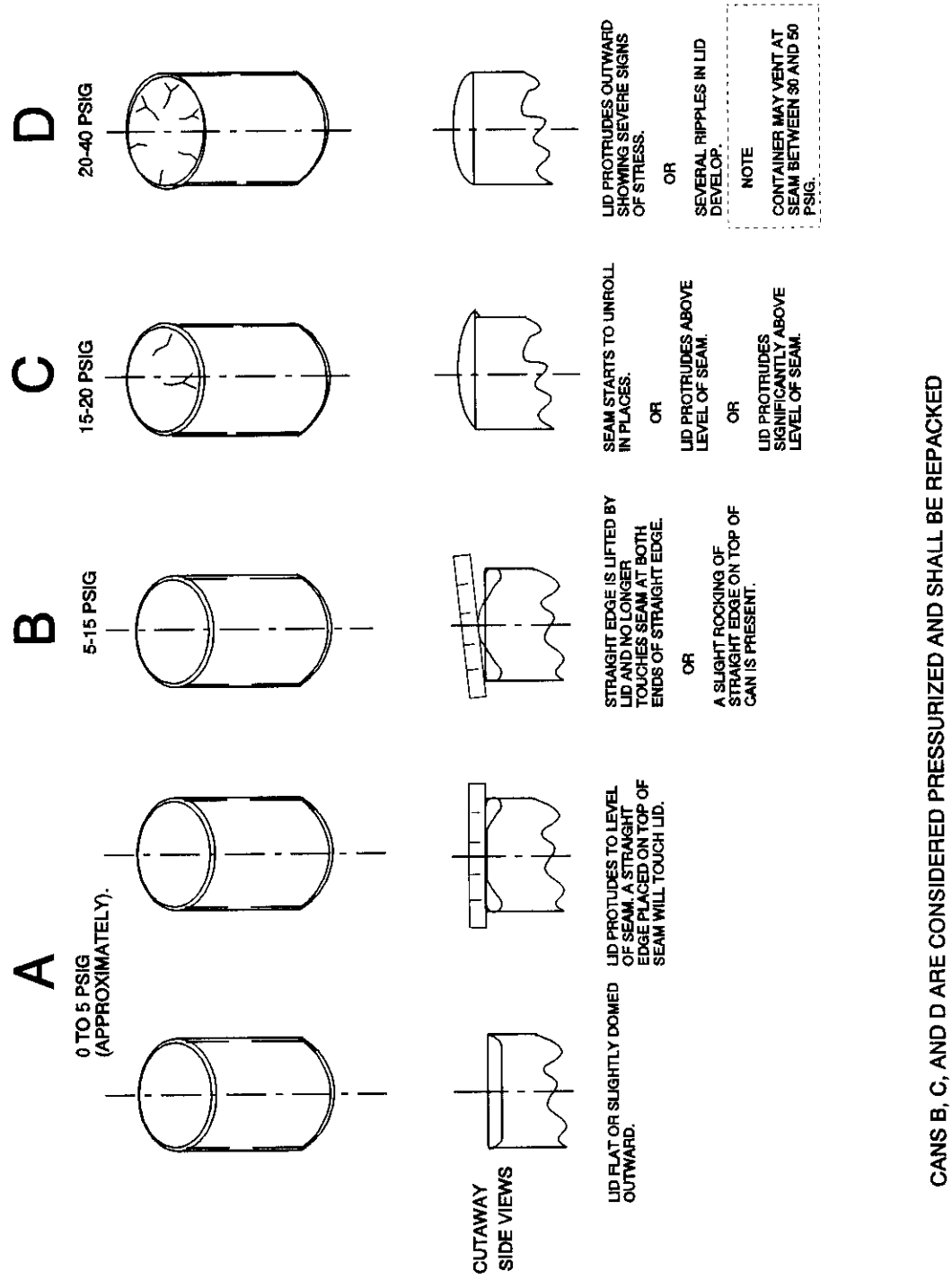


Figure 6-28. Stages of Pressurization of Pu Metal Containers.



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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 7.0

WASTE CONFINEMENT AND MANAGEMENT

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 7.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) incorporates the following:

- Revisions to the liquid waste water stream general description
- Revisions to the radioactive liquid waste treatment description
- Revisions to the solid waste packaging, handling safety and criticality prevention description
- Changes in the handling of TRU HEPAs
- Changes in the drums approved for waste packaging
- Deletion of Table 7-3

Other minor changes include editorial changes and addtional clarifications.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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7.0 WASTE CONFINEMENT AND MANAGEMENT

Chapter 7.0 describes the systems and controls for confining and managing the waste materials generated as a result of the Plutonium Finishing Plant (PFP) operations.

PFP gaseous effluents, liquid wastes, and solid wastes are managed in accordance with procedures HNF-PRO-450 (draft), -451, -455, -456, -462, -2364, and -2595. A technical interpretation of the U.S. Department of Energy (DOE) orders and other pertinent state, federal, and local laws established to protect the environment and public is provided in these procedures. The purpose of the procedures is to establish guidelines that:

- Protect the environment from radioactive materials and other dangerous substances under Hanford jurisdiction
- Protect people from radionuclides and other dangerous substances in the environment
- Provide a tool to be used in conjunction with applicable DOE orders and other pertinent Federal, State, and local laws, rules, and regulations promulgated for Environmental Protection (EP) in accordance with the policy defined in *Management Plans* HNF-MP-001 and 003.

In June 1987, the DOE released a directive to manage radioactive hazardous constituents in accordance with the *Resource Conservation and Recovery Act (RCRA) of 1976* and subsequent *Hazardous and Solid Waste Amendments of 1984*. In July 1987, Westinghouse Hanford Company (WHC) responded with an aggressive program that called for upgraded facilities, laboratories, administrative systems, and enhanced training. Since then, PFP management has implemented upgrade programs designed to achieve compliance with applicable regulations including the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1994). These effluent monitoring, treatment, and disposal upgrade programs are essentially complete and the PFP is in compliance with federal, state, and local regulations governing liquid effluent discharges into the soil column.

The waste management criteria; waste characterization (form, quantity, and location); waste equipment and description; waste monitoring, treatment, and/or processing; and waste packaging, storage and/or disposal for airborne/gaseous effluents, liquid waste, and solid waste are discussed below.

7.1 AIRBORNE EFFLUENTS

7.1.1 Criteria for Control of Airborne Effluents

The requirements for the control of airborne effluents at the PFP are contained in Hanford Site procedures HNF-PRO-450, 2364, and 2595. These requirements incorporate applicable federal, state, and local regulations, DOE orders, Hanford Site best management practices, and as low as reasonably

achievable (ALARA) considerations. Airborne effluent requirements are divided into six areas: all emissions sources, non-radioactive sources, radioactive sources, source categories, new construction and modifications, and notifications. Each of these areas is summarized in the following sections.

7.1.1.1 All Emission Source Requirements. Three categories of requirements apply to all emissions sources: general requirements, stack flow measurements and calculations requirements, and effluent monitoring directives (note that not all of the requirements apply to the PFP).

7.1.1.1.1 General Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Operational requirements to control emissions to the environment to ALARA levels
- Use of reasonably available control technology
- Contaminant opacity requirements
- Emission of particulate matter
- Air pollutants from fugitive emissions
- Odor reduction policies and procedures
- Offsite air pollutant impacts
- Emission of gases containing sulfur dioxide
- Prohibition against concealment of air contaminant emissions that would violate federal, state, or local regulation or standard
- Fugitive dust generation due to construction or related activities.

7.1.1.1.2 Stack flow Measurement/Calculation Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Frequency for determination of stack flow rates in accordance with 40 CFR 60, "Standards of Performance for New Stationary Sources"
- Determination of stack flow rates after facility modifications
- Inclusion of stack flow rate measurement requirements in the *Facility Effluent Monitoring Plan for the Plutonium Finishing Plant* (HNF-EP-0476).

7.1.1.1.3 Effluent Monitoring Report Requirements. Hanford Site procedures in Section 7.1.1 include requirements for PFP emissions inventory input to the site effluent monitoring (EM) report.

7.1.1.2 Sources Requirements. Three categories of requirements apply to non-radioactive emissions sources; ventilation requirements, equipment leak

requirements, and waste unit management requirements (note that not all of the requirements apply to the PFP).

7.1.1.2.1 Ventilation Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Regulatory appraisal of process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, and air and steam stripping processes
- Determination, documentation, and reporting of current operating status emission rates for affected vents
- Installation of additional control devices on existing emission units
- Applicability of this requirement to new and active emission units.

7.1.1.2.2 Equipment Leak Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Leak detection and repair program for equipment containing or contacting hazardous waste with organic concentrations of greater than or equal to 10 ppm (by weight)
- Compliance of leak detection monitoring with 40 CFR 265.1063, "Test Methods and Procedures"
- Time requirements for reporting of leaks
- Exclusion of vacuum service equipment
- Determination of equipment as "light liquid service" or "heavy liquid service"
- For all management units containing affected equipment, a log which includes the elements required in 40 CFR 265.1064, "Recordkeeping Requirements," must be kept in the management unit record
- Availability of equipment leak information to the contractor EM for Hanford Site environmental release reports.

7.1.1.2.3 Waste Management Unit Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Assessments of waste management units to determine applicability of requirements in 40 CFR 265 Subpart CC
- Implementation of emission control requirements and placement of implementation schedules in operation records for non-exempt waste management units
- Inspection and monitoring of emission control covers for leaks

- Onsite operations records
- Treatment, storage, and disposal (TSD) facilities reporting requirements.

(Note: The PFP, as an operator of a waste management unit, is regulated under RCRA interim status, 40 CFR 265, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities").

7.1.1.3 Airborne Radioactive Source Requirements. The requirements that the PFP must meet are predicated on the assumption that the PFP has the potential to exceed 0.1 mrem/yr effective dose equivalent (EDE) to an offsite receptor. Five categories of requirements apply to airborne radioactive sources; emission standards for all facilities and operations, continuous monitoring and alarms, emission measurements, emission filtration and treatment, and flow measurement (note that not all of the requirements apply to the PFP).

7.1.1.3.1 Emission Standards Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Offsite dose limits of Hanford Site facilities air emissions of radionuclides
- Applicability of requirements to emissions caused by emergency conditions
- Utilization of "best available radionuclide control technology"
- Hanford contractor Effluent monitoring authority to limit airborne emission concentration(s) of radioactive materials released to the environment.

7.1.1.3.2 Continuous Monitoring, Alarms, and Emission Measurement Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Continuous monitoring requirements for ventilation stacks
- Documentation of the determination of ventilation stack monitoring criteria in a FEMP
- Design of monitoring systems
- Calculation of theoretical annual emissions of radionuclides
- Calibration requirements for monitoring systems
- Monitoring sensitivity of monitoring systems
- Recording of maintenance, calibration, system anomalies, etc., for continuous monitoring instruments
- Downtime of emissions monitoring capabilities.

7.1.1.3.3 Emission Measurements Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Criteria for determination of requirements for record sampling or other emissions measurements
- Development and maintenance of emissions measuring schedules
- Limitations on gross alpha and beta measurement for sample characterizations
- Use of sample characterization for radionuclide-specific analysis
- Adequacy of gross radioactivity measurements for reports
- Emission release point and sampler tagging
- Measurement criteria for emission points and sampling systems.

7.1.1.3.4 Emissions Filtration and Treatment Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Required equipment for emissions filtration and treatment
- Testing and performance criteria for effluent filtration systems.

7.1.1.3.5 Flow Measurement Requirements. Hanford Site procedures in Section 7.1.1 include requirements for the following:

- Circumstances for flow rate determination
- Effluent flow rate measurement methods
- Time periods for flow rate measurement analysis and data logging.

7.1.1.4 Source Categories Requirements. Two categories of requirements apply to all source categories at the PFP; ozone-depleting substance control and phase-out, and asbestos requirements. The remaining requirements for fossil fuel-fired steam generators, gasoline distribution and detergent additives records, and open burning are not applicable to the PFP (note that not all of the requirements apply to the PFP).

7.1.1.4.1 Fossil Fuel-Fired Steam Generators Requirements. The requirements of this section do not apply to the PFP.

7.1.1.4.2 Ozone-Depleting Substances Control and Phase-Out Requirements. *Air Quality Program - Nonradioactive Emissions*, HNF-PRO-2595, includes requirements for the following:

- Servicing, using, record-keeping, and reporting of refrigerants
- Labeling of equipment that contain and/or use refrigerants.

7.1.1.4.3 Asbestos Requirements. *Regulated Substance Management*, HNF-PRO-451, includes requirements for removal and disposal requirements and agreements for asbestos.

7.1.1.4.4 Gasoline Distribution and Detergent Additives Records Requirements. These requirements are not applicable to the PFP because the PFP does not purchase gasoline direct from an offsite seller.

7.1.1.4.5 Open burning Requirements. The requirements of this section does not apply to the PFP because the PFP does not conduct open burning.

7.1.1.5 New Construction or Modifications Requirements. Nine categories of requirements apply to new construction or modifications; notices of construction, prevention of significant deterioration (PSD), toxic air pollutants, limitation of clean air submittals to Ecology, national emissions standards for hazardous air pollutants (NESHAP), registration of radioactive sources, portable/temporary sources of air emissions, portable/temporary radioactive airborne emission units (note that not all of the requirements apply to the PFP).

7.1.1.5.1 Notices of construction (NOC) Requirements. A notice of construction (NOC) is an application to Environmental Protection Agency (EPA), Ecology, and/or Washington State Department of Health (DOH) required to request approval for construction pursuant to the regulations given in *Environmental Notification and Reporting*, HNF-PRO-453. If a new construction or modification would constitute a regulated activity under air regulations, an advance submittal and regulatory approval of an NOC would be required. HNF-PRO-453 includes requirements for the following:

- General situations and methods dealing with the submittals of NOCs and the approval of new construction or modifications pursuant to applicable air regulations
- Application for approval of new construction or modifications that generate a new source of radioactive air emissions or impact sources of radioactive air emissions
- Provision of NOCs for construction, installation, or establishment of new sources or emissions units.

7.1.1.5.2 Prevention of Significant Deterioration (PSD) Requirements. This requirement concerns the determination of need for PSD application because of significantly increased emission of criteria pollutants from a new or modified operation or construction.

7.1.1.5.3 Toxic Air Pollutant Requirements. HNF-PRO-2595 includes requirements for the following:

- Listing of toxic air pollutants (TAPs)
- Design requirements mandated for compliance

- NOC requirements prior to the construction, installation, or establishment of any other new or modified source of toxic air emissions
- Requirements of NOC application analyses for TAPs
- Requirements, applicability, and exemptions of NOCs for TAPs.

7.1.1.5.4 Limitations of Clean Air Submittals to Ecology Requirements. These requirements deal with the number of submittals required for new sources or modifications.

7.1.1.5.5 National Emission Standards for Hazardous Air Pollutants Requirements. These requirements deal with the *Clean Air Act Amendments of 1990*, which require the EPA to promulgate, by the year 2000, an extensive number of regulations establishing maximum achievable control technologies for source categories emitting one or more of the hazardous air pollutants listed under the act. Although many of the regulations will not apply to the PFP, a regulatory analysis would still be warranted for any PFP source category for which future regulations will be promulgated.

7.1.1.5.6 Registration of Nonradioactive Sources Requirements. These requirements apply to all sources listed for registration under the WAC 173-400-100 in air emissions inventories.

7.1.1.5.7 Registration of Radioactive Sources Requirements. These requirements deal with approval of NOCs for new construction or modification of existing sources of emissions.

7.1.1.5.8 Portable/Temporary Sources of Air Emissions Requirements. These requirements deal with NOC requirements for portable emission sources at temporary locations.

7.1.1.5.9 Portable/Temporary Radioactive Airborne Emission Units Requirements. Requirements for portable/temporary radioactive airborne emission units are covered in HNF-PRO-450 (Draft), *Air Quality Program.*

7.1.1.6 Notification Requirements. There are six categories of requirements that deal with notifications for airborne effluent missions:

- Abnormal or Transient Emissions of Radioactive Airborne Material
- Planned Pre-Operational Tests
- Startup, Shutdown, or Emissions Measurement Change
- Reports of Closure
- Excess Nonradioactive Airborne Emissions

- Other Notification Requirements

  - Noncompliance with operational safety requirements (OSRs), operating specification documents, permit or approval requirements, technical specifications, or a requirement with potential to increase airborne emissions

  - Prior notification for operations that could result in exceeding the operating specification documents, permit or approval requirements, or technical specifications with the potential to increase airborne emissions

  - Shutdown of continuous effluent monitoring systems other than for maintenance, or other changes that prevent the accurate measurement of emissions to the environment

  - Failure of a required effluent treatment system test.

Requirements for notifications for these categories are given in HNF-PRO-453, *Environmental Notification and Reporting*, and HNF-PRO-2595.

7.1.2 Radioactive Gaseous Effluents Description and Stream Characterization

Gaseous effluent streams from the PFP that may contain low levels of radioactivity include are shown in Figure 7-1:

- The 291-Z-1 main stack for the 234-5Z, 236-Z, and 242-Z Buildings
- The 296-Z-3 stack for the 241-Z and 241-ZA Buildings and tanks
- The 296-Z-5 stack for the 2736-ZB Building
- The 296-Z-6 stack for the 2736-Z vaults and 2736-ZA Building
- The 296-Z-14 stack for the 232-Z Building
- The 296-Z-15 stack for the 243-Z Building (record sampler only).

The following specific radionuclides have been identified as being released from the 291-Z-1, 296-Z-3, and 296-Z-5 stacks:

- $^{239,240,241}Pu$
- ^{241}Am
- $^{238,242}Pu$ (theoretically may be present but have not been detected).

The releases from the 296-Z-6 stack are extremely low, which makes specific sampling and analysis fruitless. Routine monitoring of this stack is for gross alpha and beta. In case of a high result, a specific isotopic analysis would be performed to characterize the release. The 232-Z Building hoods and gloveboxes (which are exhausted by the 296-Z-14 exhaust system) have been cleaned of bulk radioactive material. Radionuclide emissions from the 296-Z-15 stack have not been detected because of the extremely low radioactive content of the waste water effluent and because of the efficiency of the filtering media used in the facility to extract radioactive particles.

Radionuclide discharge data are reported annually in accordance with HNF-PRO-453. Annual average concentrations are given in Table 7-1.

7.1.2.1 Sampling and Monitoring.

7.1.2.1.1 Record Sampling Capabilities. The record sampler for each of the six main PFP gaseous effluent discharge points; 291-Z-1, 296-Z-3, 296-Z-5, 296-Z-6, 296-Z-14, and 296-Z-15 (the record sampler for the sixth stack, which services the 243-Z Building, is operated on an as-needed basis) is the in-line sampler mounted downstream of the sampler line flow splitter. This sampler draws effluent through a 47-mm particulate filter by means of a vacuum pump. Sampling flow rates are designed to provide near isokinetic sampling at the flow rate of 2.0 ft^3/min (3.0 ft^3/min for the 296-Z-15 stack) through the filter media. Sample filters are collected biweekly and analyzed for gross alpha and gross beta activity. If releases in excess of the applicable limits are suspected, samples can be analyzed on a priority basis in 24 h. The minimum detection level (MDL) of the stack record sampling system is 1.0×10^{-14} μCi/mL for $^{239,240}Pu$, and 5.0×10^{-15} μCi/mL for gross alpha.

HNF-EP-0476 and plant operating procedures provide detailed operational criteria and system operating instructions. Radiological release data from the sample analyses are documented annually in HNF-EP-0527, *Environmental Releases for Calendar Year*. Risk and accident evaluations are provided in Chapter 9.0. Chapter 5.0 provides more detailed descriptions of the various ventilation systems.

Responsibilities, operation, calibrations, surveillance, reports, and record keeping are specified in the appropriate plant procedures.

7.1.2.1.2 Monitoring Capabilities. Each gaseous effluent stream is equipped with a CAM and alarm, such as an Eberline Alpha-5A CAM. The alpha CAM provides a solid-state detector and a single channel pulse height analyzer to measure only alpha particles of a specific energy. Since the principal radionuclide of concern is ^{239}Pu, which has the most restrictive DCG, setting the pulse height window for the principal ^{239}Pu alpha energy (5.16 MeV) is appropriate for the PFP exhaust system monitors. This increases the sensitivity of the CAM as the majority of the effects of the radon-thoron daughters are rejected.

The background subtraction circuit employs a separate adjustable window so that an appropriate energy window may be used to determine the amount of subtraction required. The use of a separate window for subtraction provides a more uniform background subtraction reading during rapid changes in radon concentration. The high energy ^{218}Po (Radium A) peak (6.0 MeV) was chosen for background subtraction to maximize the distance between the two functional windows. The use of an appropriate multiplier allows this peak to be used to compensate for radon and thoron daughter build up on the CAM filter so that the alarm trip point setting is a more realistic initial estimation of the stack discharge (assuming that the detected radionuclide is ^{239}Pu).

The alpha CAM has a failure warning circuit to indicate the absence of a signal from the detector along with the high level alarm. If the signal is lost, the counting light extinguishes and an external failure alarm is actuated. The instrument may be used with an external air pump or with the

facility vacuum system. Air flow is monitored with a rotameter calibrated as part of the CAM instrument and controlled with airflow regulators or needle valves where appropriate.

The alpha CAMs for each stream are normally set to alarm at an integrated activity of 40 CPM. The alarms have remote annunciators at the MICON™ control station (room 714 of the 234-5ZA Building). Although this set point may not account for the differences between individual CAM units, the basic purpose of the set point is to warn PFP Operations and Radiological Control (RC) personnel that the composition of the plant exhaust has changed and that investigative and/or remedial actions need to be initiated. This set point was selected to provide the earliest warning of changing discharge radionuclide concentrations while minimizing the number of potential false alarms as a result of rapidly changing natural radioactivity levels during certain meteorological conditions.

7.1.2.2 Analysis Continuity and Integrity. Sample integrity is maintained through implementation of procedural requirements in *Radioactive Airborne Effluent Sampling*, HNF-PRO-2364. Sample data (time collected, flow rates, collectors, time on, etc.) are noted on the sample container by the collector and/or are logged in the field using a bar-code scanner. These data and the sample are logged in at an assembly point (RC Office, Operations desk, Control Room, etc.) and then transferred to the appropriate analytical facility. At the analytical facility, the samples are logged in by the transporter and the analytical facility representative on an inventory sheet, at which time possession of the samples is transferred to the laboratory. The laboratory then implements its routine chain of custody procedures during sample analysis. The laboratory sends copies of the analytical results to the concerned parties and maintains a copy in its own files. The analytical results are used to evaluate compliance with Hanford Site and DOE requirements and are summarized in monthly, quarterly, or annual reports. The concerned parties (PFP Operations, Environmental Protection, Radiological Control, etc.) perform tracking and trending of the results based on their individual needs and requirements.

7.1.3 Nonradioactive Gaseous Effluents Description and Stream Characterization

While the majority of airborne releases from the PFP are ventilation air, other nonradiological compounds are exhausted via the heating, ventilation, and air-conditioning (HVAC) stacks. Other chemicals which could be exhausted from the stack include small quantities of TBP from the thermal stabilization process, and its degradation products of TBP: MBP, DBP, and butanol. Other gaseous releases from the PFP via the stacks and other pathways result from the routine use products such as aerosol cans, paints and thinners, laboratory chemicals, and products supporting maintenance activities. Releases associated with these products are accepted as common industrial hazards.

The $NaNO_2$ that is added to the 241-Z below-grade waste tanks before the waste is transferred to the 244-TX receiving facility has the potential for generating quantities of NO_x which could exceed the NO_x emission reporting value mandated by the *Comprehensive Environmental, Response, Compensation, and Liability Act of 1980* (CERCLA). To prevent the release of NO_x above release

limits, work control will ensure that proper review and planning of waste treatment activities is completed prior to performing the work.

7.1.3.1 Sources of Building Ventilation Exhaust.

7.1.3.1.1 291-Z-1 Stack--234-5Z, 236-Z, and 242-Z Building Exhaust.

General Description. A detailed description of the PFP complex ventilation system and 291-Z-1 stack is contained in Chapter 5.0.

Source Description. The major airborne streams contributing to the PFP 291-Z-1 main stack effluent are as follows:

- The 234-5Z E-3 system
- The 234-5Z E-4 system
- Process solution transfer vacuum pump exhaust
- The PFP air sample vacuum pump exhaust
- The 236-Z E-3 system
- The 236-Z E-4 system
- The 236-Z air sample vacuum exhaust
- 242-Z Waste Treatment Facility.

7.1.3.1.2 296-Z-3 Stack--241-Z Building Exhaust.

General Description. The 296-Z-3 stack exhausts filtered air from the sumps and vessels of the 241-Z Building, (the PFP LiquidWaste Treatment Facility). Liquid process wastes from the PFP are received in the tanks in 241-Z and are retained for batch-wise neutralization and transfer to the tank farms. The building is only a weather cover for the tanks.

The 296-Z-3 stack is 24 ft high, 14 in. in diameter, and constructed of Schedule-10 stainless steel. The flow rate averages about 1,200 ft^3/min. An isokinetic air sampling probe feeding a record sampler and an alpha CAM is located 20 ft downstream of the exhaust fans.

Source Description. Contributing sources of the 296-Z-3 stack consist of exhausts from the TK-D4, TK-D5, TK-D6 (TK-D6 is isolated from chemical transfers), TK-D7, and TK-D8 waste tanks and their surrounding cells, the sampling hood in 241-ZA, and the TK-D9 caustic tank (TK-D9 is no longer in service, but was originally used for storage of UNH and is considered to be contaminated with uranium).

7.1.3.1.3 296-Z-5--2736-ZB Building Exhaust.

General Description. The 296-Z-5 stack exhausts filtered air from the 2736-ZB Building and the glovebox in Building 2736-ZB. This building has been in service since 1984 and contains facilities for shipping, receiving, repackaging, and nondestructive assay (NDA) of plutonium and plutonium-bearing materials.

The 296-Z-5 stack is 15 ft high, 34 in. in diameter, and constructed of 14-gauge steel. The flow rate averages 12,000 ft^3/min. The stack is equipped

with two sampling probes; one feeds a record sampler, and the other feeds an alpha CAM with alarm.

Source Description. The major airborne streams contributing to the 296-Z-5 stack effluents consist of the following:

- Zone 4 exhaust
- Zone 3 exhaust
- Zone 2 exhaust
- Zone 1 exhaust
- Air sampler pump.

7.1.3.1.4 296-Z-6--2736-Z and 2736-ZA Building Exhaust.

General Description. The 296-Z-6 stack exhausts filtered air from the 2736-Z and 2736-ZA Buildings, (the plutonium storage vaults). The 296-Z-6 stack is 14 ft 8 in. tall, 36 in. in diameter, and extends 30 in. above the roof of the 2736-ZA Building. The flow rate averages 12,000 ft^3/min.

Source Description. The 296-Z-6 stack has two identical contributing streams. Each stream consists of a filter bank and an exhaust fan, and the two streams join at the base of the 296-Z-6 stack. The major airborne stream contributing to the 296-Z-6 stack effluents is from zone 2 exhaust.

7.1.3.1.5 296-Z-14--232-Z Building Exhaust.

General Description. The 296-Z-14 stack exhausts filtered air from the 232-Z Building.

The 296-Z-14 stack is 21 ft high with a 12-in. dia. The stack is constructed of stainless steel and effluents are sampled and monitored.

Source Description. The major airborne streams contributing to the 296-Z-14 stack effluents consist of the following:

- Zone 4 exhaust
- Zone 3 exhaust
- Zone 1 exhaust.

7.1.3.1.6 296-Z-15--243-Z Building Exhaust.

General Description. The 296-Z-15 stack exhausts filtered air from the 243-Z Building.

The 296-Z-15 stack is 42 ft high with a 12-in. dia and is constructed of stainless steel. This stack is not routinely sampled and monitored because of the small likelihood of any plutonium entering the 243-Z Building and then escaping the piping and train drums. The sampling and monitoring that is done is to confirm the low radioactive emissions.

Source Description. The major airborne streams contributing to the 296-Z-15 stack effluent is zone 2 exhaust airflow.

7.1.3.1.7 Drain Line Vents. Drain lines within the PFP are equipped with vent lines that exhaust out of the roof of the buildings and act as vacuum breaks. All liquid waste drains that eventually lead to TK-D8, in the 241-Z Building, have filtered vents. The filtered vent lines include the D-4, D-5, D-6, D-7, D-8 drain headers in both the 236-Z Building and the 234-5Z Building. The filters are located on the fourth floor of the 236-Z Building and the duct level of the 234-5Z Building.

7.1.3.2 Safety Features. Safety-related features are in place within this system to help reduce the possibility of significant amounts of plutonium being released into the environment and to reduce the possibility of a criticality incident. Some of these features are as follows:

- Up to three stages of HEPA filtration for zone 4 exhaust ventilation
- Continuously monitored exhaust flows
- Criticality specification limits for gloveboxes and hoods
- Backup fans for exhaust fans to prevent overpressurization
- Pressure indicators
- Fire dampers.

7.2 LIQUID WASTE

7.2.1 Criteria for Control of Liquid Wastes

Requirements for and restrictions against returning liquid waste to the environment are detailed in *Water Quality*, HNF-PRO-456. These requirements incorporate applicable federal, state, and local regulations, DOE orders, best management practices, and as low as reasonably achievable (ALARA) considerations. These water quality requirements are categorized into 11 areas; general requirements, discharges to the Columbia River (not applicable to the PFP), sanitary sewer discharges, discharges to the soil column, subsurface discharges (underground injection) (not applicable to the PFP), control standards and requirements for waste disposal sites, groundwater well installation and use (not applicable to the PFP), monitoring requirements, sampling requirements, requirements for new facilities, and drinking water supply systems (not applicable to the PFP). Items for each category of water quality requirements detailed in HNF-PRO-456 are summarized below.

7.2.1.1 General Requirements. HNF-PRO-456 includes requirements for the following:

- Regulations for discharges of liquid effluents containing dangerous wastes
- Reporting of CERCLA hazardous materials in nonradioactive liquid effluent releases to the environment

- Use of best available technology (BAT)
- Tracking and reporting releases with quantities of toxic chemicals
- Radioactive liquid effluents threshold requirements
- Limitation of dose from operations to offsite receptors via effluent release pathways (including airborne)
- Radiological concentrations limits for surface water or groundwater
- Control of discharges of radioactive liquid effluents
- Evaluation and documentation of effluent streams for the FEMP
- Effluent management system for radioactive liquid wastes (RLW)
- Isolation or reconfiguration of liquid effluent lines
- Transferal of information regarding deactivation status and method of deactivation for liquid effluent disposal sites to waste information database system (WIDS)
- Parametric values for doses.

7.2.1.2 Discharges to the Columbia River Requirements. These requirements are not applicable to PFP.

7.2.1.3 Sanitary Sewer Discharge Requirements. HNF-PRO-456 includes requirements for the following:

- Industrial waste water and toxic pollutants disposal
- Disposal limitations of dangerous waste
- Disposal limitations of waste components via septic systems
- Acceptable systems for disposal of sanitary waste
- Site characterization and planning details for the installation, repair, modification, connection to, or expansion of onsite sewage systems
- Sewerage systems operation and maintenance
- Processes for removal of septic tanks from service
- Limitations for use of holding tank sewage systems.

7.2.1.4 Discharges to the Soil Column Requirements. HNF-PRO-456 includes requirements for the following:

- Categories of waste water requiring permits

- Actions necessitating notification of Liquid Effluent Engineering
- Exclusion of water from permit applications
- Other waste water permitting methods
- Time requirements for filing engineering reports, plans, specifications, and permit applications to Ecology
- Underground injection controls; this item is not applicable to the PFP.

7.2.1.4.1 Purgewater Management Requirements. These requirements are not applicable to PFP operations.

7.2.1.4.2 RAD Limits for Releases to the Soil Column. HNF-PRO-456 includes requirements for the following:

- Compliance requirements for radioactive liquid effluents discharged to soil columns
- Use of soil columns to treat and remove suspended and dissolved radionuclides
- Establishment of administrative control values for radionuclides discharges.

7.2.1.4.3 Maintenance of Ponds Containing Radioactive Material Requirements. These requirements are not applicable to PFP operations.

7.2.1.5 Subsurface Discharge Requirements. These requirements are not applicable to the PFP.

7.2.1.6 Control Standards and Requirements for Waste Disposal Site. HNF-PRO-456 includes requirements for the following:

- Requirements for evaluation for impacts of using a waste disposal site
- Routine evaluations of liquid waste disposal sites
- Processes for notification of the Effluent Monitoring organization and Hanford Technical Services of changes in effluent streams
- Responsibility for monitoring non-RCRA/CERCLA treatment, storage, and disposal facilities for migration of contaminants to the water table.

7.2.1.7 Groundwater Well Installation and Use Requirements. These requirements are not applicable to the PFP.

7.2.1.8 Monitoring Requirements. HNF-PRO-456 includes requirements for the following:

- Determination of dangerous contents of waste water
- Monitoring requirements for waste streams
- Record monitoring system requirements.

7.2.1.8.1 Record Effluent Monitoring Requirements for Radioactive streams. HNF-PRO-456 includes requirements for the following:

- Evaluation of streams for release of radionuclides
- Effluent monitoring objectives
- Continuous monitoring requirements for emergency situations
- Continuous monitoring requirements for radionuclide release points
- Allowances for continuous sampling of emissions
- Determination and documentation of overall accuracy for continuous monitoring or sampling
- Consideration of stream characteristics for monitoring system criteria
- Environmental considerations for locating record monitoring systems
- Requirements for off-line monitoring systems
- Design and sensitivity requirements for effluent instruments and transport lines
- Continuous monitoring alarm/waste diversion requirements
- Volume, flow rate, and radionuclide concentrations measurement requirements
- Requirements for batch releases of effluent
- Detection capability requirements for laboratory methods used to analyze record samples
- Requirements for radionuclide analysis
- Statistical analyses requirements
- Contents of record monitoring programs
- Approval for sample collection regimes.

7.2.1.8.2 Calibration Requirements. HNF-PRO-456 includes requirements for the following:

- Record continuous effluent monitoring and sampling systems calibration periods
- Calibration consistency
- Calibration(s) accordances.

7.2.1.8.3 Monitor Down Time Requirements. HNF-PRO-456 includes requirements for the following:

- Corrections for loss of effluent monitoring capabilities
- Length of down time for monitoring systems
- Responsibilities of facility operations management for monitoring.

7.2.1.8.4 Notification Requirements. HNF-PRO-456 includes requirements for the following:

- Events requiring reporting to Environmental Reports
- Facility operation management reporting responsibilities for upsets or malfunctions of required effluent sampling or monitoring systems
- Reporting criteria for release levels of discharges of radionuclides.

7.2.1.9 Sampling Requirements. HNF-PRO-456 includes requirements for the following:

- Sampling for potential equivalent concentrations of dangerous waste contaminants
- Bases for representative measurements of volumes and concentrations of pollutants released to the environment
- Locations for effluent stream measurements
- Grab sampling requirements
- Sampling requirements for surface ponds
- Sampling programs for effluents affected by process configuration
- Methods for the analysis of liquid nonradioactive pollutants.

7.2.1.10 Requirements for New Facilities. HNF-PRO-456 includes requirements for the following:

- Best available technology usage

- Minimization policies of radioactive and nonradioactive liquid waste discharges
- Permit requirements for discharges of liquid effluent to the soil column
- Septic systems procedures
- Pre-operational environmental surveys requirements
- Discharge standards for effluent from domestic waste water treatment facilities
- Individual permits for activities within a Wild and Scenic River study area.

7.2.1.11 Drinking Water Supply Systems Requirements. Not applicable to the PFP.

7.2.2 Liquid Waste System Description and Stream Characterization

The PFP generates, treats, and disposes of the following liquid wastes:

- Low-level RLW collected and treated at the 241-Z Facility prior to transfer to the tank farms for storage (these wastes contain levels of radioactivity greater than allowable for release to the environment.)
- Waste water with a radioactive interface [this includes cooling water, process steam condensate, and floor drains. These liquid effluents are processed through the Low-Level Waste Treatment Facility (LLWTF) and are discharged to the offsite Treated Effluent Disposal Facility (TEDF).]
- Nonradioactive, nonhazardous streams from storm drains, roof drains, and HVAC supply fan sprayers that are sent to TEDF but do not pass through LLWTF
- Steam condensate discharged to the soil column through French drains
- Restroom, shower, and lunchroom drains sent to the 200 West Area Regional Drain Field.

7.2.2.1 Radioactive Liquid Waste. The RLW is collected in batches, sampled, and treated at the 241-Z Waste Storage and Treatment Facility before transfer through pipelines to the tank farms for storage in double-shell tanks.

The basement of the 234-5Z Building consists of a series of six tunnels that contain drain line headers for the building. The only drain line headers with active drains (i.e., have not been capped off) are drain lines D-2, D-3, D-4, D-5, and D-6. For a discussion of drain lines D-2 and D-3, see Section 7.2.3.2. The D-4, D-5, and D-6 lines combine into a new double-encased line

which leads to tank TK-D8 in the 241-Z Building. The D-6 drain line from the 236-Z Building connects to the 234-5Z Building drain line near Tunnel #3 in the 241-Z Building. The tunnels are equipped with sumps that collect any solutions that would be released in the event of a leaking drain line. The tunnels are checked daily for signs of any leaks. Following detection of liquid in a sump, the sump would be isolated from the environment and pumped out. The sumps are not geometrically favorable, as the waste solutions being transferred through these drain lines are assumed to contain a minimum amount of plutonium.

7.2.2.1.1 General Description. Liquid waste streams from various sources within 234-5Z and 236-Z (i.e., labs and process systems) are contaminated or have a high potential of being contaminated, and are therefore designated as RLW. The RLW is routed to the 241-Z Complex for temporary storage and is ultimately treated (see Section 7.2.3) with chemicals that render the wastes suitable for transport through pipelines and storage in underground tanks. A RCRA dangerous waste Part A permit application for the 241-Z Waste Storage and Treatment Facility (EPA/State identification number WA7890008967) identifies the liquid waste managed by the facility as dangerous for exhibiting the characteristics of corrosivity, metal content, and toxicity (as required in Ecology 1989).

7.2.2.1.2 Source Description. Three waste streams are or have been discharged from the 236-Z and 234-5Z Buildings are received, temporarily stored, and/or processed in 241-Z Complex tanks. These waste streams are as follows:

- The high-salt waste (HSW) from the Plutonium Reclamation Facility (PRF) (the PRF is not authorized for production operation)
- The HSW from the Remote Mechanical C (RMC) Line (the portion of the RMC Line that would generate HSW is not authorized for operation and is currently inactive)
- The low-salt waste (LSW) from laboratories, the PRF (unauthorized for operation), and the RMC Line (unauthorized for operation).

Approximately 100,000 gal/yr was discharged during previous plant processes (Remote Mechanical A (RMA) and RMC Lines, PRF operation, laboratories, etc.). This has now decreased to 3,000 gal/yr from current operations (primarily LSW).

Characterization of wastes received from the sources is based on flowsheets, practices, sample data, chemical principles, and other process knowledge which were representative of processes that are no longer authorized, but kept in this section for historical purposes (see Tables 7-2).

Plutonium Reclamation Facility Waste Streams. Waste solutions generated by the PRF was a mixture of HSW [composed of column aqueous waste (CAW), solvent cleanup waste (CXP), and CU column uranium waste (CUU)] and LSW solutions of filtrate evaporator distillate and steam jacket condensates from the filtrate and product evaporators.

The CAW stream was the highly acidic waste from the PRF extraction column (CA column). The CAW was difficult to accurately characterize because, although some components were either added or known to exist, other components were present in the waste only because they were present in the feed, which was typically only characterized with respect to plutonium content. The characterization provided in Tables 7-2 was developed assuming a PRF feed that contains RMC Line concentrated filtrate, dissolved oxide, and slag and crucible (S&C) feeds.

The CUU and CXP solutions were generated from the organic cleanup process. The CUU, although containing trace fluoride and chloride, contained high levels of uranium. When low-uranium-content feed was processed in the PRF, the CUU could be reworked and not discarded. The CXP was a carbonate solution containing degradation products from the breakdown of tributyl phosphate (TBP).

The remaining PRF-generated waste streams were filtrate concentrator distillate and steam condensate from the filtrate and product evaporators. These are reported in the tables as PRF LSW. The evaporator distillate normally contained HNO_3 and trace plutonium, but small concentrations of fluoride and chloride were present. The steam condensate was normally only water and scale inhibitor, but there was the potential for high plutonium levels in this stream in the event of a vessel failure.

Remote Mechanical C Line Waste Streams. Process wastes discharged to the 241-Z Complex from the RMC Line operation came from two sources: the potassium hydroxide (KOH) scrubber located in 234-5Z and the filtrate evaporator located in 236-Z.

The KOH scrubber solution was a HSW stream that contained KF and unreacted KOH.

The LSW stream generated by the filtrate evaporator during RMC Line operation had higher volume and lower acidity than the LSW stream generated when the PRF was in operation. Although the bulk components of the RMC LSW were the same as PRF LSW, the trace constituents were different.

Low-Salt Waste from Laboratories and Miscellaneous Facilities. This LSW contains trace amounts of HNO_3 and plutonium. The majority of this waste is generated in the Analytical Laboratory (PFP AL) and Plutonium Processing Support Laboratory (PPSL). The generation rate is nominally 10 gal/d.

Each source results in wastes that vary greatly in flow, characterization, and subsequent treatment. The major facility sources in terms of liquid volumes are given in Tables 7-2.

7.2.2.1.3 Stream Characterization. Cross-contamination between waste streams due to waste handling practices and equipment at the 241-Z Complex is likely to mask certain impurity level concentrations in some streams.

Estimates based on process knowledge of stream impurities are given in the following sections, considering the maximum allowable impurity level in essential materials.

Aluminum. Aluminum was added in the form of aluminum nitrate nonanhydrate to the acid dissolution process conducted in the MT-5 and MT-6 gloveboxes; however, this process is inactive (information provided for historical purposes only). Aluminum content of the acid dissolution preparations was 1.3 M. Contribution to aluminum concentration from entrained solids is assumed to be negligible.

Chromium and Nickel. Chromium and nickel in the PFP waste originate from corrosion products from stainless steels and impurities in cold process chemicals. Nickel and chromium do not appear in the essential material specification sampling explicitly, but could be considered by the residue on the evaporation specification of HNO_3. It is assumed that analysis is specified only for those potential impurities that can reasonably be expected. Since stainless steels are a source of chromium and nickel, all corrosive PFP liquid effluent streams are likely to be contaminated to some degree with these metals. The actual contamination level in the waste depends on very many factors (i.e., corrosivity of each liquid, relative flow rates, PRF feed contamination, age of equipment, temperatures, campaign, metal area exposed to solution, etc.). It is not practical to obtain and characterize these data. The means to estimate chromium and nickel is subject to engineering judgment at best.

Iron. There is one principal source of iron which is the chemical adjustment of the waste just prior to transfer to the tank farms (treatment). Minor sources include corrosion products and cold chemical impurities.

Iron introduced to waste from minor sources is estimated to be less than 1,000 ppm. This estimate is based on informal observations of many waste samples prior to implementation of iron addition to waste. These early samples sometimes contained clear gelatinous solids and/or tiny white solids and/or dark specks. The supernate was either clear or had a pale yellow tint. Since iron addition began, much less variability could be discerned because all samples observed ranged from light to dark reddish brown and from opaque to partially translucent. This was an expected result of iron addition. Iron forms voluminous hydroxide jelly when in a solution above a pH of about 5. The solubility of iron salts in a basic solution is extremely low (60 ppm). It is believed that if significant quantities of iron were present prior to implementation of iron addition, the presence would have been obvious. Iron (greater than 10,000 ppm) has been identified in some feeds. Therefore, to cover the uncertainty, the range of iron in CAW is estimated at 0 to 10,000 ppm. The nominal concentration is estimated at 50 ppm.

Iron nitrate is the waste additive used to provide stable solids to keep plutonium dispersed in tank 241-SY-102. Iron is presently added to all waste.

Acidity. All PFP waste streams are acidic except PRF CXP and RMC Line HSW. The HNO_3 is usually the predominant species. HNO_3 is the only strong acid used in PFP processes. Because HNO_3 is strong, its concentration is an accurate indication of acidity.

Laboratory LSW is not well characterized, but the accumulated waste is known to occasionally contain a few tenths molar HNO_3 (estimated average of 0.1 M). Since it is possible for plant acid (12.2 M) to enter the drain, the laboratory waste stream is estimated to range from 0 to 12.2 M.

Potassium. Potassium is a major contaminant of the waste streams and results from the use of NaOH as a waste neutralizer in the 241-Z waste treatment process.

Sodium. Sodium is known to be present in untreated waste streams exiting the PFP; however, these concentrations are insignificant to the composition of treated PFP liquid waste because of the addition of NaOH as part of the 241-Z waste treatment process. Accurate estimates of sodium impurities, then, are not critical to accurate characterization of total basified waste flow.

Hydroxide. Most PFP waste streams are acidic and, therefore, contain an extremely small amount of hydroxide. However, the treatment of waste streams with NaOH ensures that waste discharges to the tank farms have >0.5 M hydroxide.

Chloride. Chloride comes from many sources. All acidic wastes (all are acidic due primarily to HNO_3) will contain some chloride from the chloride impurity in the plant supply of HNO_3.

The PFP AL and PPSL LSW has no known contributors of significant amounts of chloride other than the impurity level in HNO_3. The average HNO_3 concentration of laboratory LSW is estimated at 0.7%. The impurity level is less than 0.05% of the HNO_3 concentration. The chloride concentration is estimated at 4 ppm. Based on the essential material specifications, NaOH used in waste treatment at the 241-Z Complex is expected to contain 1,500 ppm chloride.

Fluoride. Fluoride was used extensively in plutonium chemistry. Fluorine compounds were used in the dissolution of plutonium from solid forms. (Information provided for historical purposes only).

Nitrate. The majority of chemistry used at the PFP is built around nitrate systems. NO_3^-, then, originates from many sources. Because the nitrate ion is dominant in most PFP waste prior to basification, contributions from impurities in cold chemicals are considered negligible.

Normal use of the drains in the laboratories is expected to contribute some additional nitrates (<1,000 ppm). A small amount of nitrate is added to waste in the form of $Fe(NO_3)_3 \cdot 9H_2O$ at 241-Z as a part of waste treatment for criticality prevention.

Nitrite. The NO_2^- is the conjugate base of the weak nitrous acid. It has very low solubility in concentrated solutions of strong acids, and high solubility in alkaline solutions. Nitrite is detected in collected LSW in a concentration of about 0.01 M. When necessary $NaNO_2$ are added to each waste batch at 241-Z as a corrosion inhibitor.

Plutonium. Plutonium is a constituent of all RLW streams at the PFP. The estimated concentration is 0.00001 g/L for the PFP AL and PPSL LSW (the estimate is based on an average). Of course, the instantaneous concentration may be quite high during disposal of a contaminated fluid.

Americium. The PFP AL and PPSL LSW is estimated at 0.1% of the PRF LSW based, in part, on the existence of their sample evaporator.

Barium, Lead, Strontium, Phosphate, Sulfate, Ammonia, and Silica. These materials are expected to be introduced to the waste primarily as impurities in essential materials. The maximum impurity level allowed by the essential material specifications is conservatively assumed. The collective contributions of essential material impurities to each waste stream are given in Tables 7-2. The lead estimate includes all cations that precipitate upon boiling the acidified essential material with hydrogen sulfide.

It must be recognized that many of the above composition estimates are subject to variances in controlled process parameters such as certain stream flows and compositions. In cases where controlled parameters were needed, values used were nominal and tolerances were not considered.

7.2.2.2 Liquid Waste Water Stream.

7.2.2.2.1 General Description. Waste water from the PFP complex is routed to the TEDF located in the 200 East Area. This waste water stream includes all effluents that were formerly discharged to the 216-Z-20 crib and the 216-Z-21 seepage basin.

The physical arrangement of the sewer system, including the manholes, the LLWTF, the monitoring station in 225-WC, and the TEDF pump station 1 are shown in Figure 7-2.

The piping system that transports the waste water is comprised of three primary branches. The water from the building steam condensate exits the 234-5Z Building on the north side and travels through manholes S1 through S7 before reaching the TEDF tie-in at manhole C2. The supply fan condensate was part of this waste stream. The sources that formerly discharged to the deactivated 216-Z-20 crib are now tied into the TEDF at manhole C1. Of the nine manholes located along the sewer route to the defunct 216-Z-20 crib, only manholes Z1, Z2, Z3, Z4, and Z7 are still active. The new TEDF sewer line picks up the old 216-Z-20 crib sources at manhole C1.

The supply fan condensate normally flows into the JCI condensate receiver tank, from which two float activated condensate pumps pump it back to the packaged boiler. In the event the condensate receiver tank or pumps are out of service, the supply fan condensate flows into the C2 manhole via an overflow pipeline. Building steam condensate does not return to the packaged boiler and is discharged to the french drains.

Manhole Z1 receives steam condensate from the 2736-ZB Building and waste water from the duct level, second floor, and roof drains from the west end of the 234-5Z building. The 232-Z Building is also connected to manhole Z1, but all water services to this building are isolated and the building is being decommissioned. The composite stream from manhole Z1 flows to manhole Z2 via a 15-in. dia vitreous clay pipe (VCP) line.

In addition to the stream from manhole Z1, manhole Z2 receives waste from the three storm sewers south of the 234-5Z Building. In the past, manhole Z2 received steam condensate from the 241-Z Building, a source that is now out of service. The effluent from manhole Z2 flows to manhole Z7 via a 15 in. dia VCP line.

Waste streams from the 234-5Z Building drain D-1 and D-2 headers, the east end of the duct level and second floor, and the effluent from the 291-Z sump all flow to manhole Z3. The 242-Z Building is also connected to manhole Z3 but all water services to this building are shut off. All D-1 sources from the 234-5Z Building have been isolated. The composite stream from manhole Z3 flows to manhole Z4 via a 15 in. dia VCP line.

In addition to the composite effluent stream from manhole Z3, manhole Z4 receives waste from the 234-5Z Building D-3 header and from the 236-Z Building D-1, D-3, and steam condensate headers. The composite stream from manhole Z4 flows to the LLWTF via a 15 in. dia VCP line.

Manholes Z5, Z6, Z8, and Z9 are isolated (by grouting) from the waste water sewer route due to the incorporation of the LLWTF and TEDF tie-in.

The effluent streams from manhole Z2 and the LLWTF flow into manhole Z7. The 2904-ZA Sample Building is located downstream from manhole Z7 and directly over the centerline of the sewer line. The composite stream from manhole Z7 flows in a lined 15 in. dia VCP to manhole C1.

Manhole S1 is a storm drain that also receives the supply fan water and the 234-5Z Building steam condensate. It also used to receive the 2902-Z high-tank overflow; however, this water tank is drained, isolated, and out of service. Manholes S2, S3, and S4 are also storm drains. These drains are the only locations that effluent can enter the system from the north side of the PFP. The sewer lines along these manholes are 12-in. corrugated stainless steel piping.

The sewer line installed by Project W-049H to reroute the effluent to the TEDF was referred to as pipe C with the manholes being labeled C1 thru C4. Manhole C1 was added just upstream of manhole Z8 and provides the tie-in point for the 216-Z-20 crib sources. Manhole C2 is the tie-in point for the PFP's southside sources. Manhole C4 contains the flume and flowmeter and is located next to the 225-WC, Wastewater Sampling Facility. The 10 in. dia VCP pipe extends from manhole C4 to the TEDF pump station 1.

As noted above, the sewer lines from the Z-manholes are primarily 15-in. dia VCP. The original lines were installed in 1948. The pipes were laid out in 3-ft bell and spigot sections. The piping underwent a maintenance clean out in Autumn 1994 and was video-surveyed to verify the integrity of the piping. The majority of the sewer system piping is in good physical condition, but the piping between manholes Z7 and C1 and the LLWTF is known to be contaminated. The piping between manholes Z2 and Z7 show some cracks in the pipe sections and several 4 to 6 in. holes. These sections were remediated by project W-291H.

The purpose of Project W-291H was to remediate the contaminated piping between manholes Z7 and C1 and the LLWTF to allow safe discharge of waste water to the 200 Area TEDF. The pipes were "relined" with a resin-based membrane and manhole Z7 was repaired to fix contamination in-place and allow the PFP to meet the TEDF wastewater discharge requirements. This project also remediated the line between manholes Z2 and Z7 to seal up the cracks and small holes in the pipe.

7.2.2.2.2 Source Description. The waste water stream sources are widely varied. Tables 7-4 through 7-7 list a summary of sources and the facility origin.

- Eyewash stations--The drains are located in the labs. Chemical contaminants flushed off of a worker during an emergency will be heavily diluted before reaching the LLWTF.

- Storm drains--These drains are in the fenced security zone. The effluent consists of rain, slush, snowmelt, etc.

- Supply fan drains--This includes building steam condensate from the 234-5Z Building, dry air compressor cooling water (though the dry air compressor is not currently in use), and ventilation spray pan water.

- Floor drains--Floor drains throughout 234-5Z Building are located near overhead safety showers or similar potential sources of water piping. Typically, the floor drains would contain potable water, the same type of effluent as eyewash station drains.

- Condensate header--Process steam trap drains located on the third floor of the 236-Z Building have no potential for hazardous chemical contamination of the TEDF waste water stream. This is a high-pressure steam line under nearly constant operation.

- Utility water drains--These drains, located in the 236-Z Building, room 35, are normally just for water. Effluent sources include steam condensate, backflow drains, and floor drains. Hazardous chemical or radioactive contamination of these drains is considered improbable. Cooling water systems are pressurized to help ensure that any leakage would flow into the process and not discharge into the waste stream.

- The HVAC condensate drains--These drains are located in the 2736-ZB Building, room 602. The potential for radioactive or hazardous chemical contamination is very low.

7.2.2.3 French Drains (Radioactive Waste Units). French drains at the PFP are used to discharge steam condensates and floor drainage as shown in Figure 7-3. The following French drains are registered with the State of Washington as underground injection wells.

- 216-Z-13 French drain

  - Designation--Inactive RLW ground disposal unit (French drain)

  - Location/site designation--The unit is located 190 ft south of the 234-5Z Building and approximately 50 ft northeast of the 291-Z-1 stack in 200 West Area

  - Dates of waste receipt--1949 to 1998

- Waste types and amounts--The unit receives floor drainage from the 291-Z Building. It also received steam condensate from the turbine for the ET-8 emergency exhaust fan, which will be removed from service when fans ET-1 and ET-2 are connected to backup electrical power to provide emergency exhaust capability. Radiological inventories are not available; low levels of radiation are not expected, but have been assumed. In 1998, steam condensate was rerouted to discharge to LLWTF, and isolated from this drain.

• 216-Z-14 French drain

- Designation-Active RLW ground disposal unit (French drain)

- Location/site designation--The unit is located 190 ft south of the 234-5Z Building and approximately 50 ft northwest of the 291-Z-1 stack in 200 West Area

- Dates of waste receipt--1949 to present

- Waste types and amounts--It receives steam condensate from the turbine for the ET-9 emergency exhaust fan in the 291-Z building, which will be removed from service when fans ET-1 and ET-2 are connected to backup electrical power to provide emergency exhaust capability. Radionuclide inventories are not available; low levels of radiation are not expected, but have been assumed.

• 216-Z-15 French drain

- Designation--Inactive RLW ground disposal unit (French drain)

- Location/site designation--The unit is located 50 ft south of the 234-5Z Building and next to the north end of the 291-Z Building in 200 West Area

- Dates of waste receipt--1949 to 1997

- Waste types and amounts--The unit formerly received condensates from the S-12 evaporator cooler in the 291-Z Building. Radionuclide inventories are not available; low levels are not expected, but have been assumed.

7.2.2.4 Sanitary Sewer Systems.

7.2.2.4.1 General Description. The PFP sanitary sewer systems include the 234-5Z sanitary drain, the 234-5Z annex sanitary drain, and the trailer drain. These sanitary sewer systems receive liquid from restrooms, showers, and lunchroom sinks and dispose of it through septic tanks, pumpstations, and to the 2607 West Regional Drain Field located approximately one half mile away where it is percolated into the soil. The sanitary sewer systems' effluent is chemically nonhazardous and is nonradioactive according to *The Plutonium Finishing Plant Liquid Effluent Monitoring Plan* (WHC 1988). There is

virtually no potential for radioactive or hazardous chemical contamination of the sanitary sewer systems.

The requirements for disposal of sanitary waste liquids are given in *Water Quality*, HNF-PRO-456, and *On-site Sewage Systems*, WAC 246-272. No sampling or monitoring is required for facilities operating before June 15, 1987, if no corrosives are used in the system. The PFP systems are not required to be sampled or monitored since no strong acid nor bases (corrosives) are used in the systems. Small quantities of caustic cleaning solutions are used, but effluents released to the environment are noncaustic.

7.2.2.4.2 Source Description. The sanitary sewer sources are listed below.

- Sanitary drain (2607-Z)--The sanitary drain receives liquid effluents from the 234-5Z, 236-Z, 270-Z, and 2704-Z Building restrooms, lunchrooms, and the changeroom showers in the 234-5Z Building. The effluent is discharged into a tile field (2607-W1) located west of the PFP.

- The 234-5Z annex sanitary drain (2607-ZA)--This sanitary system receives waste from the 234-5Z Building annex restrooms and from the 2736-ZB Facility. The effluent is discharged into a tile field (2607-W1) located west of the PFP.

- Trailer sanitary drain (2607-ZB)--This sanitary system receives waste liquid from the restrooms, kitchen sinks, and drinking fountains located in MO trailers. The effluent is discharged into a tile field (2607-W1) located west of the PFP.

Chemicals routinely used in the sanitary system include the following:

- Toilet bowl cleaner
- Dishwashing detergent
- Pine oil disinfectant
- Cleansers (Ajax, etc.)
- Hand soap (lotion or lava)
- Shower cleaners.

7.2.2.4.3 Instrumentation and Controls. No effluent monitoring instrumentation or management procedural controls are required.

7.2.2.4.4 Stream Characterization. The sanitary waste system handles only used sanitary water, human waste discharges, and body-cleansing agents and liquids. No characterization of the streams is required.

7.2.2.4.5 Sampling and Monitoring. No waste effluent sampling or monitoring is required.

7.2.2.5 Chemical Waste System. Bulk chemicals used in the PFP for processing are prepared and transferred in the chemical makeup areas. The chemical makeup areas are located in the 234-5Z Building (rooms 336 and 337) and 236-Z Building (Room 40). All Building 236-Z Room 40 processes are currently inactive. Chemicals remaining in the PRF tanks and process lines are managed

and dispositioned in accordance with HNF-2977, *Plutonium Reclamation Facility (PRF, Building 236-Z) Layup Plan* (BWHC 1998). Electrical power supplied to instrumentation in the room has been isolated.

234-5Z Rooms 336/337 contain three active chemical tanks that are required to support future material stabilization activities.

There is a sump underneath the tanks in the chemical makeup area (room 40) that is equipped with standpipes similar to those in the RMC Line operation. All tanks are equipped with high-level alarms. A conductivity probe is installed in the drain system just below where all of the PRF drains combine. The conductivity probe gives an immediate local alarm (alert) to operators if any chemical release is detected. In addition, an interlock system is installed to prevent overfilling of tanks from the PFP bulk HNO_3 storage and feed tank. The drain systems for both of the chemical preparation areas are tied into a catch tank located within the 2735-Z impoundment. The catch tank is a 400-gal stainless steel tank equipped with sampling and loadout capabilities. Any effluents drained to this tank are sampled and loaded-out into drums for disposal or reuse.

The following are safety-related features that are in place to help eliminate the possibility of chemicals being released into the TEDF waste water stream system:

- 236-Z Building chemical preparation room, room 40--sump drain conductivity probe alarm
- Room 40--CCl_4 monitor
- Room 40--chemical makeup tank liquid-level indicators
- Room 40--spill basin leak detector
- Rooms 40, 336, and 337--spill basin risers
- Rooms 336 and 337--aqueous makeup tank liquid-level indicators and electrical interlock system.

7.2.2.6 Plutonium Finishing Plant Spill Areas. The PFP spill areas shown in Figure 7-4 include the following:

- Radioactive contamination southwest of the 236-Z Building (UN-216-W-89)
- Radioactive contamination south of the 236-Z Building (UN-216-W-90)
- Radioactive contamination near the 234-5Z Building (UN-216-W-91)
- Caustic spill at the PFP.

Areas associated with radioactive spills have been decontaminated to nondetectable levels. This effort included the removal of the contaminated ground surfaces to a depth at which the isotope was no longer detectable with

portable survey instruments. The material removed is treated as radioactive waste and packaged for disposal in UN 1A2 55-gal drums.

The caustic spill at the PFP consisted of an undetermined amount of 50% aqueous sodium hydroxide. The area affected by the caustic spill was cleaned up by removal of the soil, which was packaged and shipped offsite as hazardous waste.

7.2.2.7 Plutonium Finishing Plant Inactive *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* **Sites.** The PFP has one inactive site, the 241-Z-361 settling tank, shown in Figure 7-4.

- Designation--Inactive radioactive waste storage unit (settling tank)
- Location/site designation--The unit is located south of the PFP in 200 West Area
- Dates of waste receipt--Prior to 1976
- Description--The tank is a 1 ft thick, reinforced concrete box with a 3/8-in. steel liner. The top of the tank is 2 ft below grade. Prioritization of this facility for decommissioning classifies the relative radiological hazard as high in comparison with other 200 Area surplus facilities.

7.2.3 Liquid Waste Treatment and Control

7.2.3.1 Radioactive Liquid Waste.

7.2.3.1.1 Treatment. The 241-Z Building contains six underground stainless steel tanks (five active tanks and one isolated tank), with each tank in a concrete cell (one cell contains a tank and a smaller overflow tank). Each tank is ventilated and each cell contains leak detection equipment and the capability for pumping out of solutions that may leak into the concrete cell. One of the tanks, TK-D5, is used to treat aqueous liquids collected from the process facilities. Another tank, TK-D8, is used to collect, measure, and stage the liquids for treatment. Treatment occurs in a batch process consisting of the addition of NaOH or KOH, $Fe(NO_3)_3.9H_2O$, and $NaNO_2$ to the 241-Z treatment tank (TK-D5). A flowchart for the 241-Z facility waste storage and treatment is shown in Figure 7-5. The liquid waste is sampled and analyzed after treatment to make certain that it meets the required Waste Acceptance Criteria specifications (see OSD-184-Z-00010). The remaining active tanks (TK-D4, TK-D7, and TK-D7 overflow tank) are used to supplement the capacity of the TK-D8 and TK-D5 tanks if they overflow.

Treated wastes at the 241-Z Complex are pumped through double-encased lines to the collection tank in the 244-TX Receiver Facility located approximately 1 mi north of the 241-Z Building. The ultimate destination of the waste is to double-shell tanks. Tank TK-D5 is designed to treat 5,300 gal/d of liquid. The sump tanks and their functions are shown in Table 7-8.

7.2.3.1.2 Instrumentation and Controls. The retention tanks are monitored for leaks by a leak detection system that provides audible and visual alarms when liquids accumulate within the sump areas. The tanks are also monitored by strip charts that record the liquid levels of the tanks. The tanks are also equipped with high and low liquid-level indicators that alarm both audibly and visually when liquid reaches preset levels. The alarms and strip charts are checked every shift and the tank levels are recorded; any discrepancies are reported to plant management.

7.2.3.1.3 Tank Farm Acceptance Criteria. In order for the RLW to be accepted by the tank farms, the following criteria (see OSD-184-Z-00010) must be met:

- Pu concentration < 0.033 g/L
- Solid content limited from 0.7 to 3 vol%
- Fe to Pu weight ratio > 160:1
- No separable organic phase in liquid
- pH > 8
- If $[NO_3^-] < 1.0$ M, then $0.01 \text{ M} \leq [OH^-] \leq 5.0$ M and $0.011 \text{ M} \leq [NO_2^-] \leq 5.5$ M and $[NO_3^-]/[OH^-] + [NO_2^-] < 2.5$
- If $1.0 \text{ M} \leq [NO_3^-] \leq 3.0$ M, then $(0.1)[NO_3^-] \leq [OH^-] \leq 10$ M and $[OH^-] + [NO_2^-] \geq 0.4[NO_3^-]$
- If $3.0\text{M} < [NO_3^-] \leq 5.5$ M, then $0.3 \text{ M} \leq [OH^-] \leq 10.\text{M}$ and $[OH^-] + [NO_2^-] > 1.2$ M.

7.2.3.1.4 Criticality. Because the 241-Z tanks are geometrically unsafe, criticality prevention specifications impose a 400 g plutonium limit for each tank. As a conservative measure, all plutonium passing through a tank is considered to be resident in that tank until an NDA is conducted. In addition, plutonium concentration is limited to <0.033 g/L upon transfer of the RLW to 244-TX.

7.2.3.1.5 Safety Features. Safety-related features are in place within this system to help reduce the possibility of significant amounts of plutonium being released into the environment and to reduce the possibility of a criticality incident. Some of these features are as follows.

- Tanks are located within concrete cells
- Cells are individually ventilated
- Each cell contains leak detection and the capability of pumping out solutions that may leak into them
- Two sets of HEPA filtration provide redundancy

- Transfer lines between 241-Z and 244-TX are double-encased with leak detection and cathodic protection
- Tanks are equipped with agitators to help prevent buildup of solids
- Waste tank weight factor instrumentation and recorders are present.

7.2.3.2 Waste water Treatment.

7.2.3.2.1 Treatment Process. The waste water stream at the PFP receives input from a number of sources. Some of these sources, namely sanitary water and air-conditioning or chiller water, are all chemically nonhazardous and nonradioactive and are routed directly to the TEDF. Other sources which have the potential to contain hazardous or radioactive material are routed to the LLWTF for treatment and then to the TEDF for disposal. See Chapter 5.0, Section 5.4.9, for a detailed description of the 243-Z Building.

The D-2 and D-3 drain lines from the basement of the 234-5Z Building drain to the LLWTF. The D-1 and D-3 drain line headers in the 236-Z Building drain to manhole Z-4. The LLWTF receives potentially radioactive waste water from manhole Z4. The waste water enters the 243-ZA Building through double-contained pipe into an influent sump (which is supported with a 5,000-gal influent surge tank) (see Figure 7-2) and is then pumped into the 243-Z Building, as shown in Figure 7-6. Because the incoming effluent wastes are of a pH range about that of water, the stream pH does not typically need to be adjusted to meet a desired concentration to protect downstream cation exchange contactors. Even if an accidental acid spill does enter the waste water stream, the acidic portion of the effluent stream would be in such a small amount and of such a small duration that the trains would adequately treat the effluent to meet acceptable criteria.

Two prefilters can be used to remove suspended solids, though one filter is used at any one time with the other used as a backup. The prefilters are supplied with replaceable cartridges that remove particle sizes of 10 μm and larger, as well as a pressure gauge indicator used to measure stream flow. When a differential pressure exceeds 10 lb/in^2, operations routes the effluent stream flow through the backup prefilter and the saturated filter. Saturated filter cartridges are replaced. The cartridges are then disposed of as low-level waste (LLW).

The waste water stream is routed through two identical parallel treatment trains. Each train consists of three different adsorption medias arranged in the following order; granulated activated carbon, bone-char, and a cation (IX) resin.

All adsorption media are contained in UN 1A1 55-gal drums that are placed inside frames holding the piping and valves necessary to pass waste water through the canisters. The purpose of granulated activated carbon is to remove any traces of organic chemicals (e.g., chloroform) before the stream enters the bone-char canisters. The bone-char is specifically used in the process to remove the radionuclides that could be present in the waste water stream. Bone-char is used as the adsorption media of choice because of the following characteristics:

- High adsorption distribution coefficient for plutonium and americium over the entire range of pH expected for the waste water
- Rapid plutonium and americium adsorption under anticipated waste water conditions
- Reactivity toward all plutonium and americium isotopes that are expected to be present in the waste water
- Large particle size to minimize a pressure drop across the drums containing bone-char
- High mechanical strength and chemical stability.

The final stage of the absorption process occurs when the partially cleaned effluent passes through cation exchange contactors. These drums remove cations (e.g., barium, aluminum, mercury, copper, and other cations). The cleaned water is expected to consistently meet the DCGs as well as the 200 Area TEDF influent criteria.

The maximum flow rate to the 243-Z Building is 20-25 gal/min. Each train can clean a maximum influent rate of 30 gal/min. Train 1 or train 2 can be removed from service for maintenance without stopping the maximum influent flow to the 243-Z Building. Redundant pumps, filters, and manually operated valves are included in the process for the same purpose.

The 55-gal drums are Department of Transportation (DOT) UN 1A1 hazardous waste containers and are used for the following reasons.

- They may be filled with various adsorbents of choice
- The drums are easy to handle inside the 243-Z Building and can be easily loaded and unloaded from trucks
- The operator is prevented from coming in direct contact with radionuclides and hazardous chemicals during removal of saturated drums using the drum replacement procedures
- The UN 1A1 55-gal drums can be easily disposed of as LLW.

7.2.3.2.2 Low-Level Waste Treatment Facility Waste Streams.

Solid waste. There are five types of solid wastes generated in the waste water treatment process. All five types of solid wastes will be generated within the 243-Z Building, and will be disposed of by methods outlined in Section 7.3. The five types of solid waste are listed below.

1. Replaced suspended solids filter--this occurs when a differential pressure reaches 10 lb/in^2, indicating that the suspended solids filter must be changed.
2. Saturated activated carbon contactors--the necessity of a drum change is determined by two methods: examining the weekly sample monitoring results of a material balance, and/or by noting a flow

loss at a drum (i.e., a leak or plug). If a drum change is found to be required, that drum is removed from the process piping via quick-disconnect couplings and transported by hand cart to the drum turning room inside the 243-Z Building. The drum is mounted on a drum turning machine that raises the drum so that the liquid can be drained back into the influent sump. Two valves on the drum will be opened, the water will start to drain, and the doors to the drum draining station will be closed. The exhaust fan over the drum turning machine draws off any airborne radioactive and/or nonradioactive material through a HEPA filter before exhausting to the outside air (see Chapter 5.0, Section 5.4.1, for details of the ventilation system). Screens over the valves of a turning drum will prevent any solids from leaving the drum during the draining process. The drum is then buried as LLW.

3. Saturated bone-char contactors--these drums are disposed of in the same way as activated carbon contactors.

4. Saturated cation contactors--these drums are disposed of in the same way as activated carbon contactors.

5. HEPA filters from the 243-Z exhaust system--removal and disposal of HEPA filters is performed during the normal maintenance operations at the PFP.

Gaseous waste. Any possible hazardous chemical or radioactive gases generated in the waste water piping or the process vessels in the 243-Z Building would result from an accident. During normal operation of the primary and secondary closed-loop cooling system and the waste water treatment system, neither hazardous chemicals nor radioactive gases will be generated.

Liquid waste. Sludge will build up in the influent surge tank during operation of the 243-Z Building process system. Examination of the sump interior by looking through a flange will indicate whether build-up needs to be removed from the sump. Removal of sludge requires that an access manway on tank 101 be removed to allow for a truck vacuum hose to be used to remove any built-up solids.

7.2.3.2.3 Low-Level Waste Treatment Facility Sampling and Monitoring. After the waste stream enters the LLWTF, it is sampled before undergoing the treatment process. It is sampled using a proportional pressure-fed sampler with a 5-gal capacity and an adjustable sample rate up to 2 gal/h. There is online pH and conductivity monitoring at the inlet and outlet of the treatment trains. Before the treated effluent is transferred to manhole Z7, it is continuously monitored for pH and conductivity and proportionally sampled using a second sampler. If any of the limits or ranges do not meet specifications, the stream is recycled back through the process. If the effluent is within specifications, it is transferred to manhole Z7.

7.2.3.2.4 Treated Effluent Disposal Facility Sampling and Monitoring. The primary chemical constituents or measurements of regulatory concern for the TEDF waste water stream system are (1) pH (hydrogen ion concentration), (2) plutonium (radioactive), and (3) metal ions (conductivity). The TEDF is permitted for discharges that meet state drinking water standards on chemical

constituents and 4% of the DCG for radioactive constituents. Sampling of the TEDF stream began on June 8, 1995.

In the 225-WC Building, two flow-proportional composite samplers collect samples of waste water for analysis. One sampler is set up as the continuous or main sampler. The other is set up as the pH or backup sampler. The continuous sampler is set to collect 125 mL samples at 3,000-gal intervals. The collected effluent is composited in a 15 gal sample reservoir. The reservoir is sampled once a week.

Temperature, pH, and conductivity probes are located in the 225-WC monitoring station and are immersed in the effluent stream and the ultrasonic flowmeter is mounted in manhole C4. Local alarms annunciate when pH measurements exceed the discharge limits of 6.5 and 8.5 and when the flow rate exceeds 500 gal/min. If the pH alarm annunciates, the backup sampler is activated to collect samples of the stream. The pH monitor AIT-201, conductivity monitor AIT-202, and flow computer FQ-301 send data to chart recorder UR-201. Flow diagrams of the sampling equipment are found in the PFP procedure *225-WC Facility Surveillance*, ZO-102-018.

In addition to the effluent monitors, the waste water is sampled for radionuclides and chemical contaminates in accordance with the PFP Routine Wastewater Sample Schedule, FSS-Z-080-00003. These samples include the TEDF expanded sample, the TEDF indicator sample, the environmental composite sample, and process support samples. These samples are sent to the WSCF for analyses, except for the process support samples, which can be sent to the 222-S Laboratory.

The TEDF expanded sample is collected every 6 months and consists of grab samples and composite samples. The composite samples are analyzed for chlorides, nitrates, sulfates, total dissolved solids, arsenic, cadmium, chromium, iron, lead, manganese, mercury, Bis (2-ethylhexylphthalate), and phenol. The grab samples are analyzed for cyanides, WTPH-G, oil and grease, gross alpha, gross beta, total radium, ^{226}Ra, semi-volatiles, and volatiles. The expanded sample is collected by Sampling and Mobile Labs.

The TEDF indicator sample is a composite sample collected every 2 months and is analyzed for arsenic, cadmium, chromium, iron, lead, manganese, and mercury.

The environmental composite sample is collected weekly and is composited over the entire month at the WSCF. The monthly composite is analyzed for total alpha, total beta, gamma-energy analysis, ^{238}Pu, ^{240}Pu, and ^{241}Am. The environmental composite sample is collected under procedure ZO-102-021.

Process support samples are collected on request and can be taken from the Manning Sampler or as a grab sample. The process sample is usually analyzed for total alpha and pH. The grab sample is collected under procedure ZO-102-014. Grab samples are collected from manholes C4 and Z7, but additional sampling points may be specified.

7.2.4 Administrative Controls and Responses

Manual FSP-PFP-5-8, *Plutonium Finishing Plant Administration*, contains the procedures defining action levels and response actions to be taken in the case of high or abnormal sample results on liquid effluent samples. Responses to liquid effluent monitor alarms are discussed in *Building Emergency Plan for Plutonium Finishing Plant Complex*, HNF-IP-0263-PFP. The action levels for liquid effluents can be found in FSP-PFP-5-8.

Off-Normal Conditions and Constituents. The TEDF waste water stream sources were evaluated for possible off-normal conditions of regulatory concern. A list of PFP chemical constituents is presented in Table 7-9. All of these chemicals are used in the processing of plutonium materials and become part of the RLW. They are not discarded to the TEDF stream system. The only way these chemicals can enter the sewer system is during an off-normal plant condition. With the discontinuance of the PRF operations and the RMC Line, there is no potential for off-normal conditions because solutions no longer go to the cribs. The 236-Z exhaust duct sump is normally dry. If liquid should accumulate, it must be sampled before the sump contents can be transferred by jet pump to manhole Z-4 for discharge into the LLWTF.

7.3 SOLID WASTE

7.3.1 Criteria for Control of Solid Wastes

The PFP generates and manages the following radioactive and nonradioactive solid wastes.

- **Transuranic (TRU) waste.** These wastes contain alpha-emitting radionuclides of atomic number greater than 92, with half-lives greater than 20 yr, in concentrations greater than 100 nCi/g of waste matrix.

- **Low-level waste.** Waste that contains radioactivity and is not classified as high-level waste, TRU waste, or spent nuclear fuel.

- **Mixed waste.** Waste that contains both radioactive and hazardous components as defined by the Atomic Energy Act (AEA) and by the RCRA/WAC 173-303, respectively.

- **Dangerous waste.** Dangerous wastes means those solid wastes designated in WAC-173-303-070 through 173-303-100 as dangerous, or extremely hazardous or mixed waste. Such wastes are listed and defined in WAC 173-303 as discarded chemical projects or dangerous waste sources. As used in WAC 173-303, the term "dangerous waste" will refer to the full universe of wastes regulated by WAC 173-303 (including dangerous and extremely hazardous waste). (See HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria).*

- **Nondangerous, nonradioactive solid waste.**

Standards for control of solid wastes, including a waste minimization program, are given in *Solid Waste Management*, HNF-PRO-455 and waste acceptance criteria are given in HNF-EP-0063. These standards include segregation of wastes according to type and minimization of the volume of solid wastes.

7.3.1.1 General Requirements for Radioactive Solid Wastes. HNF-PRO-455 and HNF-EP-0063 includes the following general requirements for radioactive solid wastes:

- Smearable contamination limits for waste package exteriors
- Segregation of incompatible wastes
- Stabilization of unreacted chemicals and alkali metals
- Prohibition of disposal of nonradioactive materials in containers specifically marked for radioactive materials
- Prohibition of explosives or pyrophorics in wastes
- Venting of gas cylinders (except aerosol cans) placed in wastes
- Waste designation and waste certification.

7.3.1.2 Not Used.

7.3.1.3 Standards for Disposal of Nonradioactive Solid Wastes. HNF-PRO-455 and HNF-EP-0063 includes the following standards that apply to disposal of nonradioactive solid wastes:

- Assay and/or survey policies for suspect waste prior to disposal
- Disposal location requirements for nonradioactive solid wastes
- Waste minimization implementation requirements.

7.3.2 Nonradioactive Solid Wastes

Nonradioactive solid wastes are discussed in Section 7.3.4.1.

7.3.3 Design Objectives

All solid wastes originating from the PFP are packaged for onsite/offsite storage or disposal. The design objective for waste packaging is to safely contain the waste during temporary storage at the PFP and during transportation to storage or disposal units. The waste packages meet the criteria of the pertinent storage/disposal unit. For TRU wastes, these criteria are DOE/WIPP-069, Rev. 5, *Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (WIPP WAC) and HNF-EP-0063. For LLWs these criteria are those established by the LLW burial grounds. Hazardous and mixed waste (MW) meet regulatory standards established by the EPA, DOT, and Ecology. The

objectives of solid waste management activities also include proper segregation of all types of solid wastes.

7.3.4 Equipment and System Description

7.3.4.1 Waste Management System. Solid wastes generated at the PFP are packaged and shipped to the appropriate Treatment/Storage/Disposal (TSD) facilities in accordance with site and facility policies and procedures. The PFP interfaces with Waste Management of Hanford (WMH) to ensure all waste characterization, packaging, and transportation requirements are met for each waste container.

If possible, waste management activities are planned in advance and are included in the pre-planning stages of work being performed at the facility. WMH personnel are assigned to assist the PFP personnel meet federal, state, and site requirements and policies regarding waste characterization, packaging, and transportation.

The generated waste is characterized and determined to meet a specific Waste Specification Record (WSRd). WMH personnel develop a waste profile which describes the waste stream, characteristics, and packaging. WMH personnel also develop a portfolio which includes characterization documents (i.e., sample analysis, inventory sheets, MSDSs, etc.) as well as appropriate shipping documentation. The portfolio is sent to the receiving TSD facility for approval. When the portfolio has been approved the waste is shipped to the appropriate TSD per 49 CFR (DOT) or the applicable SARP/SEP.

The WMH managed TSD facilities perform waste verification on the waste containers to ensure the waste complies with the waste profile. Waste verification varies between 5% and 100% on waste containers depending on the waste stream and waste nonconformances.

7.3.4.2 Waste Equipment. Radioactive solid wastes are packaged in metal drums or burial boxes, depending on the size of the wastes. Burial boxes are used to dispose of failed equipment, HEPA filters, and other radioactive solids too large to fit into UN 1A1 55-gal drums. Dangerous solid wastes are collected in metal drums. Nonradioactive, nondangerous solid wastes are generally collected in metal dumpsters.

Radioactive waste drums consist of UN IA2 55-gal galvanized, aluminized, or painted drums. Each drum is quality control inspected and approved before use and is provided with a trace number. Each drum contains an absorbent or a Radpad in the bottom of the drum, a minimum of a 4-mil polyethylene liner, and an absorbent in the bottom of the liner. An alternative to the liner and absorbent components is a piping component consisting of a spacer securing an inner vessel within the drum. Drums are sealed with lock ring seals whose lock bolts are tightened in accordance with vendor information. Some, but not all, drums are equipped with a filter vented lid. Those drums that present the potential for pressurization are equipped with a filtered vent lid and may also contain a hydrogen oxygen recombinant catalyst pack be added to the drum to prevent pressurization resulting from the decomposition and/or interaction of organics that may be present.

Burial boxes consist of steel boxes or wood boxes. The steel boxes are painted inside and outside so that no bare metal is exposed. Each box is lined with a 6-mil (minimum) polyethylene liner. Boxes are designed to be watertight and are kept closed when not in use. When filled, the steel boxes are bolted shut with bolts tightened to specified torques, or secured with clips and security seals are applied. The wood boxes are nailed and banded shut.

7.3.5 Operating Procedures

Packaging of Waste. TRU waste is generally sealed out of the glovebox, bagged, and loaded into approved isolated transportation containers (ITCs). The ITCs are then subjected to an NDA measurement. As each waste package is placed into a waste container, a log sheet is filled out specifying the total plutonium present. Low level waste packages may be placed directly into the waste container after contamination survey to verify that there is no surface contamination. Management must be notified if the waste package contains greater than 187 g plutonium. After NDA, the waste package is placed in the container. Waste packages are added until the waste container is determined to be full. Drums are considered full when any of the following conditions are met:

- For PFP drums other than PRF drums, when plutonium content reaches 187 g (HNF-EP-0063 limit)
- For PRF drums, when plutonium content reaches 150 g (based on PRF operating experience; in some cases, total drum assay is higher than sum of individual package assays)
- When the drum surface dose rate reaches 200 mrem/h at any point (HNF-EP-0063 limit)
- When the drum estimated gross weight reaches 300 lb (the PFP limit based on personnel safety for drum handling) or up to 500 lb with management approval
- When the drum is physically full and additional waste can not be added.

Further actions depend on the results of the assay, as follows:

- If less than 1 g, attach CAUTION radioactive materials label, remove fissile labels
- If between 1 and 10 g, attach standard package label recording identification number, type of material, gross weight, grams of fissile material, net weight, H/X, and seal number
- If greater than 10 g, transfer the drum to a segmented gamma scan assay system in 2736-ZB. Have NDA personnel count the drum. If greater than 187 g plutonium, notify management.

Waste packages and containers are also surveyed to control radiation exposure. Department of Transportation shipping regulations limit each waste package to less than 20 dpm/100 cm^2 of removable alpha contamination, however Hanford Site and PFP radiological control policies prohibit any detectable surface contamination.

Compactible solid LLW consists of paper, plastic, cloth, tape, cardboard, etc. Compactible solid LLW is collected and transferred to the 234-5Z Building, room 192. In room 192 the LLW is assayed on the Multi-Energy Gamma Assay System. If the assay is 100 nCi/g or greater, the LLW is handled as TRU room waste. All LLW is classified and segregated according to category 1 or 3, based upon HNF-EP-0063. Category 3 waste is not compacted, but category 1 waste is compacted. The waste is stored at the PFP until ready for transport to the designated TSD facility.

Non-compactible solid LLW consists of non-compactible category 1 and 3 materials. The waste may be categorized by surface contamination levels or NDA. The waste is stored at the PFP until ready for transport to a designated TSD facility.

TRU drums are vented using a carbon composite filter in the lid of the drums. If a waste drum is determined to be pressurized, it is depressurized using a specific work plan.

Some drums have been found with small amounts of liquid (as detected by radiograph) and do not meet the WIPP WAC. These are sent to the PFP for repackaging using an approved work plan or procedure. Currently, all drums have absorbent added to absorb any "free" liquid.

Mixed Wastes. Mixed Wastes (MWs) are packaged to meet HNF-EP-0063, 49 CFR, and/or SARPs, and the appropriate waste profile in accordance with facility specific procedures or work plans. MWs are stored in designated hazardous waste 90-day accumulation areas prior to shipment to the appropriate treatment, storage, or disposal facility (TSD).

7.3.5.1 Solid Waste Packaging, Handling Safety, and Criticality Prevention. Criticality safety limits for solid waste management are based on determination of the fissionable material content of each waste package placed in a waste container and on observation of fissionable material limits and handling procedures.

- Packaging
  - Fissile material content in a standard 55 gallon drum may not exceed 187 grams. This limit is consistent with the fissionable material content limits for standard 55 gallon drums contained in HNF-PRO-0063, *Hanford Site Solid Waste Acceptance Criteria*.
  - A maximum of 250 grams fissile material is allowed in a 55 gallon drum (TRU waste) which contains an unrestricted quantity of polyethylene (CPS-Z-165-80100).

- A maximum of 100 grams of fissile material is allowed in a drum if the fissile material is contained in less than 20% (one-fifth) of the drum volume.

- The maximum material allowed per SS&C cemented billet can is 100 grams.

- For discrete "packages" of plutonium (sample vials, contaminated bottles, etc.) with less than or equal to 15 grams plutonium each, spacing, location, and volumes are not controlled provided that the total accumulation of such packages shall not exceed 100 grams.

• Handling

General Spacing Limits (CPS-Z-165-80100)

Fissile material spacing limits listed below give general spacing requirements. Other specific requirements or limits can be found in this CPS (CPS-Z-165-80100) and in other CPS's which apply to specific container or storage locations.

- Minimum spacing between two storage arrays or an array and more than 100 grams fissile material (including non-isolating walls) is 3 ft.

Transition Spacing

- Minimum spacing from other transition operations is 3 ft.

- Minimum spacing from other storage arrays while in transition is 18 in.

- Minimum spacing between items in storage during transition into and out of a storage array is not required. DOES NOT PERMIT STACKING.

ITC Spacing Requirements (CPS-Z-165-80100)

- Maintain an 18-in. minimum spacing between ITCs and between ITC and any other items containing over 100 grams of fissile material including through non-isolating walls when in storage.

- ITCs containing unmeasured waste shall be spaced a minimum of 3 ft from other unmeasured waste items and from any other items containing over 100 grams of fissile material including through non-isolating walls when in storage.

- An unattended transportation array is considered to be in storage, not in transit. Minimum spacing of 3 ft between two storage arrays or an array and items containing more than 100 grams fissile material, unless specifically permitted by a CPS.

- Minimum spacing of 3 ft is required between two unmeasured items or an unmeasured items and other arrays greater than 100 grams fissile material.

- Minimum spacing of 18-in. is required between transportation array and any storage array or glovebox during movement, unless transportation array can be combined with the storage array under posted criticality limits (i.e., introduce the item into a glovebox or storage array).

- If the spacing required would extend through a non-isolating wall, then the space on the other side of the wall must be examined to determine no spacing violations would exist when items or arrays are stored near the wall.

The following criticality safety-related limits and procedures have been established for standard waste boxes (SWBs).

- Maximum plutonium content is 325 g per SWB.

- A 3-ft minimum spacing is to be kept between each SWB and other fissile material.

Additional safety procedures have been established for waste containers.

- All water-soaked rags are wrung out and dried before loading. Absorbent is added to all packages that might contain inorganic liquid to help ensure that all free liquids are absorbed.

- Sharp corners and edges are padded and taped before packages are loaded into drums and boxes.

7.3.5.2 Administrative Procedures. Administrative controls are relied upon for solid waste segregation. Separate waste containers are provided for each type of waste (i.e., TRU waste, LLW, MW, and DW). Contents inventory sheets (CISs) are used to track the inventory of each waste container to ensure that unauthorized wastes are not present. In addition, written procedures exist for each waste type and container type.

7.3.6 Characteristics, Concentrations, and Volume of Solid Waste

Nonradioactive and radioactive solid wastes are generated at a number of sites at the PFP. The sites are not fixed; they can be moved or deleted or new sites can be added.

LLW generation rate for 1996 is anticipated to be 1500 UN 1A2 55-gal drums. The LLW absorbed organic (12 L per drum) CCl_4, TBP nominal waste generation rate is 50 ft^3/yr. For low-level PCB hydraulic fluids (greater than 50 ppm and less than 70,000 ppm PCB in diesel or PYDRAUL or FYRQUEL hydraulic fluids--30 L liquid per drum) the nominal waste generation rate is 66 ft^3/yr or 90 drums per year.

The TRU-absorbed organics [CCl_4, tributyl phosphate (TBP) and its degradation products; dibutyl phosphate (DBP) and monobutyl phosphate (MBP), TBP in normal paraffin hydrocarbons, xylene, trimethyl benzene, nonionic detergent, and trioctal phosphine oxide) are placed in UN 1A2 55-gal drums.

Drums contain 12 L of liquid. The nominal waste generation rate would be 52 ft^3/yr or seven drums per year if the PRF were operating.

The TRU PCB-contaminated solid waste (rags, protective clothing, tools, hydraulic hoses, and equipment) is placed in UN 1A2 55-gal drums. The nominal waste generation rate is 30 ft^3/yr or four drums per year. The TRU PCB-contaminated burial box waste nominal waste generation rate is 50 ft^3/yr.

The TRU PCB hydraulic fluids (greater than 50 ppm and less than 70,000 ppm PCB in normal paraffin hydrocarbon or polyphenyl phosphate-based hydraulic fluids) are placed in UN 1A2 55-gal drums. The nominal waste generation rate is 50 ft^3/yr or seven drums per year.

7.3.7 Packaging

All radioactive waste, DW, and MW is packaged, transported, and stored in an environmentally safe manner. The packaging requirements for radioactive waste, DW, and MW are described in *Hanford Site Solid Waste Acceptance Criteria*, HNF-EP-0063, specific SARPs/SEPs, and/or 49 CFR.

The specific packaging, labeling, and manifesting requirements for actual waste packages or waste items are defined in *Responsibilities and Procedures for All Hazardous Materials*, HNF-PRO-154; *Radioactive Material/Waste Shipments*, HNF-PRO-157, and *Non-Radioactive Material/Waste Shipments*, HNF-PRO-156. This document is prepared in accordance with applicable state and federal dangerous waste and transportation regulations or DOE-authorized alternate criteria.

Other requirements have been established in *Radioactive Material/Waste Shipments*, HNF-PRO-157, and Non-Radioactive Material/Waste Shipments, HNF-PRO-156. These define the control of handling, storage, cleaning, packaging, preservation, and shipping of items to prevent damage or loss and to minimize deterioration. These requirements have been implemented using approved procedures, instructions, drawings, specifications, shipment instructions, or other pertinent documents or procedures.

7.3.8 Storage Facilities

Containerized LLW is stored either in radioactive material areas (RMAs) within the 234-5Z or 2736-ZB buildings or outside in the 234-5Z West Pad or South Pad waste storage RMAs.

Containerized TRU waste may be stored in the same locations. When TRU waste is stored in an outside RMA it must meet the requirements of WHC-SD-CP-OSR-010, 5.24.1, *Management of TRU Material stored in RMA Outside Facility Buildings*.

MW and DW must be stored in established satellite accumulation areas (SAAs). When a SAA accumulates 55 gallons of DW/MW or 1 quart of acutely hazardous waste it must be moved to the appropriate 90 day accumulation area within three days. 90 day accumulation areas are inspected on a weekly basis per WAC 173-303.

7.4 VENTILATION EXHAUST SYSTEMS AND OFFGAS TREATMENT

See Chapter 5.0, Section 5.4.1 for details of the HVAC system of the PFP complex.

The ventilation exhaust systems provide for the discharge of all treated airborne and gaseous effluents. These systems provide exhaust for the ventilation systems and the offgas treatment systems.

The ventilation systems at the PFP are designed and constructed to confine airborne radioactive materials within the appropriate areas of the building. The ventilation systems clean all normally or accidentally contaminated air effluent streams before release to the environment to as far below established limits as is reasonably achievable.

The ventilation systems are a safety feature of the facility. As such, they are designed to compliment the building layout and remain functional during all operational modes and fail safely during credible accident conditions where stopping is acceptable. Safety considerations and controls for the ventilation systems can be found in Chapter 5.0, Section 5.4.1.

7.5 LIQUID WASTE SOLIDIFICATION

Small amounts of sludge, glovebox floor sweepings, glovebox residue with free moisture, and other TRU waste are solidified into a cement matrix. The ingredients are mixed in accordance with approved plant operating procedures. Contents are allowed to solidify and cure for 24 h, inspected for free liquids, packaged, NDA'd, and transferred to TRU waste drums.

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Table 7-1. Radioactive Releases (Annual Average Concentrations in μCi/mL). (3 sheets)

Year	Location	Radionuclide	Airborne release (Ci)	Average concentrations (μCi/mL)
1990	291-Z-1	^{238}Pu	8.1 E-06	2.2 E-15
		$^{239,240}Pu$	2.2 E-04	6.0 E-14
		^{241}Pu	1.2 E-03	3.2 E-13
		^{241}Am	6.1 E-05	1.7 E-14
		Total flow (L)	-	3.7 E+12
	296-Z-3	$^{239,240}Pu$	5.8 E-06	2.1 E-13
		^{241}Am	4.6 E-07	1.7 E-14
		Total flow (L)	-	2.7 E+10
	296-Z-5	$^{239,240}Pu$	ND	<1.3 E-15
		^{241}Am	ND	<2.6 E-15
		Total flow (L)	-	1.6 E+11
	296-Z-6	Total flow (L)	-	1.7 E+11
	296-Z-14	Total flow (L)	-	1.1 E+09
1991	296-Z-1	$^{239,240}Pu$	2.4 E-04	6.3 E-14
		^{241}Pu	1.8 E-03	4.6 E-13
		^{241}Am	5.7 E-05	1.5 E-14
		Total flow (L)	-	3.9 E+12
	296-Z-3	$^{239,240}Pu$	3.5 E-06	1.4 E-13
		^{241}Am	4.4 E-07	1.7 E-14
		Total flow (L)	-	2.6 E+10
	296-Z-5	$^{239,240}Pu$	ND	<2.9 E-15
		^{241}Am	ND	<5.8 E-15
		Total flow (L)	-	1.6 E+11
	296-Z-6	Total flow (L)	-	1.4 E+11
	296-Z-14	Total flow (L)	-	2.4 E+10

Table 7-1. Radioactive Releases (Annual Average Concentrations in μCi/mL). (3 sheets)

Year	Location	Radionuclide	Airborne release (Ci)	Average concentrations (μCi/mL)
1992	291-Z-1	$^{239,240}Pu$	4.2 E-04	7.9 E-14
		^{241}Pu	2.9 E-03	5.5 E-13
		^{241}Am	7.2 E-05	1.4 E-14
		Total flow (L)	-	3.7 E+12
	296-Z-3	$^{239,240}Pu$	1.0 E-06	2.0 E-14
		^{241}Am	8.8 E-07	1.7 E-14
		Total flow (L)	-	3.6 E+10
	296-Z-5	$^{239,240}Pu$	ND	<7.5 E-16
		^{241}Am	ND	<1.9 E-15
		Total flow (L)	-	1.2 E+11
	296-Z-6	Total flow (L)	-	1.5 E+11
	296-Z-14	Total flow (L)	-	2.5 E+10
1993	291-Z-1	^{238}Pu	ND	<1.2 E-14
		$^{239,240}Pu$	5.1 E-04	1.4 E-13
		^{241}Pu	3.4 E-03	9.4 E-13
		^{241}Am	9.3 E-05	2.5 E-14
		Total flow (L)	-	3.7 E+12
	296-Z-3	$^{239,240}Pu$	4.4 E-07	1.6 E-14
		^{241}Am	1.9 E-07	7.1 E-15
		Total flow (L)	-	2.7 E+10
	296-Z-5	$^{239,240}Pu$	ND	<9.7 E-16
		^{241}Am	7.9 E-07	5.3 E-15
		Total flow (L)	-	1.5 E+11
	296-Z-6	Total flow (L)	-	1.4 E+11
	296-Z-14	Total flow (L)	-	2.5 E+10

Table 7-1. Radioactive Releases (Annual Average Concentrations in μCi/mL). (3 sheets)

Year	Location	Radionuclide	Airborne release (Ci)	Average concentrations (μCi/mL)
1994	291-Z-1	^{238}Pu	1.5 E-05	4.3 E-15
		$^{239,240}Pu$	3.0 E-04	8.6 E-14
		^{241}Pu	2.0 E-03	5.7 E-13
		^{241}Am	5.5 E-05	1.6 E-14
		Total flow (L)	-	3.5 E+12
	296-Z-3	^{238}Pu	9.0 E-08	4.7 E-15
		$^{239,240}Pu$	1.1 E-07	5.8 E-15
		^{241}Am	ND	ND
		Total flow (L)	-	1.9 E+10
	296-Z-5	$^{239,240}Pu$	ND	ND
		^{241}Am	ND	ND
		Total flow (L)	-	1.2 E+11
	296-Z-6	Total flow (L)	-	1.3 E+11
	296-Z-14	Total flow (L)	-	2.3 E+10
1995	291-Z-1	^{238}Pu	2.3 E-06	6.2 E-16
		$^{239,240}Pu$	7.6 E-05	2.0 E-14
		^{241}Pu	2.0 E-04	5.4 E-14
		^{241}Am	1.5 E-05	4.0 E-15
		Total flow (L)	-	3.6 E+12
	296-Z-3	^{238}Pu	3.5 E-08	2.5 E-15
		$^{239,240}Pu$	3.1 E-08	2.2 E-15
		^{241}Pu	3.1 E-06	2.2 E-13
		^{241}Am	1.5 E-08	1.0 E-15
		Total flow (L)	-	1.3 E+10
	296-Z-5	Total flow (L)	-	1.3 E+11
	296-Z-6	Total flow (L)	-	1.3 E+11
	296-Z-14	Total flow (L)	-	2.9 E+10
	296-Z-15	Total flow (L)	-	2.3 E+10

SOURCE: Environmental Releases for Calendar Year, WHC-EP-0527
ND - No data.

Table 7-2. Plutonium Finishing Plant (Historical) Radioactive Effluent Stream Compositions. (2 sheets)

Species	Units	PRF CAW	Range	PRF CXP	PRF CUU	RMC HSW	PRF LSW	RMC LSW	Labs LSW
Normal flow	L/h	158	-	18	20	25	43	66	20
Peak flow	L/h	200	-	30	25	100	110	90	200
SpG	g/cc	1.18	-	1.05	1.05	1.27	1.06	1.03	1.01
Nominal composition									
Al^{+++}	M	0.7	0.47 - 0.78	0.00	0.00	0.00	0.00	0.00	0.00
	ppm	20,000	10,000 - 18,000	0.00	0.00	0.00	0.00	0.00	0.00
Ba^{++}	M	0.0000005	-	1 E-06	0.00	0.00	0.000004	0.000001	2 E-07
Ca^{++}	M	0.001	-	0.000033	0.00	0.00	0.001	0.00006	0.000007
Cr	M	0.002	2 E-07 - 2 E-03	2 E-07	2 E-07	0.000002	2 E-07	2 E-07	2 E-07
Fe^{++}	M	0.001	0 - 0.2	0.000036	0.00	0.00	0.0002	0.00007	0.000008
H^+	M	2.6	1.9 - 3.5	0.00	0.4	0.00	2.0	0.8	0.456
K^+	M	0.001	0 - 0.2	0.00	0.00	6.0	0.005	0.003	0.00
Mg^{++}	M	0.00003	-	0.000005	0.00	0.00	0.00002	0.00001	0.000001
Mn^{++}	M	0.001	0 - 0.2	0.000001	0.00	0.00	0.003	0.005	4 E-07
Na^+	M	0.03	0 - 0.5	0.92	0.005	1.0	0.006	0.005	0.004
Ni^{++}	M	0.0008	0 - 0.002	2 E-07	2 E-07	0.000002	2 E-07	2 E-07	2 E-07
Pb^{++}	M	0.005	-	0.00	0.00	0.00	0.00	0.00	0.00
Sr^{++}	M	0.00003	-	4 E-07	0.00	0.00	0.000001	7 E-07	9 E-08
OH^-	M	0.00	-	0.005	0.00	2.6	0.00	0.00	0.00
CO_3^{--}	M	0.00	-	0.5	0.00	0.02	0.00	0.00	0.00
Cl^-	M	0.01	0 - 0.7	0.0001	0.0001	0.3	0.006	0.001	0.0003
F^-	M	0.05	0.02 - 0.06	0.06	0.07	3	0.00	0.00	0.00
I^-	M	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
NO_3^-	M	4.8	4.0 - 5.6	0.4	0.4	0.00	2.0	0.8	0.135
NO_2^-	M	0.02	-	0.001	0.00	0.00	0.01	0.01	0.109
PO_4^{--}	M	0.0002	-	0.00002	0.00	0.00	0.00009	0.00004	0.000004
SO_4^{--}	M	0.002	-	0.00	0.00	0.00	0.00	0.00	0.480
CCl_4	M	0.005	-	0.005	0.005	0.00	0.002	0.00	0.00
Ammonia	M	0.01	-	0.00	0.00	0.00	0.00	0.00	0.00
TBP	M	0.02	-	0.02	0.02	0.00	0.00	0.00	0.00
Butanol	M	0.0002	(1.7 - 2.1) E-04	0.00	0.00	0.00	0.008	0.00	0.00
DBP	M	0.00	-	0.004	0.00	0.00	0.00	0.00	0.00
MBP	M	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
TOC	g/L	3	-	4	3	0.00	0.4	0.00	0.00
Silica	g/L	See ppm for all streams	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pu	g/L	0.009	0.002 - 0.2	0.06	0.015	2 E-06	0.003	0.007	0.0401
Am	g/L	0.001	2 E-05 - 3 E-02	0.00	0.003	0.00	0.001	0.001	0.0006
U	g/L	0.001	-	0.00	0.02	0.00	0.00	3 E-06	0.00

Table 7-3. Plutonium Finishing Plant (Historical) Radioactive Effluent Stream Compositions with Slag and Crucible Processing.

(Note: Data incorporated in Table 7-2)

Table 7-4. 234-5Z Building Waste Water Streams. (2 sheets)

Stream description	Manhole number	Location
Analytical Laboratory:		
Corridor 4D eyewash drain	Z3	LLWTF
Room 132 90-lb air line condensate trap	Z4	LLWTF
Room 141 cold chemical sink	Z4	LLWTF
Cold Development Laboratory:		
Room 202 mezzanine eyewash drain	Z4	LLWTF
Room 202 sink drains (3)	Z4	LLWTF
Room 169 HA-40F furnace cooling water (2) (Inactive)	Z3	LLWTF
Room 169 HA-40F condenser (4) (Inactive)	Z3	LLWTF
Room 170 HC-46F condenser (4) (Inactive)	Z3	LLWTF
Room 221A RADCON Office:		
HVAC condensate drain	Z3	LLWTF
HVAC cooling water drain	Z3	LLWTF
Room 229 RMC control room HVAC cond (2)	Z4	LLWTF
Room 235A2 RMA hydraulic pump	Z4	LLWTF
Room 235B RMA line cooling water drains	Z4	LLWTF
Room 262 duct level:		
Funnel drains (2)	Z4	LLWTF
Cold water overflow drain	Z4	LLWTF
HVAC condensate drains (3)	Z4	LLWTF
HVAC condensate drain	Z3	LLWTF
HVAC cooling water drains (4)	Z3	LLWTF
Protected process water backflow preventer drains	Z1	TEDF
Room 263 duct level:		
RMC control room HVAC condensers (2)	Z1	TEDF
Room 265 duct level:		
Backflow preventer drain	Z4	LLWTF
Room 308 duct level:		
26 in. vacuum pump cooling towers (2)	Z1	TEDF
Room 319 heat exchanger cooling water (2)	Z1	TEDF
Room 321 Ventilation Room:		
Supply fan condensate and overflow (8)	S1	TEDF
Electric dry air units (2)	S1	TEDF
Steam dry air units (2)	S1	TEDF
Distilled water tank overflow	S1	TEDF
Backflow preventer No. 12	S1	TEDF
Steam traps-PRV stations (6)	S1	TEDF
Steam traps-30 lb line (14)	S1	TEDF
Sink drain	S1	TEDF

Table 7-4. 234-5Z Building Waste Water Streams. (2 sheets)

Stream description	Manhole number	Location
Room 340 Instrument Shop:		
Computer room HVAC drain	Z3	LLWTF
Roof drains, west end (15)	Z1	TEDF

SOURCE: PFD-Z-180-00006 E-0

Table 7-5. 236-Z Building Waste Water Streams.

Stream description	Manhole number	Location
Fire water drains to exhaust duct sump (10)	Z4	LLWTF
Slag and crucible:		
Tank 12 cooling jacket J-13 drain (Inactive)	Z4	LLWTF
Tank 125 protected process cooling water and steam condensate - BLANKED OFF (Inactive)	Z4	LLWTF
Corridor 30 process steam supply condensate trap (2)	Z4	LLWTF
Ventilation heater steam condensate drains (7)	Z4	LLWTF
Tank 43 concentrator steam supply condensate drain (Inactive)	Z4	LLWTF
Corridor 33 chemical preparation room steam supply trap	Z4	LLWTF
Tank 21 filtrate evaporator steam supply condensate drain (Inactive)	Z4	LLWTF
Room 35 Equipment Room:		
Vacuum pump seal water drain (2) CLC	Z4	LLWTF
90-lb air filter drains (2)	Z4	LLWTF
Floor drain	Z4	LLWTF
Process water supply backflow preventer drain	Z4	LLWTF
Room 41 Miscellaneous Treatment: (Inactive)		
H-3 Tank 144 cooling water drain	Z4	LLWTF
H-4 furnace condenser cooling water drain	Z4	LLWTF
H-4 still condenser cooling water drain	Z4	LLWTF
Room 45 Shift Office HVAC drain	Z4	LLWTF

SOURCE: PFD-Z-180-00006 E-0

Table 7-6. 291-Z Building Waste Water Streams.

Stream description	Manhole number*	Location
Air sample vacuum system vacuum pump No. 1 seal water drain	Z3	LLWTF
Air sample vacuum system vacuum pump No. 2 seal water drain	Z3	LLWTF
No. 1 instrument air dryer prefilter drain	Z3	LLWTF
No. 2 instrument air dryer prefilter drain	Z3	LLWTF
No. 1 instrument air compressor condensate blowdown drain	Z3	LLWTF
No. 2 instrument air compressor condensate blowdown drain	Z3	LLWTF
Instrument air receiver drain	Z3	LLWTF
Process air compressor	Z3	LLWTF
Process air traps	Z3	LLWTF
Process air receiver drain	Z3	LLWTF
Exhaust fan ET-8 cooling water/steam condensate drain+	Z3	LLWTF
Evaporative air conditioner No. S-11 drain	Z3	LLWTF
Evaporative air conditioner No. S-12 drain	Z3	LLWTF
Evaporative air conditioner No. S-13 drain	Z3	LLWTF
Evaporative air conditioner No. S-14 drain	Z3	LLWTF
Evaporative air conditioner No. S-15 drain	Z3	LLWTF
Transformer room floor drain	Z3	LLWTF
Backflow preventer No. 25	Z3	LLWTF
Backflow preventer No. 26	Z3	LLWTF
CLC sock filters (2)	Z3	LLWTF

SOURCE: PFD-Z-180-00006 E-0
*Effluent streams are collected in the 291-Z sump before transferring through manhole Z3 to LLWTF.
+Exhaust turbine ET-8 has been deactivated.

Table 7-7. Other Building Waste Water Streams.

Stream description	Manhole number	Location
Building 242-Z[a]		
W-3 jacket cooling water drain riser	Z3	LLWTF
W-4 jacket cooling water drain riser	Z3	LLWTF
Tank A-1 overflow floor drain	Z3	LLWTF
Tank A-2 overflow floor drain	Z3	LLWTF
Tank A-3 overflow floor drain	Z3	LLWTF
Tank A-4 overflow floor drain	Z3	LLWTF
Safety shower floor drain	Z3	LLWTF
Wound flushing station drain	Z3	LLWTF
Building 232-Z[b]		
HVAC condensate drains	Z1	TEDF
HVAC room floor drain	Z1	TEDF
243-ZB Cooling Towers[c]		
FC-1 Cooling Tower drain	Tk-101	LLWTF
FC-2 Cooling Tower drain	Tk-101	LLWTF
Backflow preventer BFP-1	Tk-101	LLWTF
Backflow preventer BFP-2	Tk-101	LLWTF
Building 2736-ZB		
Room 602 HVAC condensate drains	Z1	TEDF
Room 602 floor drain	Z1	TEDF

SOURCE: PFD-Z-180-00006 E-0

[a]Water utilities are shut off to this building. There are no routine contributors to the LLWTF from 242-Z.
[b]Water utilities are shut off to this building. There are no routine contributors to the TEDF from 232-Z.
[c]The cooling towers and backflow preventers drain directly to the LLWTF feed tank, Tk-101.

Table 7-8. Active Sump Tanks.

Sump tank	Location	Function	Description	Normal operating level (L)	Nominal plutonium inventory (g)	Physical form	Nominal chemical form	Criticality specification limit (g)
Tk-D4	241-Z	Radioactive mixed waste storage tank. Reserve storage capacity for tank overflows.	10-ft. x 10-ft. 3-in. stainless steel with 3/8-in. wall thickness	12,000	100	Liquid	$Pu(NO_3)_4$	400
Tk-D5	241-Z	Radioactive mixed waste storage and treatment tank. Receives waste solutions primarily from storage tank Tk-D8 with ability to receive from Tk-D7. All waste transfers to tank farms are through tank Tk-D5.	10-ft. x 10-ft. 3-in. stainless steel with 3/8-in. wall thickness	12,000	100	Liquid	$Pu(NO_3)_4$	400
Tk-D7	241-Z	Radioactive mixed waste storage tank. Reserve storage capacity for tank overflows.	10-ft. x 10-ft. 3-in. stainless steel with 3/8-in. wall thickness	12,000	100	Liquid	$Pu(NO_3)_4$	400
Tk-D8	241-Z	Radioactive mixed waste storage and treatment tank. Receives waste from PFP Laboratory and miscellaneous stabilization processes. Batch transfers are made from Tk-D8 to Tk-D5.	10-ft. x 10-ft. 3-in. stainless steel with 3/8-in. wall thickness	12,000	100	Liquid	$Pu(NO_3)_4$	400

Table 7-9. List of Plutonium Finishing Plant Chemical Constituents.

Chemical constituent	Formula
Potassium permanganate	$KMnO_4$
Potassium hydroxide	KOH
Oxalic acid	$H_2C_2O_4$
Nitric acid	HNO_3
Hydrogen peroxide	H_2O_2
ANN (aluminum nitrate nonahydrate)	$Al(NO_3)_3\ 9H_2O$
Sodium hydroxide	NaOH
Hydrazine	$NH_2 \cdot NH_2$
Tributyl phosphate	$(C_4H_8)_3\ PO_4$
Sodium nitrite	$NaNO_2$
Hydroxylamine nitrate	$NH_2OH\ HNO_3$

Figure 7-1. Gaseous Effluent Streams from the Plutonium Finishing Plant which Contain Low Levels of Radioactivity.
(Figure needs updating regarding the primary and backup ventilation)

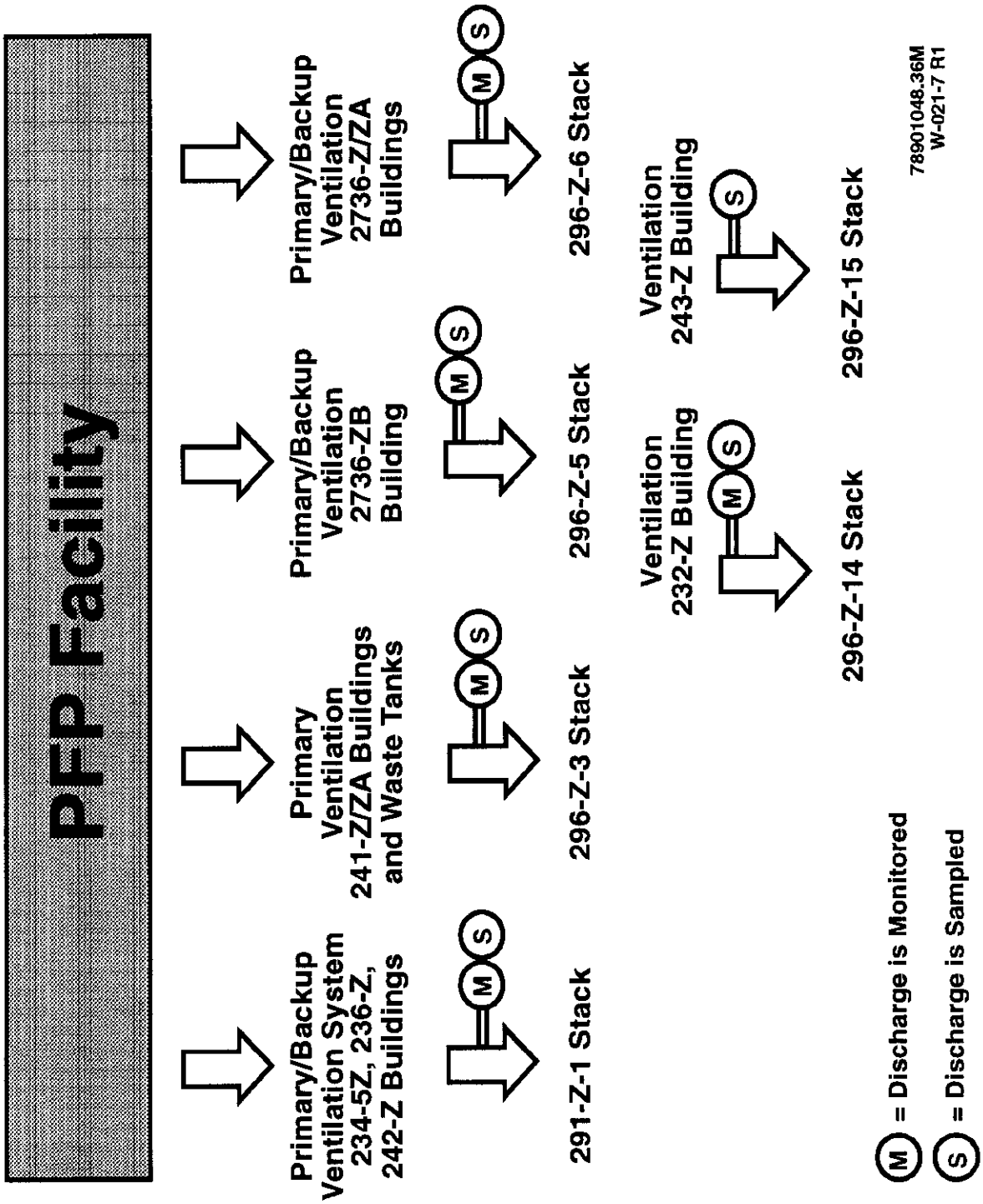


Figure 7-2. Facility Waste Water Stream.

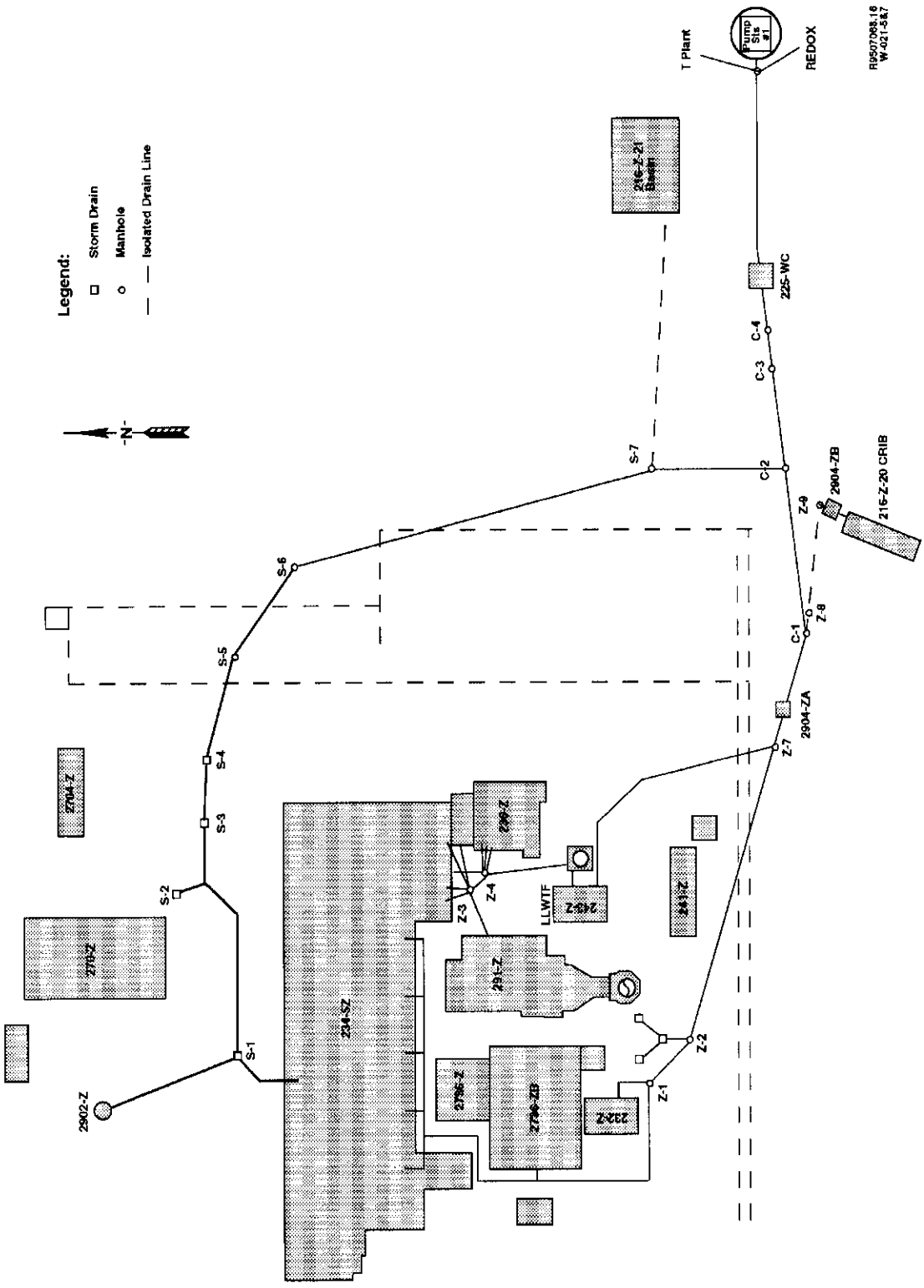


Figure 7-3. Location of French Drains.

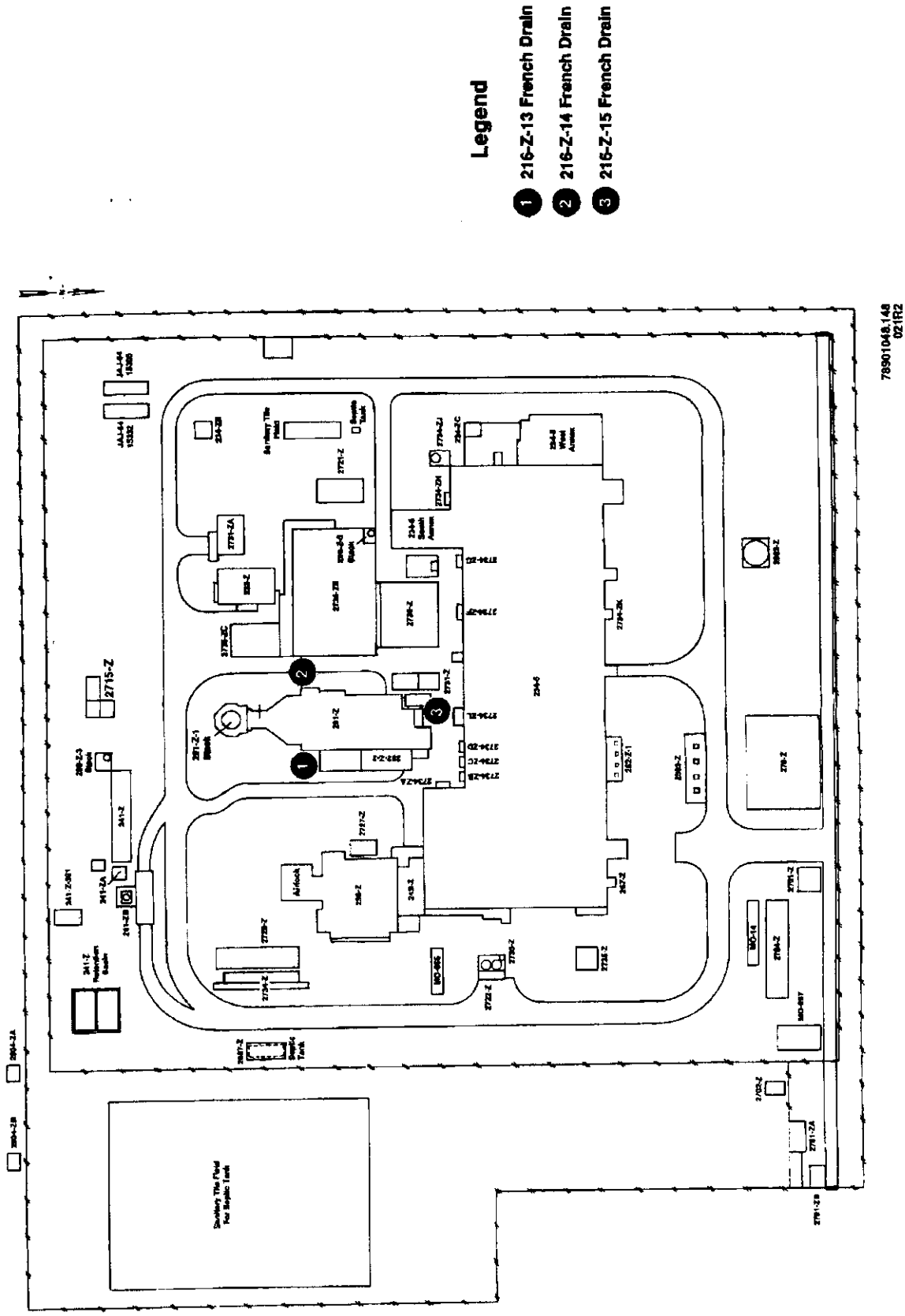


Figure 7-4. Comprehensive Environmental Response, Compensation, and Liability Act/Resource Conservation, and Recovery Act Sites within Plutonium Finishing Plant.
(Figure needs updating with respect to unplanned release sites)

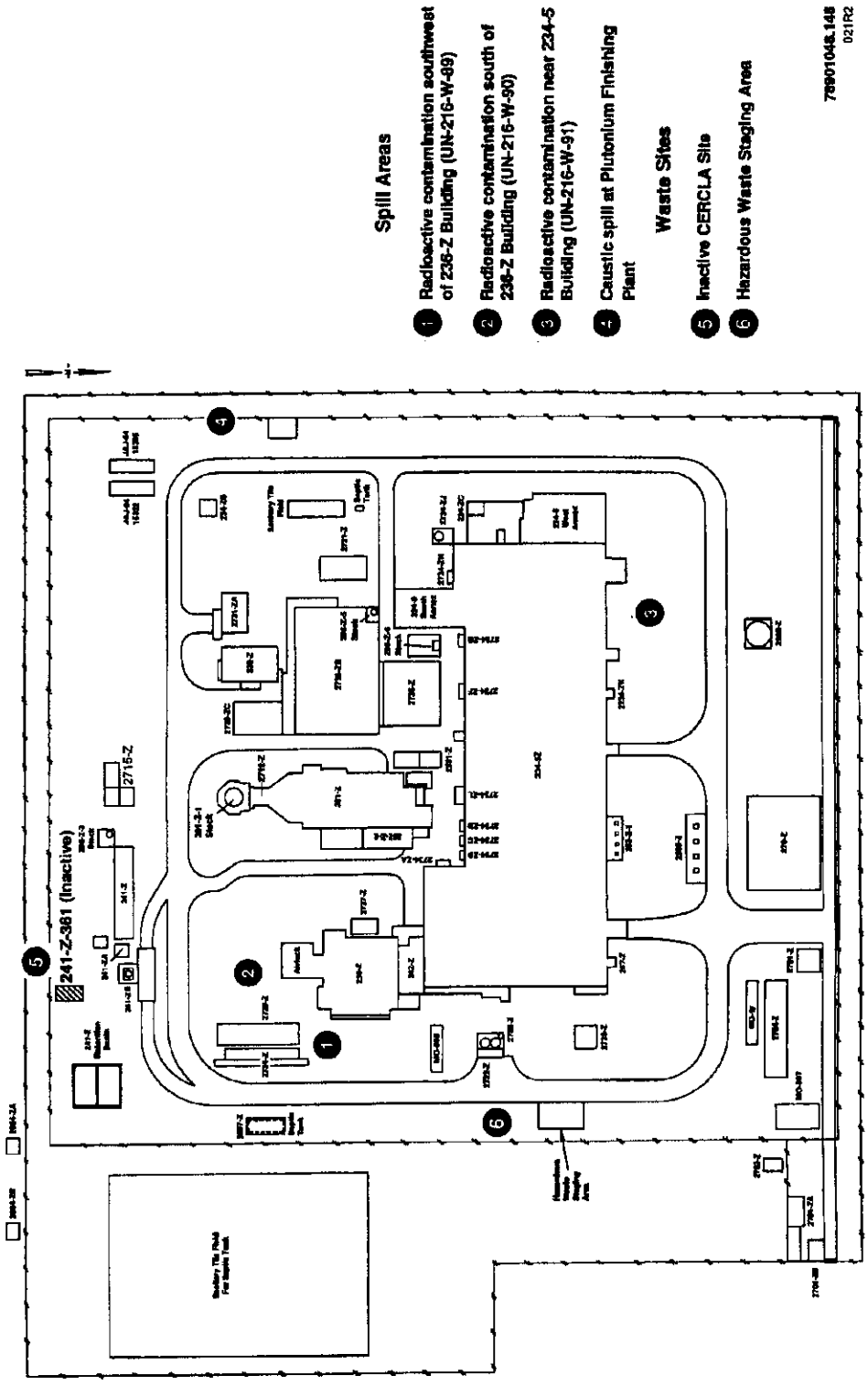


Figure 7-5. Building 241-Z Waste Storage and Treatment.

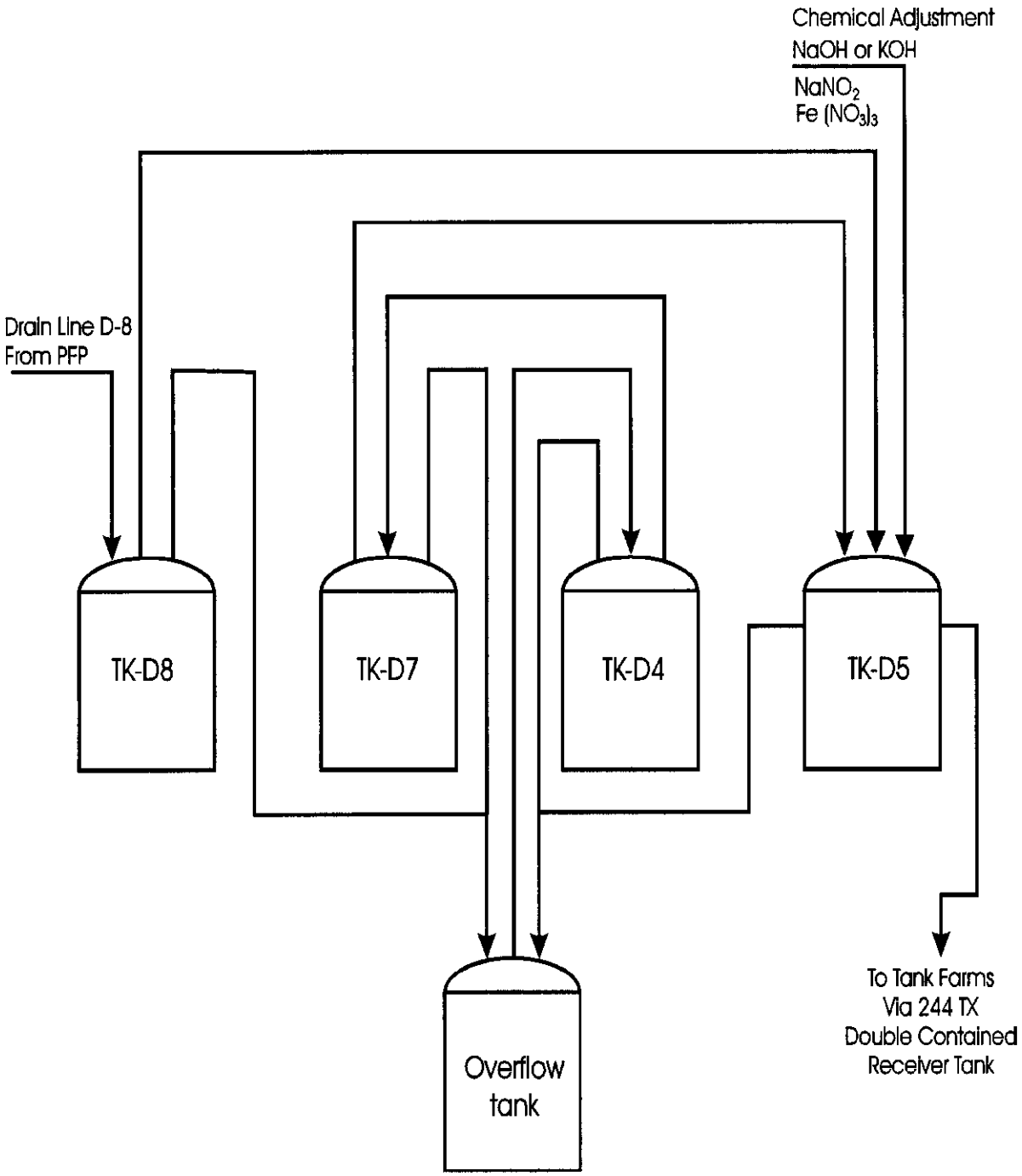
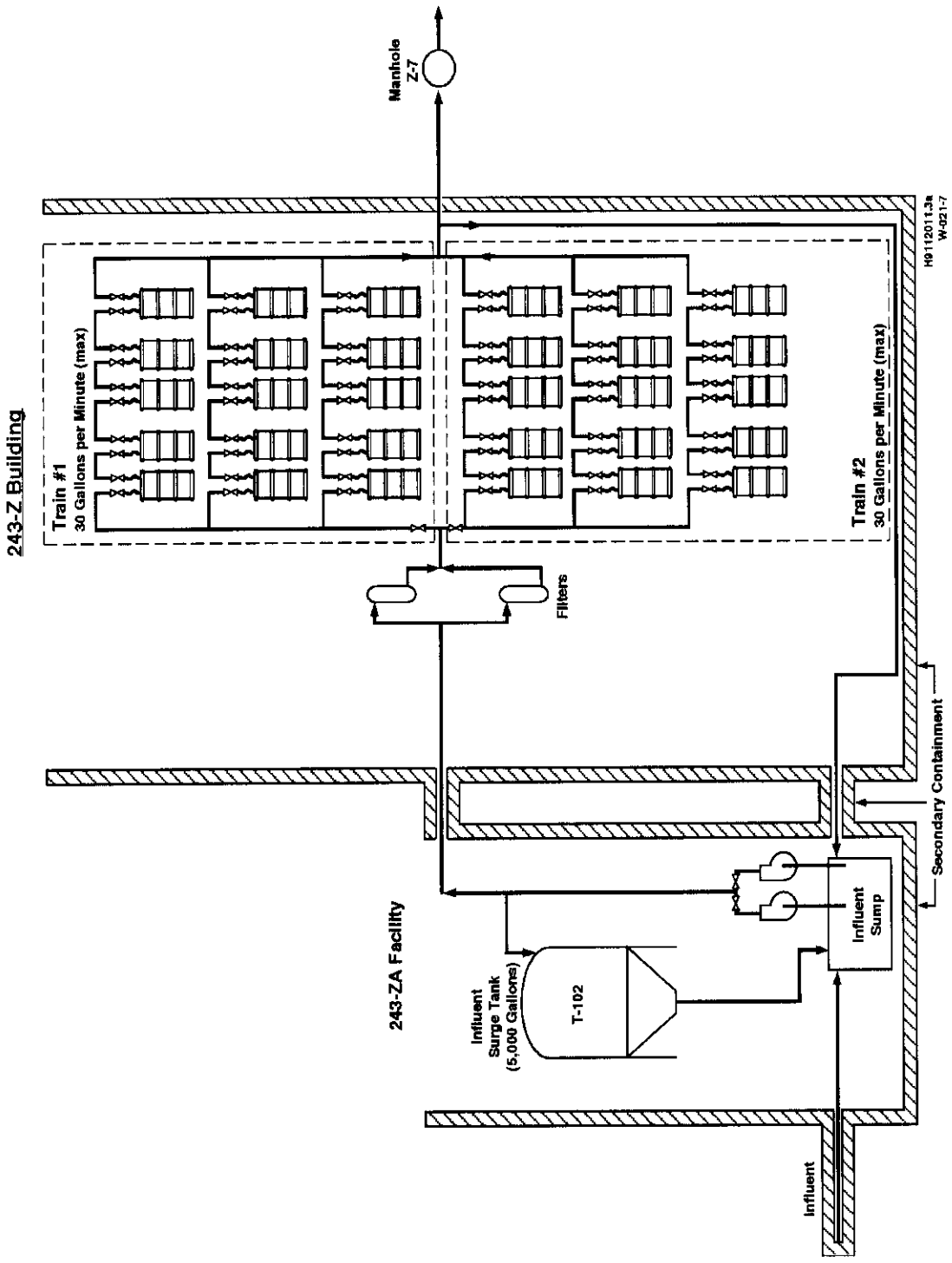


Figure 7-6. Low-Level Waste Treatment Facility Process Diagram.



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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 8.0

RADIATION PROTECTION

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 8.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) includes modifications for the following:

- Revision of the description of the solid waste stream
- Provide additional clarification of the airborne radioactivity sampling guidance documents and program responsibilities
- Clarification of the internal dosimetry programs

Other minor changes include editorial changes and additional clarifications.

It is noted that various sections of Chapter 8.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner located in the Plutonium Process Support Laboratories. Operation of either the production calciner or the laboratory calciner for solution stabilization is not authorized at this time and the related portions of Chapter 8.0 will be updated, if necessary, prior to initiation of operations.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the standby power system. However, the conversion from using steam-driven fans to standby power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply at some future date. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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8.0 RADIATION PROTECTION

This chapter describes the Hanford Contractor and Plutonium Finishing Plant (PFP) radiation protection program, which is designed to minimize the exposure of individuals and the environment to radiation, considering all potential sources of radiation and radioactive materials.

The Hanford Site customary radiological protection units are used in this chapter. This means that "rad" is used to denote beta particulate exposures, "R" or "roentgen" denotes gamma exposures, and "rem" denotes neutron exposures or the combination of any of these units. The term "dpm" (disintegrations per minute) indicates that readout of a radiation detection device that reads in "cpm" (counts per minute) has been corrected for its detection efficiency. In the PFP, dpm indicates an alpha or beta particulate survey measurement (see Section 8.5.2). The derived air concentrations (DAC) and derived concentration guides (DCGs) are based on International Commission on Radiological Protection (ICRP) 30 considerations as expressed in 10 CFR 835 *Occupational Radiation Protection*, Appendix A (DOE 1993a) and DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993b), respectively.

10 CFR 835 establishes radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from the conduct of Department of Energy (DOE) activities. The requirements found in 10 CFR 835 are the minimum required by law. 10 CFR 835 requires that each DOE contractor write a radiation protection program (RPP) that will implement the requirements of 10 CFR 835. Enforcement of 10 CFR 835 will be against the RPP.

The RPP was developed using requirements from the Project Hanford Radiological Control Manual, PHRCM; HNF-5173 (FH 2000), that best implement the 10 CFR 835 requirements. Therefore, the requirements are derived from the minimum requirements found in 10 CFR 835 and implemented through the RPP using the PHRCM. Implementation is described in *Fluor Daniel Hanford Radiation Protection Program Implementation of Title 10, Code of Federal Regulations, Part 835*, HNF-SP-1145.

Safety structures, systems, and components (SSCs) and procedures are required to minimize or mitigate the impact of design-basis accidents on the public, the environment, or the work force per DOE Order 6430.1A, *General Design Criteria*, Section 0111-99.0.1 (DOE 1989). Two safety categories have been defined as safety class and safety significant which are described in *Hazard and Accident Analysis Process* (HNF-PRO-704), Table 5, Safety SSC Criteria.

The use of the safety classification system aids the facility operations to establish priorities for equipment operation, maintenance, and repair. Plant SSCs related to safety are categorized as Safety Class or Safety Significant in a Safety Equipment Listing (SEL). The SEL for the PFP includes (among other systems) the stack effluent monitoring, supply ventilation seismic shutdown system, criticality alarm systems (CAS) and continuous air monitors (CAM), which are described in this chapter. Chapters 4.0, 5.0, 6.0, and 7.0 contain many of the details on how the PFP conforms to the design requirements of DOE Order 6430.1A (DOE 1989). This chapter contains

information that shows the PFP functional conformance with DOE Order 6430.1A (DOE 1989) criteria. See Section 4.4 of Chapter 4.0, "Safety Protection Systems", for additional details. See WHC-SD-CP-ES-128, *Preliminary Evaluation of PFP Conformance to DOE Order 6430.1A Principal Design Criteria* (WHC 1995a) for additional information on the PFP conformance to current design guidelines.

8.1 OCCUPATIONAL RADIATION EXPOSURES

8.1.1 As Low As Reasonably Achievable Policy

It is the site contractor policy that line management (facility manager) is responsible for the safe operation of facilities. The Radiological Control (RC) organization provides the services and overview necessary for a radiation protection program meeting the operational needs of the PFP.

The as low as reasonably achievable (ALARA) guidance philosophy required by 10 CFR 835, PHRCM, and DOE Order has been incorporated into the management policy and organizational structure. Management is committed to ALARA, and those responsible for implementing the program are alert to opportunities for reducing exposures.

The radiation dose to Hanford employees, visitors, and members of the general public originating from company operations is controlled to levels which are less than applicable DOE limits. Such radiation doses are further limited to levels that are ALARA. The following manuals describe the organizational structure and the methods for controlling and ensuring that human exposures to hazardous substances and conditions are maintained to ALARA: *ALARA Management Commitment and Policy*, HNF-PRO-1618; *ALARA Organization and Responsibilities*, HNF-PRO-1619; *ALARA Program Scope*, HNF-PRO-1620; and, *Plutonium Finishing Plant Administration*, FSP-PFP-5-8.

Facility line management has the responsibility for the implementation of and compliance with DOE safety regulations. Management has assigned the RC organization the responsibility for implementing company radiation protection standards and procedures, providing independent review and evaluation of the program, conducting the radiological support and dosimetry effort, and administering the company-wide ALARA program. The RC organization is assigned directly to plant director. See Chapter 10.0 for additional information.

The PFP line management is responsible for the radiological safety of the personnel assigned to the PFP as well as of visitors. The PFP line management and the PFP RC organization work together to identify the plant's radiation protection needs and to implement the Radiation Protection and ALARA programs.

The PFP line management has designated an ALARA Team which is a subcommittee to the ZAC, to aid the plant Manager in the application of ALARA. The PFP ALARA Team consists of representatives from various organizations such as: Engineering, Transition Operations, RC, Operations, Analytical Laboratories, Maintenance Work Control, PFP Safety, and Plutonium Process Support Laboratory (PPSL) groups, as well as the Plant Director and the ALARA Team Chairperson. The team meets as necessary to support changing plant

conditions. The ALARA team activities follow the requirements and HNF-PRO-1619, *ALARA Organization and Responsibilities.*

Plant personnel are made aware of management's commitment to ALARA via the establishment of the PFP ALARA goals, the ALARA procedure in the plant administrative manual, and pre-job meetings. Modifications have been made and will continue to be made to the facilities and plant procedures to implement ALARA improvements. Any person in the plant may submit ALARA-based suggestions for changes to plant procedures or modifications of plant facilities for reduction of personnel exposure to radiation or radioactive materials.

The ALARA representative or local contact is the interface with the function manager, functional organizations, and work package preparers/persons-in-charge (WPP/PIC). Facility management implements the formal ALARA program and acts as the interface between organizations in daily work activities within the PFP.

In addition to the ALARA program, the RC organization conducts periodic audits and appraisals of company operations. The purpose is to provide independent radiological control assessment to ensure that the applicable radiological safety standards and ALARA are being followed and are in compliance with the PHRCM (FH 2000), and 10 CFR 835 (DOE 1993a).

Sections 8.1.2 and 8.1.3 provide information on how ALARA is implemented in PFP design and operation.

8.1.2 Design Considerations

The original design for the PFP was based on the Uniform Building Code (UBC) of 1946 (ICBO 1946) and National Bureau of Standards (NBS) Handbooks 23 (NBS 1938) and 42 (NBS 1949).

Facilities were built and operated before there was a significant amount of design or ALARA guidance developed for this type of facility. The current DOE design and ALARA requirements have evolved from the design criteria developed for the PFP construction project.

The design philosophy used throughout the PFP was based on the premise that any exposure of personnel to possible internal plutonium depositions shall be avoided if at all possible. New or modified facilities, systems or equipment are designed today in accordance with current radiological design principles including ALARA. Design guidance is provided by *Radiological Design Review Process*, HNF-PRO-1622. 10CFR835 design criteria are utilized for the design of new or modification of existing shielding. The ALARA philosophy is applied to all areas of the plant. Some areas of the PFP that were designed to >1 mrem/h criteria remain. To maintain a $\leq$1 mrem/h average dose rate, administrative restrictions have been applied. Administrative control offsets higher design dose rates. This is acceptable because of the following:

- The original design was usually conservative

- Dose rates or personnel occupancy rates are lower than the designers expected

- Administrative restrictions have been implemented to minimize personnel occupancy.

The process equipment was and the new equipment is designed to provide confinement of airborne activity, completely separating the atmospheres exposed to possible plutonium contamination from air breathed by operating personnel. Since various operations performed in the different building spaces have varying potentials for external contamination spreads from a loss of confinement situation, a high degree of compartmentalization has been provided to isolate various spaces in the event of a contamination incident. Chapter 5.0 discusses how the facility structures respond to natural phenomena hazards. This chapter describes the special features that were incorporated into the design and ultimately built into the facilities to make the facilities appropriate for processing and handling large quantities of plutonium materials.

Facility management, with the aid of its ALARA program personnel:

- Review new designs or facility modifications to ensure that radiological design criteria principles include ALARA

- Ensures that facilities or modifications are designed to minimize exposure of personnel to radioactive materials or radiation

- Ensures that environmental assessments include ALARA principles so that design-based releases are ALARA

- Review technical work documents and work plans, determine the ALARA review requirements, and obtain the RC Organization concurrence in this determination [PHRCM, 312.3, 315.2 (FH 2000)].

At the time of construction there was minimal design or ALARA guidance, but the following features of the PFP have evolved as a result of ALARA and past operating experience. Lead shielding, ALARA panels, and lead-loaded rubber gloves are used in gloveboxes to reduce whole-body and extremity exposures. Gloveboxes are used in cases where handling of bare material is required or the risk of airborne contamination is high. The PFP design features and ALARA improvements have evolved over the last 40 yrs and are in functional conformance with today's standards. Some of these features are:

- The ventilation system is designed to ensure control of airborne contaminants even if normal airflow patterns may be disrupted, such as by an open glovebox access port. This system also maintains airflows from lowest to highest contamination potential and filters all radioactive material work areas and confinement device exhausts to ensure minimal escape of radioactive materials.

- The gloveports of new gloveboxes are strategically located to permit servicing of glovebox equipment.

- Service connections to the gloveboxes are protected with high-efficiency particulate air (HEPA) filter backflow preventers or are

sealed to minimize radioactive material contamination of the service lines.

- Operation and control of certain process equipment, valving, and material transfer are remote from the glovebox interior, thereby minimizing extremity and whole-body exposure.

- Supply airflow in radiological areas within process areas sweeps from ceiling to floor to maintain clean air in the breathing zone.

- Shielding is used for gloveboxes in many of the process areas for shielding neutron and gamma radiation, thereby reducing dose to personnel.

- Remote sensing penetrations have been installed in the plutonium materials storage vaults, where practical, to allow remote continuous air monitoring and sampling of storage vault atmospheres.

- The plutonium materials vault storage areas use various administrative and engineered controls to minimize dose, such as shielded pedestals and a real-time inventory system to minimize personnel dose.

- Air sampling, radiation monitors, and communications systems are provided to assist in early identification of a release to the environment and providing notification of an upset situation at the facility. All of the monitors have local alarms; some alarms have remote alarming features.

Consideration of decontamination and decommissioning (D&D) criteria for plant design was introduced to the nuclear industry after most of the PFP buildings were constructed.

Shutdown facilities first undergo terminal cleanout operations (TCO). This is intended to (1) recover any residual plutonium-bearing material in the equipment, gloveboxes, and heating, ventilation, and air-conditioning (HVAC) system and (2) leave the area in a stable condition requiring minimum surveillance pending D&D or reactivation. Following TCO, a facility will eventually be further decontaminated and decommissioned.

Shutdown facilities remain on ventilation control as long as radioactive materials remain. The CAMs are also maintained active and portable units are brought in if infrequent entry is required where there is a probability of airborne radioactivity. Fire protection is also maintained active when required by the site fire protection program. Criticality incident detection normally is not maintained since TCO results in fissile material quantities, forms, or configurations which ensure criticality prevention. Equipment is typically isolated from electrical services though support systems, such as fire protection and CAMs, may remain operational until D&D of the shutdown facility.

There was no initial requirement for incorporation of D&D features, but the following design features are an aid in the D&D of the facility: (1) compartmentalization and modularization of the facility and its processes; (2) isolated service piping and access levels for utilities and heating,

ventilation, and HVAC systems used in the various process modules and work areas; and (3) strategically located HEPA filters and filterboxes.

New or modified facilities/systems/equipment are designed in accordance with HNF-PRO-1622, *Radiological Design Review Process*, which is in accordance with accepted radiological design principles of DOE Order 6430.1A (DOE 1989) and *Radiological Performance and ALARA Goals*, HNF-PRO-1630. The Safety organization and RC is responsible for approving engineering documents for both initial release and subsequent revision based on assigned approval designators. The approval process is specified in *Engineering Release and Approval Requirements*, HNF-PRO-317.

8.1.3 Operational Considerations

The pertinent techniques of PNL-6577 (PNL 1988b) have been incorporated into the PFP procedures and methods of operation used to ensure that occupational radiation exposures are ALARA.

The Hanford contractors are responsible for the development of programs and procedures for occupational health protection in contractor-operated facilities. Whenever a new or revised DOE directive is issued, DOE-RL advises the affected contractor(s) in a formal letter. The appropriate executive is assigned the responsibility for incorporating the directive into procedures. *Managing DOE Directives*, HNF-PRO-116, establishes and maintains a controlled system of written management directives in the form of policies, requirements, and procedures. The controlled system governs the activities of the company performing work under the prime contract with the DOE. These management requirements and procedures establish the ALARA and Radiation Protection programs (see *ALARA Management Commitment and Policy*, HNF-PRO-1618, *ALARA Organization and Responsibilities*, HNF-PRO-1619, and *ALARA Program Scope*, HNF-PRO-1620).

The PFP operating and administrative procedures incorporate safeguards that help to ensure that contamination levels are ALARA. The principle of total confinement is used throughout the PFP where practical. Tasks involving resuspendable transuranic (TRU) element/compounds are performed using at least one engineered barrier between the material and personnel. If confinement cannot be achieved, administrative procedures identify requirements; for deviating from the confinement philosophy in FSP-PFP-5-8, *Plutonium Finishing Plant Administration*, Section 1.1, "Safety Policy." Appropriate approvals by the RC, Operations, and Plant Engineering functions are required.

PFP approves operating procedures and work plans. The facility team performs a hazards analysis that identifies unique hazards and incorporates methods for dealing with the hazard into the procedures as safety requirements. The PFP Safety and RC organizations review the procedures for Federal regulation, DOE order, and requirements compliance and ALARA implementation. The PFP Safety and RC organizations approve operating procedures, along with plant and transition operations.

Plant management establishes annual ALARA goals for its operations based on projected processing campaigns, proposed modifications, and anticipated work scope. These goals and quarterly status reports are provided to the

ALARA Program Office, which tracks plant status and incorporates plant reports into documentation provided to DOE-RL.

The operation of the PFP ALARA program is described in Section 8.1.1.

8.2 RADIATION SOURCES

The PFP is designed to process plutonium, a TRU element. The TRUs have the most restrictive radiological control values of any radioisotopes in the PFP. Processing TRUs requires extensive analytical capabilities for process control. Modern analytical tools (e.g., atomic absorption spectrometry, mass spectrography, gas chromatography, etc.) are used to minimize the amount of hands-on activities during routine analytical functions, which is a major source of personnel dose and a potential source for loss of contamination control. The PFP radiation protection program assumes that any alpha contamination found is plutonium and responds accordingly. This conservative assumption is applied to all operations. The PFP Analytical Laboratory (PFP AL) and the PPSL contain a wider range of radionuclides than are found in the principal facility processes. This wider range is used in analytical procedure verification, procedure and process work, and process-upset investigations. The radiation protection program is based, primarily, on controlling alpha-emitting radionuclides at or below those values established for ^{239}Pu. The program has the flexibility needed to provide similar controls for specialized PFP areas that handle and/or process nonplutonium radioisotopes such as uranium and americium. Additional information relating to the handling of plutonium materials for processing and storage is contained in Chapter 6.0.

The following is a description of the principal radiation sources and their locations in the PFP facilities.

8.2.1 Contained Sources

This section describes the existing radiation sources which were considered during the design of the PFP. The design considered radiation shielding and criticality control. The sources are categorized as follows:

- Process streams
- Nonairborne waste streams
- Storage of product and recoverable materials
- Holdup.

8.2.1.1 Process Streams.

8.2.1.1.1 Inactive Processes.

Plutonium Reclamation Facility. The Plutonium Reclamation Facility (PRF) is not operating and is not authorized for operation. The PRF was used to recover plutonium from plutonium-bearing materials and solutions. See Chapters 5.0 and 6.0 for discussion of PRF facility/equipment descriptions and operations, respectively.

The PRF tanks, vessels, and equipment are essentially empty and do not represent significant radiation sources. The remaining sources are due to holdup and heels in tanks, and general contamination on equipment, in hoods and in the canyon. Table 8-2 provides the location, function, description, working volume, and source chemical form for the equipment that contains potential radiation sources in the PRF.

Remote Mechanical A Line. The Remote Mechanical A (RMA) Line was used to produce plutonium metal. Gloveboxes HA-21I, HA-22B, HA-23S, and HA-28 are currently used during the thermal stabilization process, with the remainder of the gloveboxes being inactive.

See Chapter 5.0 for a description of active RMA Line gloveboxes. See Chapter 6.0 for a discussion of the thermal stabilization process. See Chapter 6.0, Section 6.4, for discussions of past RMA processes and glovebox functions.

High dose rates (multiple rem per hour) exist in this processing line, but it is not normally accessed, which keeps personnel doses ALARA.

Remote Mechanical C Line. The Remote Mechanical C (RMC) Line was previously used to produce plutonium metal. RMC Line gloveboxes HC-1, HC-2, HC-3, HC-4, HC-13MD, HC-21A, HC-21C, HC-18BS, and HC-18M are currently being used in the thermal stabilization process, with the remainder of the gloveboxes not currently being used.

See Chapter 5.0 for a description of RMC Line gloveboxes used in the thermal stabilization process. See Chapter 6.0 for a discussion of the thermal stabilization process and the present RMC Line operations and glovebox functions.

The location, function, description, working volume and source chemical form for the equipment that contains potential sources of radiation in the RMC Line are identified in Table 8-3.

The RMC Line radiation dose rates are subject to significant changes depending on housekeeping, operating campaign source materials, and accumulated cleanup materials.

8.2.1.1.2 Active Processes.

Thermal Stabilization. Reactive plutonium-bearing materials are converted to a stable form by heating the material to high temperatures in a furnace. See Chapter 5.0, Section 5.2.1, for details of the equipment used in the thermal stabilization process for reactive materials.

An estimation of personnel dose equivalents (DEs) were calculated for the thermal stabilization of the inventory contained within the PFP (Chew 1996). The total whole body and extremity DE for the process was determined by the summation of individual process task DEs. After the two man rule was factored into the total whole body, the values were then divided by the number of operators (who are trained on all processes and are regularly rotated) to estimate the average whole body and extremity DE over the estimated campaign duration (four years). The whole body DE/operator/yr was 1.0 rem and the extremity DE/operator/yr was 12.2 rem (Chew 1996).

The thermal stabilization process for reactive materials was analyzed for four sets of material: plutonium oxide, mixed plutonium oxide, other, and sludge. The oxide and mixed oxide material were further subdivided into low ^{240}Pu weight percent, mid ^{240}Pu weight percent, and high ^{240}Pu weight percent for oxide material, and mid ^{240}Pu weight percent, and high ^{240}Pu weight percent for mixed oxide material. Other material such as product from the 188-1 glovebox Laboratory Prototype Calciner, was considered to be low ^{240}Pu weight percent material. Sludge material was considered low ^{240}Pu weight percent.

See Chapter 5.0 for a detailed description of the equipment used in reactive plutonium-bearing material thermal stabilization operations. See Chapter 6.0 for a complete discussion of the thermal stabilization process. See the Laboratory Prototype Calciner addendum to this FSAR for descriptions of the equipment and process associated with the laboratory calciner.

Nitrate Load In/Load Out and Vertical Calcination. This process involves transfers of solution from product receiver (PR) cans and 10-L polyethylene bottles in glovebox HC-227S and hood HC-227T. See Chapter 5.0, Section 5.2.1.2.2 for details of the HC-227S glovebox and HC-227T hood. See Chapter 6.0, Section 6.2.3 for discussions of the load-in/load-out (LI/LO) operations. See the Laboratory Prototype Calciner addendum to this FSAR for interface operations between the HC-227S glovebox and the laboratory calciner.

Repackaging. This process involves the repackaging of plutonium metal from failed or damaged containers. Repackaging activities occur primarily in the 2736-ZB Building, room 636, in the 636 repackaging glovebox. See Chapter 6.0, Section 6.2.5.2 for more details of the repackaging process.

An estimation of personnel DEs were calculated for repackaging of plutonium metal contained within the PFP (Chew 1996). The total whole body and extremity DE for the process was determined by the summation of individual process task DEs. After the two man rule was factored into the total whole body, the values were then divided by the number of operators (who are trained on all processes and are regularly rotated) to estimate the average whole body and extremity DE over the estimated campaign duration (four years). The whole body DE/operator/yr was 0.1 rem and the extremity DE/operator/yr was 0.6 rem (Chew 1996).

8.2.1.2 Nonairborne Waste Streams.

8.2.1.2.1 Liquid Effluents. Four liquid effluent streams are generated by the PFP operations RLW, waste water, sanitary liquid waste, and french drains. Of these, the radioactive liquid hood and laboratory wastes [radioactive liquid waste (RLW)], collectively referred to as salt waste, are collected at the 241-Z sump tanks for eventual routing to Tank Farms. This stream is not discharged to the environment. Condensates, cooling water, and other non-contaminated streams from the PFP are routed to the 200 East Area Treated Effluent Disposal Facility (TEDF). The waste water streams that have a potential of becoming contaminated are routed through the Low-Level Waste Treatment Facility (LLWTF) before discharging to TEDF. Nonradioactive sanitary liquid waste is discharged to a tile drain field. Details of the liquid effluent facilities (LLWTF and 241-Z Complex) and their operation are contained in Chapters 5.0 and 7.0.

Prior to the startup of the TEDF, the "cold" liquid effluent streams from the PFP were transferred to the 216-Z-20 Crib and 216-Z-21 Seepage Basin for discharge to the ground. Historical data estimate that the 216-Z-20 crib has accumulated (as of December 1994) $\leq$33.7 g of ^{239}Pu and $\leq$0.3 g of ^{241}Pu since its 1981 startup. This material is in the underground lines, the distribution tile, and the soil beneath the crib.

The activity and collection points of the low-level liquid effluents are identified in Table 8-4. Chapter 5.0 contains more detailed information about this system. Chapter 7.0 contains details on the waste water effluent sources and the sampling system associated with it as well as waste water effluent treatment processes at the PFP.

8.2.1.2.2 Solid Wastes. Radioactive wastes generated at the PFP are low-level waste (LLW), TRU waste, low-level mixed waste, TRU mixed waste, and polychlorinated biphenyl (PCB)/absorbed organic waste. Isotopes commonly found in PFP wastes are typical of those found in weapons and reactor grade plutonium (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{242}Pu).

Waste Management Hanford acceptance organization is the organization within WMH that is responsible for waste acceptance, including approval of waste stream profiles and approval of individual waste packages and shipments, and for coordinating the approval of case-by-case evaluations for specific criteria and exceptions to the acceptance criteria.

DOE Order 5820.2A requires that each treatment, storage, and/or disposal facility (referred to as TSD unit) that manages low-level or transuranic waste (including mixed waste and TSCA PCB waste) maintain waste acceptance criteria. These criteria must address the various requirements to operate the TSD unit in compliance with applicable safety and environmental requirements.

The baseline criteria for acceptance of radioactive waste at TSD units operated by WMH is HNF-EP-0063," Hanford Site Solid Waste Acceptance Criteria". The criteria for each TSD unit have been established to ensure that waste accepted can be managed in a manner that is within the operating requirements of the unit, including environmental regulations, DOE Orders, permits, technical safety requirements, waste analysis plans, performance assessments, and other applicable requirements.

Acceptance criteria apply to the following TSD units: the Low-Level Burial Grounds (LLBG) including both the nonregulated portions of the LLBG and trenches 31 and 34 of the 218-W-5 Burial Ground for mixed waste disposal; Central Waste Complex (CWC); Waste Receiving and Processing Facility (WRAP); and T Plant Complex. Waste from all generators, both from the Hanford Site and from offsite facilities, must comply with these criteria. Exceptions can be granted as provided. Specific waste streams could have additional requirements based on the identified TSD pathway. These requirements are communicated in the Waste Specification Records (WSRds).

Low-level waste (LLW). Waste that contains radioactivity and is not classified as high-level waste, transuranic (TRU) waste, or spent nuclear fuel or 11e(2)-byproduct material as defined by DOE Order 5820.2A. A test specimen of fissionable material irradiated for research and development only, and not for the production of power or plutonium, could be classified as LLW provided

the concentration of transuranic materials is less than 100 nanocuries per gram.

The waste typically is room waste and consists of surgical gloves, plastic, tape, wrappers, unused containers, and protective clothing. Normally it does not contain alpha contamination detectable with a hand held alpha survey instrument. LLW is compacted where practical and placed in an approved UN 1A2 55-gal drum. Non-Compactible or large LLW packages are typically packaged and shipped in burial boxes.

Transuranic waste or TRU waste. Waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level waste; (2) waste that the Secretary (of Energy) has determined, with the concurrence of the EPA Administrator, does not need the degree of isolation required by the disposal regulations; or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61 (Public Law 102-579: Waste Isolation Pilot Plant Land Withdrawal Act).

Waste Isolation Pilot Plant (WIPP) certifiable transuranic (TRU) waste (or hood waste) WIPP is the disposal facility identified for TRU waste from the Hanford Site. At the time of writing, the Hanford Site TRU waste certification program currently is being developed to meet various requirements to ship and dispose of waste at WIPP. The TRU waste certification program will identify portions of the certification process that are the responsibility of the waste generator, while other portions will be performed at WRAP. Until completion and approval of the TRU waste certification program, APPENDIX G of HNF-EP-0063 identifies the interim requirements applicable to generators. Section 3.0 of DOE/WIPP-069 presents the requirements that must be met before TRU waste can be transported to and managed and disposed of at WIPP. TRU waste is not compacted. It is placed into an approved container as specified APPENDIX D of HNF-EP-0063 for long term storage. The contact exposure rates on these drums is typically $\leq$1 mrem/h, with an average dose rate of slightly less than 0.5 mrem/h.

Alpha contaminated hood and glovebox waste is designated as TRU waste and may consist of other contaminated confinement barriers or pieces of process equipment. The TRU waste, including contaminated HEPA filters, is processed to meet the Hanford Site Solid Waste acceptance criteria. This waste will ultimately be shipped offsite for long term disposal at the Waste Isolation Pilot Plant (WIPP). TRU waste drums packaged for WIPP disposal must have a $\leq$200 g plutonium content. Criticality safety analysis for the routinely used UN 1A2 waste drum allows for higher drum plutonium inventories, however PFP administratively holds all waste drum contents to the $\leq$200 g WIPP limit.

Waste items that are too large or to heavy are loaded into steel waste boxes called Standard Waste Box (SWB). The SWB is used for the general transfer of TRU waste material within the 200 West Area boundary. The TRU waste contents of the SWB will typically consist of tank sections, pumps, greenhouses, and other miscellaneous solids. The SWB is a carbon steel container designed and fabricated at the WIPP. A maximum of 325 g of fissile material distributed over equipment or objects as contamination is allowed in a SWB. The SWB shall not contain more than 15 grams of fissile material if waste in the form of plastic (excluding wrapping and liners) is part of the payload.

It is understood that certain TRU waste might require extensive processing and/or treatment before disposal at WIPP. As a policy, however, generators of newly generated TRU waste shall generate, segregate, and package the waste to minimize the need for additional processing at WRAP. More specifically, generators shall segregate their waste by TRUCON code (DOE/WIPP-89-004) and shall attempt to meet those requirements of the Waste Acceptance Criteria for the Waste Isolation Pilot Plant (DOE/WIPP-069) identified in Table G-1 of HNF-EP-0063.

TRU waste drums packaged for WIPP disposal must have a ≤200 g plutonium content. Criticality safety analysis for the routinely used UN 1A1 waste drum allows for higher drum plutonium inventories, however PFP administratively holds all waste drum contents to the gram limit, as set by HNF-EP-0063, to comply with the regulatory, permitting, safety, environmental, and operational requirements of the Hanford Site Central Waste Complex.

Non WIPP certifiable transuranic (TRU) waste requirements are also presented in Section 3.0 of DOE/WIPP-069.

Low level mixed waste (LLMW) and TRU mixed waste - "Mixed waste" means a dangerous, extremely hazardous, or acutely hazardous waste that contains both a radioactive hazardous component and, as defined by 10 CFR 20.1003, source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.).

The CWC is a storage unit for low-level mixed, TRU, TRU mixed, TSCA PCB waste, and other waste types requiring treatment before disposal (e.g., nonregulated low-level organic liquids, unstabilized chelating compounds, and contact-handled low-level waste that exceeds radiological disposal criteria). Waste stored at CWC will be treated and repackaged as required for disposal as treatment capabilities become available.

The CWC manages waste having characteristic waste numbers D001 through D043, all listed discarded chemical product waste numbers (U- and P- listed waste), certain F-listed waste (F001 through F005, F020 through F023, F026 through F028, and F039), and all Washington state-only waste numbers. In addition, the CWC manages TSCA PCB waste from Hanford Site generators in accordance with 40 CFR 761. The CWC also can store waste from CERCLA cleanup activities.

Polychlorinated biphenyl (PCB)/absorbed organic waste - HNF-PRO-3152 establishes requirements for activities involving polychlorinated biphenyls (PCBs). PCBs shall be managed in accordance with the Toxic Substances Control Act (TSCA) regulations (40 CFR 761) and with the Washington State Department of Ecology (Ecology) Dangerous Waste Regulations [Washington Administrative Code (WAC) Chapter 173-303]. This procedure primarily identifies general requirements and provides reference to more detailed requirements. As references are readily available, detailed descriptions of requirements are not provided. Identified references should be used in conjunction with this procedure. Packaging requirements are taken from HNF-EP-0063, Hanford Site Solid Waste Acceptance Criteria, 49 CFR, and/or the applicable SARP.

Currently TRU waste is packaged in 55-gal drums for 20-yr retrievable storage. Waste items that are too large or too heavy for 55-gal drums are loaded into steel waste boxes. These waste boxes are also placed into 20-yr

retrievable storage. TRU waste drum contact dose rates are ≤200 mrem/h by definition.

8.2.1.3 Storage of Recoverable Plutonium. Plutonium-bearing recyclable, excess, or out-of-specification material in various forms has been generated at the PFP or received for processing at the PFP for over 35 yr. This material is stored in gloveboxes and vaults in the PFP.

Some of the recoverable plutonium items have been processed in the PRF during its periods of operation. Other residual recoverable plutonium items that have known or suspected reactive characteristics are chemically stabilized.

The residual recoverable plutonium items are divided into three categories:

1. **Stable Material**--Material for which the source data contain no information that would indicate that the material may be unsuitable and the information in the source data is judged adequate to avoid undue risk and meets the requirements of plant operating specifications in *Special Nuclear Material Storage*, OSD-Z-184-00013 (BWHC 1998).

2. **Potentially Unstable Material**--Material for which the source data contain information that would indicate that material may be unstable or the information in the source data is judged inadequate to evaluate the risk (BWHC 1998).

3. **Reactive Material**--Material that has known or suspected reactive characteristics that could not be administratively controlled during shipment or is unshippable or unstorable because of its physical form (e.g., with liquids or recoverable material). A complete definition of reactive material can be found in plant operating specifications (BWHC 1998).

Table 8-5 identifies gloveboxes and hoods that contain potential plutonium sources. The table provides the location and description of the equipment and the physical and chemical forms of the plutonium materials contained therein. The gloveboxes are used for processing or interim storage of recoverable materials.

Plutonium and other radioactive materials that either have been stabilized or were received from offsite as stable material are stored in various containers approved for storage in vaults. Typical radioactive material packaging configurations for vault storage are identified in Table 8-6.

Plutonium materials in the form of nitrate, oxide, and metal that meet the specifications identified for product material are stored as plutonium product in vaults and staging areas within the PFP. Plutonium product nitrate solutions are stored in PR cans in storage vaults and staging areas awaiting conversion to stabilized PuO_2 powder. The PuO_2 and metal product are typically stored in a triple can configuration consisting of a minimum of two contamination-free, mechanically sealed food pack cans. The typical product materials that are the sources of radiation within storage vaults at PFP are

identified in Table 8-6. The various food pack cans used for the packaging of plutonium or plutonium-bearing materials are identified in Figure 8-1. The storage containers used for storage and the facilities in which they are stored meet the intent of Section 1300-5 of DOE Order 6430.1A (DOE 1989). The storage containers have been approved for this purpose by facility management in accordance with DOE guidance documents (Section 4.7 of FSP-PFP-5-8 implements this guidance).

Radioactive materials are stored in containers approved for vault storage according to plant operating specifications (e.g. Special Nuclear Material Storage (BWHC 1998), and CH-TRU Solid Waste Disposal (BWHC 1998c)). The majority of the stable material and product plutonium metal and oxide radioactive material confinement consists of packaging the plutonium in metal containers that are placed in one or two layers of polyethylene. The material is then packaged in at least two contamination-free, mechanically sealed food pack cans.

Exposure and dose rates associated with plutonium-bearing materials and products vary with chemical form, container characteristics, isotopic abundances, moisture content, specific activity, total quantity, and storage location characteristics.

The exposure rates associated with the PuO_2 1-lb storage container ranges from 40 to 80 mR/h gamma. The resulting dose rate is 5 to 10 mrem/h neutrons at contact depending on ^{240}Pu content and age. The higher dose rate is related to the higher ^{240}Pu content.

A plutonium metal button storage container normally reads ~50 mR/h gamma exposure rate with a corresponding 20 mrem/h neutrons dose rate at contact. A PuF_4 crucible charge from the RMC Line, when placed in a storage container, has a contact exposure and dose rate of ~30 mR/h gamma and 60 mrem/h neutrons, respectively.

The exposure rates associated with plutonium nitrate solutions in PR cans varied from 4 to 12 mR/h gamma. The resulting dose rate is 1 to 6 mrem/h neutrons at contact with a greater dependence on can construction than on contents. The PR cans in use vary in construction materials used [e.g., shielded or unshielded (lead-lined outer)] and with material thicknesses used. The average contact exposure and dose rates for all PR cans is approximately 6 mR/h gamma and 2 mrem/h neutrons, respectively.

These contact dose rates are established using the standard Hanford Site instrumentation.

8.2.1.3.1 Characteristics of Contained Sources in the Plutonium Finishing Plant. Plutonium decay via charged particle emission and spontaneous fission results in the generation of alpha particles, neutrons, beta particles, and electromagnetic radiations. The presence of light elements enhances the neutron radiation emissions via the alpha-n reaction. The X-ray emissions are related to bremsstrahlung from beta particle interactions and internal conversions. Gamma rays are associated with alpha emissions, spontaneous fission, and fission product decay. The even numbered isotopes (i.e., ^{238}Pu, ^{240}Pu, and ^{242}Pu) are principally considered as alpha emitters with a nominal spontaneous fission neutron generation rate of 2×10^3 neutrons per second per gram of isotope. Alpha-n neutron generation

rates vary depending on which light elements are present. Plutonium fluoride neutron emission rates are approximately two orders of magnitude higher than those observed for the plutonium oxides. ^{241}Plutonium is principally a beta particle emitter, and its daughters, ^{241}Am and ^{237}U, are alpha and internal conversion X-ray emitters. ^{239}Plutonium is considered principally an alpha emitter.

The plutonium isotopic fractions in the sources stored at the PFP are directly related to the dose rates from handling the material and criticality concerns. See WHC-SD-CP-TI-190, Rev. 0, *Technical Basis for Characterization of Plutonium for the PFP Safety Analysis* (WHC 1993c), for a description of the isotopic concentrations used in the PFP Safety Analysis.

8.2.1.3.2 Effects of Aging. Aging of the material has a small effect on neutron dose rates, much less than that associated with ^{240}Pu content. The metallic form remains at an essentially constant neutron emission rate over the first 40 yr. The oxide form increases its neutron emission rate by about 15%, the nitrate form increases about 20%, and the fluoride form increases by 40% in the same time frame. Aging does have a significant effect on gamma and X-ray dose rates from ingrowth of daughter products (principally ^{237}U and ^{241}Am). The ^{237}U component reaches 90% of its maximum contribution to dose rate in about 40 days and eventually decreases with the half-life of ^{241}Pu (13 yr). The ^{241}Am ingrowth continues until it peaks at about 45 yr and then decreases with its half-life (432 yr). Based on total X-ray and gamma ray output, the surface dose rate can increase by a factor of approximately 10 over 40 yr, when compared to the dose rate 1 day after separation.

8.2.1.3.3 Shielding Considerations. When low energy gamma photons are appropriately shielded, fast neutrons from alpha-n reactions are the principal source of personnel doses. Neutron shielding designs for the older parts of the PFP were based on empirical experiments, experience, and knowledge of this and other plutonium-handling DOE sites. Construction of the 2736-Z Building was based on early computer shielding codes and hand calculations. Later, the existing storage vaults were evaluated using contemporary neutron shielding codes. Later vault buildings were designed using neutron codes such as Monte Carlo neutron (MCN) and Monte Carlo neutron photon (MCNP) (WHC 1993a).

The X-ray and gamma energy groups and strengths for the isotopes that are the sources of radiation within the PFP are shown in Table 8-7. These values were used as input to a computer program named PUSHLD (Plutonium Shielding) developed by Battelle Northwest (BNW) Laboratories, now known as Pacific Northwest National Laboratory (PNNL). Additional information is provided in *Calculation of Gamma Dose Rates at the Surface of Plutonium Oxide Sources*, BNWL-1259 (Van Tuil 1970).

8.2.1.4 Holdup of Plutonium in Facility Systems. Table 8-8 identifies potential plutonium sources in filterboxes. These filterboxes contain HEPA filters, which are used to remove radioactive particulate from the process glovebox and cell exhaust streams. The table lists the location and function of each filterbox and the physical form of the Plutonium Oxide therein.

Several other process exhaust systems within the PFP also contain radioactive materials. They are described below and summarized in Table 8-9.

- E-4 exhaust system--Dose rates associated with this system range from nondetectable to ~150 mrem/h (exposure rate of ~100 to 105 mR/h gamma and 45 to 50 mrem/h neutrons) at contact depending on the plant operating status, hood and glovebox use, and length of filter accumulation time. The higher E-4 system dose rates are associated with the process line filterboxes and their upstream lines. Dose rates of E-4 system lines downstream of the filterboxes decrease with distance from the filterbox.

- 26-in.-Hg process vacuum--Dose rates associated with this system range from nondetectable to approximately 110 mrem/h (exposure rate of ~80 mR/h gamma and ~30 mrem/h neutrons). The highest dose rates are associated with the pump-protecting (upstream) HEPA filters and vacuum lines servicing processes involving plutonium-bearing liquids.

- Exhaust manifold system--Dose rates associated with this system are as high as 100 mrem/h (exposure rate of 65 to 75 mR/h gamma and 25 to 35 mrem/h neutrons) depending on what component parts of the E-4 system are present.

During the years of plant operation, process upsets have caused plutonium to be deposited in piping identified in the systems mentioned. A total of 6 kg of plutonium was contained in the 234-5Z Building E-4 exhaust system ducting as of 1995. This plutonium holdup value is based on a series of in situ nondestructive assay (NDA) measurements using gamma ray spectroscopy. Approximately 1.9 kg has been removed during the remediation process leaving approximately 4.1 kg in the E-4 exhaust system (see Appendix A, Westsik 1999 and Westsik 1998). All of the holdup is isolated from the environment by at least two independent and testable stages of HEPA filtration. There was approximately 20 g of plutonium contained in a single portion of ventilation ducting roughly 140 ft long, but this section was removed as part of the remediation project. There is less than 1 kg plutonium spread across approximately 40 primary filterboxes in the 234-5Z Building. This material is also isolated from the environment by two stages of testable HEPA filtration. The plutonium holdup in ventilation ducting is contained in a slightly moist atmosphere and is potentially airborne dispersible, although no movement has been observed to date.

The plutonium holdup in the 234-5Z Building ventilation system comes from a variety of process sources and is located primarily in ventilation systems servicing solid-form plutonium processing areas. The plutonium chemical composition is characteristic of the processing area of origin (i.e., primarily solid-form material). The material form ranges from condensate to powder as one of the following chemical forms of plutonium: oxide, oxalate, fluoride, or crystalline nitrate. The chemical form of the plutonium would tend to change towards PuO_2 interspersed within a matrix of nonradioactive material over the years. It is likely that any plutonium compound in the condensate in the ventilation ducting would have dried to a crystalline form.

A total of about 8.4 kg of plutonium is contained in the 234-5Z Building 26-in. mercury process vacuum system (Westsik 1989). This plutonium holdup value is based on nuclear material accountability measurements with confirmation from in situ NDA measurements using gamma ray spectroscopy. This plutonium holdup is isolated from the environment by at least two independent

stages of testable HEPA filtration. This material is contained in a moist atmosphere, is nondispersible by air, and exists primarily in a crystalline form in the main vacuum system headers in rooms 262, 263, 264, and 265.

A total of 175 g of plutonium (with an uncertainty range of 23 to 584 g) is contained in the inactive process equipment of the 232-Z Building (Westsik 1996). This material is isolated from the environment by two stages of testable HEPA filtration. Potential plutonium holdup in the abandoned 232-Z to 291-Z underground ductwork has not been determined because of inaccessibility.

A radiation and NDA survey program is in operation to verify that these deposits are in a static condition.

No significant plutonium holdup is observed, using in situ NDA measurements, in ventilation systems servicing the 236-Z and 2736-ZB facilities. The 236-Z facility was a plutonium solution processing facility and, as such, did not generate significant quantities of solid form plutonium materials. The 2736-ZB facility contains one plutonium repackaging glovebox.

More detailed information on this subject, including a description, schedule, and cost estimate of remedial actions, can be obtained in WHC-SD-CP-PMP-003, *Plutonium Finishing Plant (PFP) Remediation Project Management Plan* (WHC 1989).

The estimated quantities of plutonium and other radioisotopes that are the source of radiation in these process systems are listed in Table 8-9 and Appendix A.

8.2.2 Airborne Radioactive Material Sources

The ventilation areas are defined in Chapter 5.0. The current designation of ventilation zones are contained in DOE Order 6430.1A (DOE 1989), U.S. Energy Research and Development Administration (ERDA) 76-21 (ERDA 1976), *Nuclear Air Cleaning Handbook*, and Van Tuil (1970).

During normal operations in the PFP, sources of gaseous and airborne radioactive materials are confined inside of enclosures such as open-face hoods, gloveboxes, filterboxes, and process cells. Gaseous and airborne materials generated within these enclosures are handled by the exhaust system. The air is filtered through two or three stages of HEPA filters before being discharged to the atmosphere from one of the exhaust stacks. Air pressure in the enclosures is negative with respect to ambient air, thus helping to minimize the spread of contamination in the event that a breach of confinement occurs.

Tables 8-3, 8-5 and 8-8 list the process enclosures, gloveboxes, hoods and filterboxes containing radioactive materials with the potential for becoming an airborne hazard. The materials in the gloveboxes, filterboxes, and other process enclosures are not easily accessible. The materials in the hoods are accessible and are a potential airborne radioactivity exposure hazard. This potential exposure is averted by the use of ported sashes, a hood airflow testing and verification program, quantity limitations imposed by process and criticality control requirements, and personnel training.

Personnel training includes the fundamentals of radiation and criticality safety, use of radiation detection instruments, regulatory requirements, facility operating and emergency procedures, and training and familiarization with the processes performed and equipment to be used in the hoods. Materials in transport or storage are packaged to ensure that multiple barriers must be breached before the material would become an airborne hazard. See Chapter 6.0, Sections 6.2.8, 6.3.8, 6.4.1.8, and 6.5.8, for additional information on product handling.

The PFP HVAC exhaust system for the 234-5Z Building is described in Chapter 5.0, Section 5.4.1.

In the event of a contamination incident, airborne contamination may spread along with the airflow towards the exhaust vents. Most rooms have more than one exhaust vent to the E-3 system. In case of a contamination spread, CAM alarms are used to alert personnel to evacuate a contaminated area.

During normal operations, the CAM and fixed head sampler (FHS) filters are collected by radiological control technicians (RCTs) for counting. Any activity from the sample filter that exceeds the operational plant limit of 2×10^{-13} μCi/mL of gross alpha prompts the room containing the sampler or CAM to be posted as an airborne radioactivity area. An investigation to find the source of the release is performed. Gross alpha activity is assumed to be ^{239}Pu until proved otherwise. The DAC for ^{239}Pu is 2×10^{-12} μCi/mL, the most restrictive value listed for alpha emitters.

Descriptions of anticipated off-normal occurrences are provided in Section 9.1. The plant operational limit under which respiratory protection is not required is 2×10^{-13} μCi/mL. Personnel involved with plant or process operations that may result in airborne radioactivity are routinely required to wear respiratory protection during these evolutions as specified in plant and RCT operating procedures.

8.3 RADIATION PROTECTION DESIGN FEATURES

The PFP location was selected based on the same criteria that were used to locate the Hanford Site. It was remote, barren, had a small local and peripheral population, was close to transportation, had an abundant energy supply, had an adequate water supply, and had enough area to ensure that hazardous operations could be isolated from each other such that a problem at one location would not affect other installations. All these factors mitigate the potential for an offsite radiological consequence and were undoubtedly considered in the 1946 PFP site selection process. The evaluation of potential consequences of accidents involving radioactive materials was included as part of the siting criteria, but the methods used were not as sophisticated as those in current use. Calculations show that the location selected meets the current criteria given in 10 CFR 100, *Reactor Site Criteria* (NRC 1995) or DOE Order 6430.1A, Section 200 criteria (DOE 1989), as shown in Chapter 9.0.

Radiation protection features were built into the PFP. These features include a zoned HVAC system, compartmentalized process and analytical facilities, gloveboxes and hoods for hazardous operations, geometrically favorable plutonium material process and storage facilities, shielded storage, remote

location of liquid lines for process and waste materials systems, shielded storage vaults and remote areas for surge and accumulation tanks. The building layout is such that access to potentially hazardous areas is controlled via engineered features such as airlocks or administrative controls. Almost all of these features were built into the original design many years before the development of DOE Order 6430.1 (DOE 1983). The facility meets the intent of applicable DOE Order 6430.1A, Division 13, Section 1300 (DOE 1989), requirements for special facilities and Section 1304 for plutonium processing and handling facilities through the use of engineered features or administrative controls. The glovebox and other specialty viewing windows were selected using the appropriate standards. Additional information on the PFP compliance with DOE Order 6430.1A is in Chapters 5.0, 6.0, and 7.0 and WHC-SD-CP-ES-128 (WHC 1995a). The policy of confinement of plutonium materials was made a part of the facility design and was ultimately built into the facility.

8.3.1 Plant Design Features

The building layout is such that there is a radiological side and a nonradiological side of the facility. The radiological side contains the process facilities; process feed and product materials storage; PFP AL, radiochemistry laboratory, and PPSL; decontamination facilities for equipment and personnel; contaminated equipment repair facilities; and other similar facilities that need to be in a controlled access area for radiological control purposes. The nonradiological side contains offices, changerooms and restrooms, repair shops (mechanical, electrical, electronic, etc.), cold chemical and other storage areas, and other areas that do not need to be under stringent radiological controls.

The design of the PFP ventilation system incorporates features that enhance confinement of radioactive materials. Some of the unique features are identified below.

- Radioactive materials are removed from a contaminated effluent stream as close to the point of origin as practicable. HEPA filters are installed on the hoods and gloveboxes upstream from effluent's entry into the exhaust system. Credit is not taken for this filter, and there are two separate testable stages of HEPA filters before release to the environment.

- The 234-5Z, 242-Z, and 236-Z Buildings are a part of a single large supply-exhaust, once-through ventilation system. The 232-Z, 241-Z/ZA, and 243-Z Buildings have their own supply and exhaust systems. The 2736-ZB Building has its own supply and exhaust system. Supply air for the 2736-Z Building is provided by the 2736-ZB Building and exhaust ventilation is supplied by the 2736-ZA Building.

- Two of the exhaust fans for the 234-5Z, 236-Z, and 242-Z exhaust system are provided with backup power. One of these fans runs continuously under all conditions. If failure in the operating fan is detected, the alternate backup fan automatically starts. In the event of failure of the normal electric supply, one of the two exhaust fans restarts with power supplied from diesel-generators located in Building 2721-Z.

- Exhaust air from the PFP Complex is discharged through different stacks. Chapter 5.0, Section 5.4.1, identifies the location of stacks and the buildings they service.

- The PRF process cell is equipped with a large airlock for providing containment when introducing larger pieces of process equipment to the cell.

- Air is normally supplied to rooms and areas near the ceiling and exhausted near the floor.

- All contaminated or potentially contaminated zones are designed and operated to maintain a negative pressure referenced to ambient or to the adjacent lower contamination potential ventilation zone.

- Inward airflow through open-face fume hoods is maintained between 125-150 linear ft/min. Inward air flow through arm-port fume hoods is maintained between 125-180 linear ft/min. Glovebox exhaust systems are sized based on heat loading and assumed breached gloveports.

- Gloveboxes that are supplied air from the room around the gloveboxes are equipped with HEPA filters on the inlet to the glovebox to minimize the amount of particulate matter that would be carried out of the glovebox to the room in case of a pressure reversal.

Some examples of plant design features for systems or components within the PFP are provided in the following paragraphs.

8.3.1.1 Feed Material Receiving Preparation. Material received from onsite or offsite is packaged in DOT- or DOE-approved shipping containers. Plutonium oxide, recoverable material, and metal are primarily shipped (onsite) in DOT-6M containers. The packaging configuration for shipping radioactive materials is shown in Figure 8-2. The design of the DOT-6M provides for confinement of radioactive materials by use of multiple barriers as required for packaging alpha-emitting radioactive materials for shipment (WHC 1994c). The use of the DOT-6M container complies with the Users Guide for Shipping Type B Quantities of Radioactive and Fissile Materials, including Plutonium, in DOT-6M Specification Packaging Configurations (DOE-RL 1994) so that this container may continue to be used for offsite shipping.

8.3.1.2 Plutonium Nitrate Storage. Plutonium nitrate solutions are stored onsite in PR cans (information in Appendix B indicates that these cans will last a minimum of 50 yr with solution in them). Several different types of PR cans are in use. A typical packaging configuration of one of several types of PR cans used onsite is shown in Figure 8-3. This particular PR can consists of 6-in. Schedule 80S stainless steel pipe 27 in. long. It is sealed with a vented polyethylene closure that is packed with glass wool (for deentrainment of liquids and solids from the gaseous discharge). This PR can is capped with an impact-limiting hood when placed in a 55-gal stainless steel 18-gauge drum with a bolt-on lock ring. Plutonium nitrate solutions are also stored in polyethylene containers (e.g., FL-10, L-10, etc.).

8.3.1.3 Chemical Processing Areas. In the chemical processing areas, the PRF (236-Z Building) provides unique plant design features. One of the single

most important features is that approximately 70% of process equipment operation was done remotely. Also, remote operations were used in much of the valving and solution transfers. The operation of the canyon hoist can be done entirely in a remote mode. The PRF was also designed for conducting the majority of maintenance work in a designated maintenance cell or glovebox, thus minimizing manned entries required for maintenance of process equipment. Maintenance required on process vessels is conducted through lead-lined gloves in gloveboxes that are shielded with lead for reduction of exposure to maintenance personnel. Some of the design features of PRF are shown in Figure 8-4.

8.3.1.4 Product Load-out and Storage. Plutonium metal is placed in a 3 3/8-in. by 2-in. food pack (tuna size) can that is purged with argon gas. The food pack can is then mechanically sealed and subsequently bagged out of the glovebox. This package is then placed into a 4-in. by 4.5-in. food pack (tomato size) can that is mechanically sealed. The food pack can is then placed into a 4 1/4-in. by 7-in. food pack can that is mechanically sealed. This is the final configuration for placement into vault storage. Figure 8-1 identifies containers typically used for packaging plutonium metal, oxide, and recoverable items.

8.3.1.5 Product Handling. Product or recoverable plutonium-bearing materials are repackaged or packaged in gloveboxes. An illustrative example of one of the types of gloveboxes used for this work is the repackaging glovebox in the 2736-ZB Building. The unique design of the glovebox, which has a smooth inner and outer surface with lead shielding enclosed between the stainless steel exterior and interior skin, is described in Figure 8-5. Also 1/4-in. clear lead glass shielding is in place over the glovebox viewing windows.

8.3.1.6 General Operations. Radiological areas of the PFP are posted in accordance with 10CFR835 and PHRCM requirements. The process equipment, gloveboxes, and tanks that contain radioactive sources are described in Section 8.2.1. Routine access to operating areas is through a limited number of airlocks. Additional doorways are shown that are used for emergency egress only, rather than routine access.

An additional interface to control zone pressures for maintaining proper ventilation is airlocks. The airlocks are normally provided between zone 1 and zones 3, 3A, or 3B and between the building zones and outside wherever there is routine personnel traffic. All exterior doors, other than those provided with airlocks, are sealed to the greatest degree possible, while still allowing their use for emergency purposes. Most Airlocks are equipped with audible and visual alarms that will sound locally when both doors are open. Airlock doors are well fitted and gasketed to reduce in-leakage to a minimum. Additional information pertaining to the zones and airlocks at the PFP is located in Section 5.4.1 of Chapter 5.0.

The various process areas and gloveboxes within the PFP where radioactive materials are handled, processed, or stored have different types of shielding provided to reduce radiation exposure to personnel. The typical types and shield wall thicknesses of materials used for shielding are identified in Figure 8-7.

Piping runs containing radioactive liquids are routed through spaces not routinely occupied by plant personnel. Process-associated lines are routed

through the duct level of the facility, while waste streams are routed through the tunnel level prior to exiting the building.

Within the PFP, areas are posted to identify radiological hazards to prevent personnel from being exposed to high levels of radiation and/or radioactive contamination. These areas are administratively controlled through requirements established in Chapter 2.0 of PHRCM (FH 2000). These areas are classified based on the radiation or radioactive contamination levels posted. The criteria given in Table 8-10 identify requirements for posting controlled areas. High radiation areas have locked entrances or entrances that are controlled by the PFP Operations Management to prevent unauthorized entry.

The PFP has one personnel decontamination and one equipment decontamination area. The personnel decontamination area is located in room 126 of the 234-5Z Building. The equipment decontamination area is located in room 159 of the 234-5Z Building.

Room 221-A of the 234-5Z Building is the location of the main PFP RCT office. Room 631 of the 2736-ZB Building houses the other RCT office. Section 8.5.2 provides a description of the RCT facilities.

8.3.1.7 Monitoring Systems. Other PFP design features include the monitoring systems that are in place at strategic locations to detect and evaluate airborne contamination at work locations. The FHS systems are positioned to measure air concentrations to which persons are exposed. CAMs are required for sampling airborne contamination levels that may exceed 40 DAC-hours in one week.

The guidelines for placement of FHSs and CAMs were determined based on the type of operations, nuclides involved, ventilation patterns, potential release type, and magnitude and area/equipment configuration (HNF-PRO-331). The HVAC exhaust effluents from the PFP Complex are monitored by CAMs with local and remote alarm capability and fixed-head record samplers. Representative locations of the PFP CAMs are shown in Figure 8-13. Current locations are shown on the most recent revision of the CAM Station Locations drawing, H-2-80107. Section 8.3.4 provides a description of FHSs and CAMs.

Portal monitors are located at exits to plutonium material handling areas for detection of possible diversion of plutonium materials and are not considered for personnel protection purposes.

The PFP also uses portable instruments designed to survey personnel, equipment, and process areas for radioactive contamination and to provide an indication when contamination is detected. These instruments play an important role in contamination control and personnel safety. Some of the survey instrumentation used in the PFP consists of semiportable and fixed poppy alpha meters. These instruments are located throughout radiological areas within the PFP Complex where radioactive materials are processed, handled, transported, or stored. Representative locations of other types of survey instrumentation used within the PFP are shown in Figure 8-14.

8.3.1.8 Physical Considerations. Space has been provided in various areas so that temporary radiological containment (greenhouses) may be constructed. These structures ensure that the confinement function is maintained when

normal process confinement is breached for maintenance, repair, or modification outages.

Tanks and piping systems handling process or waste fluids use welded construction where possible to minimize the potential for leakage.

8.3.2 Shielding

The PFP was designed before the 1 rem/yr total whole-body dose criterion identified in DOE Order 6430.1A (DOE 1989). The PFP maintains occupational dose requirements, as given in 10 CFR 835, Subpart C, "Standards for Internal and External Exposure," (DOE 1993a) consistent with ALARA and the *Project Hanford Radiological Control Manual*, PHRCM (FH 2000). These guidelines limiting facility worker annual and quarterly whole-body and extremity exposures are applicable to the PFP. Radiological administrative control levels are shown in Table 8-11.

These Project Hanford Radiological Control Manual Administrative Control Levels are more restrictive than the requirements identified in 10 CFR 835, Subpart C (DOE 1993a). The DOE radiation exposure limits are listed in Table 8-12.

8.3.2.1 Radiation Shielding for Plutonium Materials Vault/Room Storage. The 2736-Z Building is the primary storage area for plutonium material in the PFP. This building consists of four rooms that are used for storage. The building is constructed of 14-in. reinforced concrete walls for shielding and safeguards protection. Three of the rooms have cubicles that are constructed of 8-in. thick precast concrete panels designed for shielding. Each cubicle has a cross-sectional area 1 by 2 ft and is approximately 8 ft tall with two doors constructed of 8-in. thick precast concrete.

The following is a summary of the storage vaults and rooms located within the PFP. This information provides a brief description of the vaults, rooms, and wall thickness where plutonium materials are stored. The movement of materials into, out of, and within the storage areas results in changes in dose rates. An example of dose rate values is given below for one vault. These dose rate values represent a single point in time but are representative of rates normally observed.

8.3.2.1.1 2736-Z Building. Storage vault 1 contains 68 cubicles (66 of the cubicles house 45 storage pedestals each, 2 cubicles consist of shelf storage). Vaults 3 and 4 contain 68 cubicles each (each cubicle has 28 storage pedestals). The cubicles are provided with 8-in. thick concrete doors that were designed for shielding. Vault 2 in 2736-Z is used for storage of 7-in. cans and lard cans (7.5 gal size). An overview of the 2736-Z Building and its layout is provided in Figure 8-15. An example of radiation field dose rate readings is provided for Vault 1 in Figure 8-16. These readings were made in August 1994. The dose rates have been normalized to 100% to correct for partial inventories existing at the time of the survey. Both neutron and gamma total dose readings are shown for the cubicles and the rooms adjacent to the cubicles.

8.3.2.1.2 Vaults 1, 3, and 4. The dose rate readings for each of the cubicles in the vault storage area were made with the cubicle doors open. The

readings in the rooms were made at 18 different locations with the cubicle and room doors in various open and shut configurations. This information provides approximate reductions of exposure with the cubicle concrete shielding doors in place. Example dose rate readings for vault 1 are given in Figure 8-16. Dose rates in Vaults 3 and 4 are similar to Vault 1.

8.3.2.1.3 Vault 2. This vault does not have shielding in place inside the room. The exterior walls are 14 in. thick, providing shielding from the room contents. This vault has the highest exterior dose rate. This exterior dose rate is routinely monitored, and high-dose-rate materials are not stored or concentrated near walls adjacent to routinely occupied areas.

The walls and cubicles that provide shielding for the radiation sources in the 2736-Z Building are shown in Figure 8-15.

8.3.2.1.4 Vault 174. This storage area consists of interim plutonium material storage in cubicle-type cabinets. The 1-ft thick reinforced concrete walls reduce the radiation levels outside the vault.

8.3.2.1.5 Vault 175. This storage area consists of interim plutonium material pedestal storage. The 1-ft thick reinforced concrete walls reduce radiation levels outside the vault.

8.3.2.1.6 Room 192-A. This area is used for storage of unirradiated Fast Flux Test Facility (FFTF) fuel assemblies and fuel rods. The 4-ft thick concrete walls reduce the radiation levels on the outside walls.

8.3.2.1.7 Rooms 192-B and 192-C. These rooms consist of plutonium material pedestal and lard can rack storage. The 2 ft 6 in. thick reinforced concrete walls reduce the radiation levels outside the rooms.

8.3.2.1.8 Vault 225. This room contains cubicle type plutonium-bearing material storage. The 1-ft thick reinforced concrete walls provide reduction of radiation levels outside the vault.

8.3.2.1.9 Vault 190. This storage area consists of plutonium material pedestal storage. The 1-ft thick reinforced concrete walls provide reduction of radiation levels outside the vault. Waste drums in the process of being filled are currently staged in this room.

8.3.2.1.10 Vault 166. This storage area contains inactive gloveboxes previously used for staging $Pu(NO_3)_4$ solutions. The 1-ft thick reinforced concrete walls reduce the radiation levels outside the vaults.

The shielding configuration is complex in that individual sources are stored in a shielded vault that has a variety of storage locations, internal shielding units, and storage arrangements.

It was determined that the total effective shielding may be more practically described by comparison of the dose rates of the occupied areas within the vaults with the dose rates at the nearest occupied area outside the vaults.

8.3.2.1.11 2736-ZD Vault. This facility is a reinforced concrete cylindrical vault 8 ft tall and 9 ft in diameter, with 1-ft thick interlocking

cover and base plate. The vault wall is about 10-in. thick. The cover and base are gasketed and bolted into place by stainless steel bolts. This facility is used to store EBR-II casks (maximum number of casks permitted in the vault is 7). The vault currently contains three EBR-II casks. According to the Criticality Prevention Specification "EBRII Shielded Cask Storage/Transfer, CPS-Z-165-83070 (BWHC 1997), the EBR-II cask is a 60 in. tall, 17 in. diameter steel casing with a 38 in. high, 6 in. diameter central payload cavity. Irradiated metallic fuel is contained inside a primary containment consisting of a 4 in. diameter (schedule 40) stainless steel pipe. This vessel is then enclosed inside another 6 in. diameter stainless steel container. Both vessels are weld-sealed and placed inside the cavity of the cask.

The casks contain Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) fuel. This fuel is in the form of metallic fuel rods which consist of six percent ^{240}Pu. The total plutonium content of the fuel comes to 7.8 kg.

8.3.2.2 Radiation Shielding for Special Nuclear Material Handling. Certain locations within the PFP use particular types of shielding to minimize radiation dose to personnel who handle or transport radioactive materials. Some examples of the shielding provided and equipment used to enhance reduction of radiation exposure follow.

8.3.2.2.1 Fixed-Array Wagons. These carriers are four-wheel wagons with five fixed positions designed with 1/4-in. lead shielding. These carriers are used for transporting various plutonium items contained in cans within the PFP Complex. These wagons are a method of remote handling for transporting plutonium materials. A typical fixed-array wagon is shown in Figure 8-20.

8.3.2.2.2 Mettler Balance Shielding. The 1-in. thick lead X-ray glass is used for shielding personnel while performing weight checks of plutonium materials on Mettler-type balances (see Figure 8-21 for this shielding configuration).

8.3.2.3 Radiation Shielding For Processing Areas. The processing areas within the PFP are provided with various types of shielding to minimize exposure to personnel. Concrete, lead, leaded glass, masonite, Lexan™, and water are the principal shield materials used. Water levels are verified by procedure and visual inspection. Table 8-13 lists the specific areas or gloveboxes, rooms, and types of shielding that are located there.

8.3.3 Ventilation

This section provides a description of the personnel protection features of the PFP ventilation system and the general design features. The specific details that address the PFP ventilation and offgas treatment systems are addressed in Chapter 5.0, Section 5.4.1.

See Section 5.4.1 of Chapter 5.0 for a complete description of the PFP exhaust systems; Chapters 5.0 and 9.0 contain an evaluation of the natural forces acting upon these and other PFP systems.

8.3.3.1 Personnel Protection Features of the Ventilation System.

8.3.3.1.1 Maintaining Internal Exposure to ALARA.

- Inward airflow through open-face and arm-ported hoods is required to be maintained to 150 ± 25 lin ft/min and 180 ± 25 lin ft/min, respectively. The inward airflow prevents suspendable material from inadvertently migrating into the room around the worker at an open-face hood or through the penetrations of a ported hood while the penetrations are in use. Within the laboratory, limits have been established that minimize the quantities of radioactive material allowed in open-face hoods based on the potential for internal deposition.

- The radiological areas are maintained at a negative pressure referenced to ambient. This design feature provides airflow from zones of lowest to highest contamination potential and from outside to inside the building.

- In the case of a loss of ventilation, the process areas are immediately evacuated. The RCTs, in respiratory protection, reenter to assess the exposure potential. Reentry is not allowed until directed by management.

8.3.3.1.2 Preventing Spread of Radioactive Materials in Normal Plant Operations.

- The exhaust system for the 234-5Z, 242-Z, and 236-Z buildings is designed to operate continuously during most off-normal conditions (see Chapters 5.0 and 9.0 for the exceptions). Following loss of normal power or if the exhaust plenum pressure increases to -3.5 in. w.g., the electric supply and exhaust fans automatically shut down and one of the two emergency exhaust fans restart with backup power supplied by diesel-generators in Building 2721-Z to maintain some ventilation and a slight negative pressure in the facility. The diesel generators in Building 2721-Z also provide power for the HVAC control system and exhaust fans in the 2736-ZA Building in case of a loss of normal power. The continued operation of the ventilation system ensures that facility confinement is maintained.

- Most of the PFP buildings are part of a single supply-exhaust once-through ventilation system. The purpose of the once-through ventilation system is to prevent air that potentially could be contaminated from being recirculated back into the building or clean areas of the facility.

- The E-4 exhaust system maintains a negative pressure (with respect to zone 3) in process enclosures (zone 4) such that, during normal operation, air flows from the zone 3 areas through zone 4 and subsequently is filtered by E-4 HEPA filters before being discharged to the common exhaust plenum. The PFP ventilation exhaust system is detailed in Chapter 5.0, Section 5.4.1.

8.3.3.1.3 Minimizing Spread of Radioactivity During Abnormal Operations or Under Accident Conditions.

- Air is supplied to gloveboxes from the room where the glovebox is located through inlet HEPA filters [with the exception of dry air gloveboxes, which are supplied by the dry air system (see Chapter 5.0, Section 5.4.3, for details of the dry air supply system used in the 234-5Z and 2736-ZB Buildings)]. These filters would reduce the quantity of particulate matter that might be carried out of the glovebox to the room in the event of an air reversal. Supply air to dry air gloveboxes is filtered through a single HEPA located in the common supply duct.

- Dampers are in place in the supply-exhaust air ducts, which provides a means of reducing or increasing airflow during hazardous tasks where there is a high potential for a release of contamination (i.e., during a panel change).

- The E-3 exhaust system provides exhaust ventilation for all rooms within radiological areas. The individual room pressure and airflow can be altered by changing the position of the dampers in the E-3 exhaust vent ducts.

8.3.3.1.4 Controlling Contamination Between Areas.

- Airlocks are used throughout the PFP as a means to control zone pressures for maintaining proper ventilation. Airlocks are provided between zone 1 and zones 3, 3A, or 3B and between the building zones and the outside wherever there is routine traffic.

- The zone pressures are established as a means to ensure confinement of radioactive materials. A differential pressure exists even between rooms within zones where there is a potential for contamination so that the airflow is desinged to move toward the area that has the greatest contamination potential.

8.3.3.1.5 Controlling Air Contamination When Personnel Access Doors or Cell Hatches are Opened or Windows, Bags, or Gloves are Breached.

- Ventilation and balance personnel are required to adjust the ventilation airflow for tasks involving the opening of process cell doors, glovebox panel changes, etc., to ensure that confinement of radioactive materials can be maintained.

- The glovebox negative pressure is maintained between -0.5 in. w.g. to -2.0 in. w.g. relative to room atmosphere to provide confinement of radioactive material if a glove or bag is breached.

8.3.3.1.6 Interfacing with Process Offgases.

- The E-4 system provides offgas ventilation for tanks and process components that are ventilated directly or indirectly to the process or access gloveboxes.

- The E-4 system is a component of the offgas ventilation train for several components (calciner, evaporators, concentrators, etc.) that are provided with specific offgas treatments as described in Chapter 6.0.

8.3.3.1.7 Limiting the Spread of Radioactivity Within the Ventilation System.

- Radioactive materials within gloveboxes are confined close to the point of origin through the use of HEPA filters installed at the entrance to exhaust ducts.

8.3.3.1.8 Providing for Ventilation Exhaust in the Event of a Stack Failure.

- Natural forces studies, which are addressed in Chapters 5.0 and 9.0, show that the 291-Z-1 stack will not fail.

8.3.3.1.9 Providing for Power Outages.

- The PFP gloveboxes are designed with inlet and exhaust HEPA filters that provide for confinement of radioactive materials if there is a loss of ventilation.

- The quantities of radioactive materials in the laboratory hoods are limited and contamination in these hoods is maintained ALARA to minimize a potential spread of contamination during a power outage.

- In the event of a power outage, diesel-generators located in the 2721-Z Building provide backup power to two of the exhaust fans ventilating the 234-5Z, 236-Z, and 242-Z buildings. One of these exhaust fans runs continuously under all conditions. If a failure of normal power occurs or if a failure in the operating backup fan occurs, the alternate backup fan automatically starts. Only one of the two emergency exhaust fans operates on loss of normal power. The HVAC control system, also connected to backup power, actuates the second fan and switches dampers in the event the online fan fails during backup power operation. The diesel-generators in Building 2721-Z provide backup power to the exhaust fans for Building 2736-Z. See Section 5.4.2 of Chapter 5.0 for additional information on the backup power system.

8.3.3.1.10 Limiting Radioactivity in the Stack Effluent.

- The exhaust from the E-3 areas of the 234-5Z Building is filtered through a single stage of testable HEPA filters before discharge to the 291-Z-1 stack. If the filters in the E-3 filter room fail, the airflow is diverted to another E-3 filter room for filtration.

- The exhaust from the E-4 areas of the 234-5Z Building is filtered through a minimum of two stages of testable HEPA filters before discharge to the 291-Z-1 stack. The E-4 filter rooms 309 and 310 are the final exhaust HEPA filters for the 234-5Z Building ventilation exhaust. Only one of these filter rooms is in use at a time. If the filters in the filter room in service fail, the spare filter room is placed in service. See Chapter 5.0, Section 5.4.1 for additional details of the HVAC system.

- There are three stages of testable HEPA filters that filter the room and glovebox exhaust in the 2736-ZB Building. Within the 2736-ZA Building there are two stages of testable HEPA filters that filter the room exhaust. The 2736-Z Building consists only of storage rooms and exhausts through the 2736-ZA Building.

- The 236-Z Building room exhaust is filtered through a single stage of testable HEPA filters. The process cell and glovebox exhaust is filtered through two stages of HEPA filtration.

- The exhausts from the 241-ZA glovebox, 241-Z vaults/tanks and the 242-Z Building are filtered through two stages of testable HEPA filters. The 232-Z Building glovebox exhaust (E-4) is filtered through two stages of HEPA filters (untestable). Glovebox exhaust (E-4) then combines with the room exhaust (E-3) and is filtered through two stages of testable HEPA filters before discharging to atmosphere.

The gloveboxes and filterboxes are equipped with Magnahelic instruments that read the differential pressure across the filters. The power operators are required to conduct readings of all gloveboxes and filterboxes on a routine frequency (at least biweekly for filters related to current processing procedures) to ensure the Magnahelic readings are in the acceptable range. Any readings outside the acceptable range require that the filters be replaced. The testable HEPA filters are required to be tested periodically using a challenge aerosol to ensure filter integrity.

8.3.3.2 234-5Z, 236-Z, 242-Z, 2736-Z, and 2736-ZB Buildings and the 241-Z Complex.

8.3.3.2.1 Steam Supply Systems. Supply systems for these buildings are described in detail in Chapter 5.0, Section 5.4.6.

8.3.3.2.2 Dry Air Supply. Portions of the plutonium conversion lines in the 234-5Z Building received dry air to maintain low moisture content for the oxide or metal product. The dry air system currently supplies normal air to these lines. The 2736-ZB Building dry air system continues to supply dry air to the repackaging glovebox in room 636. See Chapter 5.0, 5.4.3 for a description of this system.

8.3.3.2.3 Instrument Air Supply. The instrument air supply system to these buildings is described in detail in Chapter 5.0, Section 5.4.3.

8.3.3.2.4 Vacuum Systems.

26-in.-Hg Process Vacuum Exhaust System. Process solutions can be transferred between gloveboxes within the PFP using the solution transfer vacuum system. The exhaust system for the 26-in. mercury process vacuum system is described in Chapter 5.0, Section 5.4.5.

17-in.-Hg Air Sampling Vacuum Exhaust System. Air is drawn through CAMs and FHSs located in the PFP buildings by two liquid-seal-type vacuum pumps. This system is described in detail in Chapter 5.0, Section 5.4.5.

5-in.-Hg Vacuum Exhaust System. This system is used to draw off gases from the furnaces in the HA-21I glovebox. This exhaust system is described in detail in Chapter 5.0, Section 5.4.5.

The vacuum systems supplied to these buildings are described in detail in Chapter 5.0, Section 5.4.5.

8.3.3.2.5 Exhaust System General Description. The PFP main stack (291-Z-1) exhausts filtered process air from gloveboxes, hoods, and process cells in the 234-5Z, 236-Z, and 242-Z Buildings and from those rooms that may have a potential for contamination. See Chapter 5.0, Section 5.4 for a detailed description of the exhaust system for the 234-5Z, 236-Z, and 242-Z Building. Exhaust ventilation for the 2736-Z and 2736-ZB Buildings is described in Chapter 5.0, Section 5.4.1. See Chapter 5.0, Section 5.4.1 for details of the ventilation system for the 241-Z Complex.

The exhaust monitoring and sampling system provides an alarm indication if radioactive materials are being discharged to the environs. The sampling part of the system obtains a record sample for laboratory analysis of what has been discharged. The range of the exhaust monitor is such that it can respond to the accidents categorized in Section 9.2.

E-1 Exhaust System. A description of this system for each building in the PFP can be found in Chapter 5.0, Section 5.4.1.

E-3 Exhaust System. A description of this system for each building in the PFP can be found in Chapter 5.0, Section 5.4.1.

E-4 Exhaust System. A description of this system for each building in the PFP can be found in Chapter 5.0, Section 5.4.1.

8.3.4 Criticality Alarm System

This section describes the criticality monitors and continuous airborne radioactivity monitoring instrumentation including calibration requirements; criteria for placement of instruments, detectors, recording devices; auxiliary and/or backup power supply; and alarms for monitoring instrumentation.

8.3.4.1 Criticality Alarm System.

8.3.4.1.1 General Description. The CAS uses gamma and neutron detectors located in areas (detector selection is dependent on the background radiation field encountered in the detector location) in which fissionable material may

be processed, stored, or transported. The number of detectors covering an area depends on area size, intervening shielding, and other factors, as identified in the following: DOE Order 5480.24, *Facility Safety* (DOE 1995a); HNF-SD-CP-SDD-003, *Definition and Means of Maintaining the Criticality Detectors and Alarms Portion of the PFP Safety Envelope*; *Criticality Alarm System*, HNF-PRO-546; and, ANSI/ANS 8.3, *Criticality Accident Alarm Systems*. An operable criticality alarm system is required by Operational Safety Requirements. Additional descriptive information is contained in HNF-IP-1115, *Nuclear Criticality Alarm Manual for the Plutonium Finishing Plant* (BWHC 1998a) and HNF-PRO-334, *Criticality Safety General, Requirements*, and HNF-PRO-546, *Criticality Alarm System*. Because the system is modular with spare modules and components readily available, unit replacement may be used to minimize system down time. All work involving fissionable materials is suspended or terminated in an affected area if the area's CAS is out of service. Alarm set points are based on the "minimum criticality event" (an absorbed dose of 20 rads at 2 m in 1 min) and area background radiation levels. The system alarms when 2 detectors in an area reach alarm threshold settings.

An alarm energizes a system of evacuation alarms. Personnel have been trained to make a safe rapid exit to at least 100 ft from the occupied facilities when the alarm sounds. Blue flashing lights are used to supplement the audible alarms in some areas.

A preventive maintenance and surveillance (PMS) procedure is used to perform verification of alarm audibility.

Individual detector coverage was established during the design phase of the system. The IRON 19 computer code was used. The information was used to establish detector overlap for verification of "2 out of n" logic coverage of potential criticality locations.

The CAS has the incidental collateral function of area radiation monitoring. Mobile criticality detection and alarm units [transportable criticality alarm system (TCAS)] are used as temporary criticality monitors for entries into areas not routinely protected by the CAS.

8.3.4.1.2 Gamma Detection Instrumentation. The gamma detection system is used with an audible signal generator (ASG), horn, power supply, intertie circuitry, and alarm monitoring equipment to form a complete CAS. Most of the components (except the detectors, horns, and power supply) are mounted in a criticality alarm panel. A typical criticality alarm panel is shown in Figure 8-22. A large facility like the PFP has the CAS grouped into a total of nine criticality alarm panels.

The criticality alarm detector (CAD) uses a plastic, NE 102 scintillator to detect gamma radiation. The scintillator produces a light output proportional to the gamma ray exposure rate. This light falls on the cathode of a photomultiplier tube providing an electrical signal proportional to the gamma ray exposure rate. A photomultiplier tube has an inherent logarithmic function relating amplification to voltage, which results in a logarithmic scale on the panel meter on the criticality alarm detector module (CADM).

Although the photomultiplier tube current originates as pulses, the CAD circuit response is to the integrated value of the pulses (i.e., the resultant current).

The CAD assembly is approximately 2.5 in. in diameter and 13 in. long. Figure 8-23 shows the CAD mounted on an assembly with brackets for positioning a calibration source.

Each CAD has an associated CADM that provides gamma indication and alarm functions. Calibration adjustments of the CAD-CADM combination are on the CADM. The CADMs are plug-in-type modules that plug into a criticality alarm panel.

The CADMs have an adjustable trip range. The practical gamma dose rate range is from a nominal 100 to 500 mrem/h. The choice for a particular location is determined by the postulated criticality event and two other considerations: the desired range of detection and the possible background levels. The background radiation may be either constant or transitory due to movement or storage of material near a CAD.

A key-lock switch is associated with each CADM. Turning the switch from "operate" position to "inhibit" position prevents a high-alarm output signal from the CADM to the logic and alarm circuitry. This switch is used during test, calibration, and replacement of CADs and CADMs. The key may be removed from the switch only in the operate position. Figure 8-24 identifies and lists the various components that are a part of the CADM.

Criticality alarm logic modules (CALM) and criticality alarm relay modules (CARM) are shown in Figure 8-25. The CALM provides the logic circuitry that causes the criticality alarm horns to sound if two or more CADMs on the same criticality alarm panel (CAP) are in the high-alarm state. One CALM accepts the inputs of up to six CADMs. Additional CALMs may be connected as required to accept outputs from all of the CADMs in a criticality alarm panel. Any two of the CADMs in an individual CAP will cause the alarm.

If one CADM goes into the high-alarm state, the CALM causes the CARM to go into "alert" condition. The signal would call for operations/maintenance response to determine the cause of the alert. If two or more CADMs on the same CAP go into the high-alarm condition, the CALM causes the associated CARM to go into "alarm" condition. (This 2-out-of-N logic alarm system ensures that a false alarm is not initiated by one CADM failing in alarm condition.) Relay contacts close, turning on an audible signal generator. An alarm monitor signal is also provided. The CADMs go into the failure trip state if the reading falls below the low set point, which can be caused by several different failures (e.g., a loss of power to the detector, a broken cable to the detector, a burned out artificial background light bulb, etc.) or by loss of power to the CADM. The failure trip state does not cause the CALM to put the CARM into the "alert" condition. That is, the failure trip state is not treated as an alarm and does not satisfy any of the "2-out-of-3 logic" for alarming. The CALMs and CARMs plug into a bin, which is mounted in CAP instrument rack.

The gamma detection instrumentation (as well as the rest of the system) operates from a float battery charger, with a battery backup. Backup power is

thereby provided if main power is lost. An alarm monitor signal is provided to warn of reduced voltage or loss of power to the system.

A gamma radiation source in a source holder is used to calibrate and routinely test the gamma detection instrumentation of the CAS. The design of the CAD mounting bracket enables the source to be placed in repeatable geometric positions with respect to the scintillation crystal in the CAD. This holder was designed to permit alarm trip calibration from a nominal value of 2 mrem/h to 100 mrem/h. The source holder can be adjusted to provide a radiation field intensity traceable to the National Institute of Standards and Technology (NIST). The gamma calibration source holder is adjusted annually using a transfer instrument calibrated by the PNNL calibrations section. A typical criticality alarm source holder is shown in Figure 8-26.

Each gamma detector and detector module within the PFP is calibrated at least annually and functionally tested at least monthly.

8.3.4.1.3 Neutron Detection Instrumentation. The neutron detectors are used exclusively in the 2736-Z Building. The neutron detectors are used where gamma ray shielding of storage arrays would require a large number of gamma detectors to provide adequate detection coverage (WHC 1993c).

The neutron detection instrumentation consists of two principal components: the detector (including associated electronic circuitry) and the comparator panel (located in 2736-ZA). This instrumentation is used with an audible signal generator, horns, power supply with battery backup, and alarm monitoring equipment to form a complete CAS. Detectors are located so that at least three are within detection range of a possible criticality.

Neutron detectors are periodically removed from service and calibrated to a uniform neutron flux at the PNNL calibration facility. When in service, neutron detectors are functionally tested for alarm trip monthly using an americium/beryllium neutron check source with a strength of approximately 1.0 E+07 neutrons/second. The source is contained within an outer source holder container and, when being used, is affixed to a 60 in. extension handle to provide distance between the source and source handler. When not being used for neutron detector testing, the source is stored in a heavily shielded 30 gal drum in the 2736-ZB Building. Drawing H-2-28814 documents construction of the neutron source holder, extension handle, and storage drum.

The audibility testing of all criticality alarm horns is conducted quarterly. Sufficient alarm audio sound generators are installed to achieve a sound level of at least 10 dB above the maximum background noise and not less than 75 dB in all occupied locations within the 25 rem/1 h boundary (except for areas with very high background noise) but does not subject any personnel to sound intensities greater than 115 dB. In areas with high background sound, the alarm sound is supplemented by local blue rotating beacons or flashing blue strobe lights. The alarms are present at every location from which prompt evacuation is essential, as specified in *Nuclear Criticality Alarm Manual for the Plutonium Finishing Plant*, HNF-IP-1115 (BWHC 1998a). The alarm system is designed to meet the criteria of ANSI/ANS 8.3 for evacuation signals.

8.3.4.1.4 Criticality Detector, Alarm Panel, and Horn Locations Within the PFP Complex. The 234-5Z Building has an installation of gamma ray

detection instrumentation. There are four criticality alarm panels located at intervals along corridors 2 and 13. The detectors are located in groups of three. The detector groups are divided among the four criticality alarm panels, although not necessarily in equal numbers per criticality alarm panel. Each criticality alarm panel has an associated 24-V storage battery and battery charger. The horn connections likewise are divided among the four criticality alarm panels. The audible alarm circuitry is intertied so that all of the horns in the PFP Complex will sound for an alarm originating at any one of the criticality alarm panels (except CAP 8). The horns are also intertied to sound with those in the 236-Z, 2721-Z, 2736-Z, 2736-ZA, and 2736-ZB Buildings.

The 236-Z Building has an installation of gamma detection instrumentation. The detectors are located in groups of three, divided between two CAPs. The two CAPs are located in the control room on the fourth floor. Each CAP has an associated storage battery and battery charger. The horn connections are divided between the two CAPs. The audible alarm circuitry in the two CAPs is intertied so that all the horns in the 236-Z Building will sound for an alarm originating at either CAP. The horns are also intertied to sound with those in the 234-5Z, 2721-Z, 2736-Z, 2736-ZA, and 2736-ZB Buildings.

The 2736-Z Building has an installation of neutron detection instrumentation to provide coverage of the plutonium storage vaults. In addition, a gamma-sensitive detector station is installed in the hallway of the 2736-Z Building as a backup detection system. The criticality alarm horns in the adjacent 2736-ZA Building are supplemented with four blue flashing lights in the exhaust fan and generator room because this building has a high noise background.

Three neutron detectors are installed in each of the four storage vaults of 2736-Z. These detectors are grouped near the ceiling at the center of each room. There are 12 neutron detectors in the building. Two comparator panels, required to interconnect the detectors, are located in the 2736-ZA Building. Three gamma detectors are installed in the hallway. The audible signal generator, the power supply equipment, and the gamma monitor logic and relay modules are in the 2736-ZA Building. The horns are intertied to sound with those in the 234-5Z, 236-Z, 2721-Z, 2736-ZA, and 2736-ZB Buildings.

The 2736-ZB Building has an installation of gamma detection instrumentation. There are five criticality detector stations with three detectors each. The CAP, battery, and battery charger are located in room 638. The alarm horns are intertied to sound with those in the 234-5Z, 236-Z, and 2736-Z Buildings. The criticality horns in the adjacent 2721-Z (generator) Building are supplemented with a blue flashing light because this building has a very high noise background.

The 241-Z Building has an installation of gamma detection instrumentation, CAP-Z8. There are two CAD stations that have three detectors each. The CAP, battery, and battery charger are in the 241-ZG Building. No alarm horn intertie is provided with any of the other buildings. This building is not continuously occupied and is located such that a criticality in the below-ground-level tanks will not have a significant effect on other buildings of the PFP Complex. Personnel hearing an alarm in or associated with the 241-Z Building are trained to report the fact to the PFP shift manager.

The 232-Z Building does not have the new CAS installed in the facility. The 232-Z building is awaiting D&D and is classified as a limited control facility.

Representative locations of the CAS within the PFP Complex (234-5Z, 236-Z, 2736-Z, 2736-ZA, 2736-ZB, 2721-Z, 241-Z, and 232-Z Buildings) are shown in Figure 8-27. Current locations of CAS detectors are in the most recent revision of the CAS drawings H-2-28885, H-2-80143, H-2-28888, and H-2-91823.

In all instances of outages of the CAS or components of the system, the Plutonium Operations management is notified in accordance with Limiting Conditions for Operation and Surveillance Requirements 3.1 "Criticality Safety Systems" of WHC-SD-CP-OSR-010 (WHC 1994c) and fissile movement is prohibited in the affected area. Notification of a "No Fissile Movement" restriction is required before the outage action starts or, if the outage is unplanned, notification is made within the compensatory action completion time specified in OSR LCO 3.1.2. All planned outages must have the approval of the Manager of PFP Safety and plant management of the PFP. In addition to outage approval, these managers will issue any special instructions for fissile material control during the outage. For further discussion, see FSP-PFP-5-8, Chapter 1.0 Conduct of Operations and Chapter 3.0, Safety.

8.3.5 Airborne Radioactivity Sampling and Monitoring.

Each year PFP RC reviews work space air sampling and monitoring to ensure compliance with 10CFR835, the Project Hanford Radiological Control Manual (DOE 1994), and Site procedures. Routine evaluations of air monitoring results ensure that airborne plutonium concentrations in the PFP are compliant with DOE limits (BWHC 1997a).

8.3.5.1 General Description. The purpose of the air sampling and monitoring program is to warn personnel of the unexpected release of airborne radioactive materials, provide data regarding potential personnel doses and the effectiveness of containment systems, to provide a legal record of personnel dose, and to determine if doses are maintained ALARA. In all applications, the intent is to restrict airborne radioactive materials to ALARA levels and not to exceed levels in the applicable DOE orders. This statement is applicable to the effluent monitors, also.

8.3.5.2 Sampling and Monitoring Systems.

8.3.5.2.1 Fixed-Head Samplers. The FHSs have been placed in strategic locations in the PFP to evaluate average airborne concentrations of contamination at work locations. As a minimum, FHSs are located where there is a potential for airborne radioactive contamination intakes greater than 2% of the ALI as contained in 10 CFR 835, Appendix A (DOE 1993a). The FHSs are used to sample room air for evaluation of potential inhalation hazards to personnel. Because of space or mounting limitations or airflow direction, not all FHSs installed for this latter purpose have been located in the breathing zone. Portable air samplers (goosenecks), and portable CAM units are used as required by radiation work permits to augment the FHS system. In areas where there are no FHSs and temporary sampling is required, CAMs or other types of portable samplers are provided.

The FHSs in the PFP are the open-face-type nominal 47-mm filter heads with filters that are supported by a screen. All FHSs are equipped with a calibrated flow-indicating device (rotameter) and pressure regulating device (to keep flow constant as the filter loads). The FHS particulate air samples are drawn at a 1.0 ft^3/min or 2.0 ft^3/min flowrate depending upon the building.

The FHS filters are exchanged by the PFP RCT personnel weekly. These filters may be exchanged at the discretion of RCT supervision to help evaluate an airborne contamination event. Data from filters also may be used to support the concentrations recorded by a CAM alarm. The sample filter is sent to the PFP A-Labs for analysis. The fixed-head stack environmental sample filters (record samplers) are sent to the Waste Sampling and Characterization Facilities (WSCF) for alpha and beta particle analysis.

The vacuum sources for FHS consist of the 17-in. mercury vacuum system (also referred to as the air sample vacuum system) or portable rotary pumps. The 291-Z and 236-Z air sample vacuum systems are not provided with backup power. Loss of plant vacuum does not present an immediate safety concern for those plant areas sampled by FHS units only. The 291-Z-1, 296-Z-3, 296-Z-5, and 296-Z-14 stack portable rotary vacuum pumps and the 2736-ZB air sample vacuum system are provided backup power from diesel generators in the 2721-Z Building.

Operability checks of the FHSs are conducted by the RCT organization weekly. The calibration frequency for FHSs is yearly.

8.3.5.2.2 Continuous Air Monitors. Within the PFP, CAMs are installed where there is potential for airborne concentrations exceeding the applicable DAC. The CAMs are used for sampling and monitoring areas where equipment, containment, or confinement failure could cause a rapid increase of airborne contaminant levels exceeding occupational DAC or ALARA concentrations. Because of the necessity of frequent changes of their sample filters, CAMs are not normally used to establish breathing zone air concentrations or to quantify chronic low-level airborne exposures.

In situations where the CAM sample is the only air sample being drawn in the workplace, care is taken to ensure that it is run as long as possible, up to a one week period between filter changeouts.

Room CAMs are located in areas recommended in PNNL air sampling evaluations for the PFP. Representative CAM locations at the PFP Complex are shown in Figure 8-13. Current locations are shown on the most recent revision of the CAM Station Locations drawing, H-2-80107.

The CAMs located within, and used as effluent monitors at, the PFP are primarily alpha sensitive (Eberline ALPHA-4A, -5A and 6, and Canberra type). They measure the alpha emission of airborne radionuclides that have been trapped on a filter media by detecting alpha particles having specific energies. This allows discrimination between ^{239}Pu and alpha emitting airborne radioactive materials. A typical alpha CAM used in the PFP is shown in Figure 8-28.

The sample filter holder for these units is designed with the radiation detector in close proximity to the surface of the filter. As sample air is

drawn through the filter, the detector measures the radioactivity accumulated on it. Filter media used for particulate CAMs and effluent exhaust record samplers in the PFP are of the membrane type, depending on the application of the CAM. Membrane filters are normally used in the alpha CAMs as the particulates collect on the surface of the media rather than being embedded in it. This significantly reduces degradation of alpha particle energies thus improving resolution and discrimination between radioisotopes and reduces the possibility of false alarms. Both filter types used are nominally 47 mm in diameter.

Most Eberline CAMs in the PFP have the conventional level rate meter and chart recorder configuration. The CAM amplifier electronics output the background-subtracted signal to the count-rate meter and chart recorder devices. When it is necessary to determine approximate air contamination concentrations after a valid CAM alarm, the chart can be used to estimate the total volume of sample collected during the off-normal condition. This is accomplished by examining the chart record and tracing the recorded count-rate data back to the sample's equilibrium point (i.e., the point of constant background). The time increment between the beginning of the count-rate increase and the time the sample is removed can then be estimated. Multiplying the estimated time duration of the event by the sample flowrate provides an estimate for total flow volume data. Chart records are normally retained in the individual RCT field office for 30 days and are disposed of after that time.

Most Eberline CAM electronic assemblies include an adjustable high-alarm set point. The CAM systems are equipped with a set of high-alarm-point external contacts that may be used to initiate automatic actions (equipment trips, remote alarms, etc.). All CAMs within the PFP have audible and visual alarms. Operator control stations (OCSs) in the MICON™ control station (room 714 of the 234-5ZA Building) provide remote annunciation capability for all stack CAM/loss of vacuum service alarms. The Building 2736-ZB and Building 2736-Z room CAM alarms annunciate to annunciator panels in room 631 of the 2736-ZB Building and room 221A of the 234-5Z Building.

The adjustable high-alarms set point is called the Alpha Set Point (ASP), and is established in accordance with HNF-PRO-5675, *Radiation Protection Real-time Monitoring*, using facility specific procedures, it is typically 25-35 cpm.

When an alarm situation does occur, the affected area is treated as if the unknown activity on the CAM sampling filter is the most restrictive dispersible contaminate in the facility. Analysis of sample filters from the affected area is then performed. If the analysis determines that the activity on the sample filter is radon and radon daughters, and an inspection of the area reveals no other circumstances requiring the area to remain on respiratory protection status, the CAM alarm set point can be raised to the normally used count value, above the current equilibrium point of the sample filter, in accordance with PHRCM.

CAMs rely on the same vacuum sources as the FHSs described in Section 8.3.5.2.1. The 291-Z-1, 296-Z-3, 296-Z-5, and 296-Z-14 stack CAMs and record samplers are provided backup power from the diesel generators in the 2721-Z Building. The 296-Z-6 stack CAMs are provided backup power from a diesel generator installed in the 2736-ZA Building. Portable pumps may be

installed upon loss of 17-in. mercury vacuum service. Loss of plant vacuum results in ceasing work activities in all contamination potential areas that use air monitors (CAMs). Personnel are not allowed to restart work activities in areas with CAMs until monitoring capability is restored. Vacuum supply for portable CAM units is by ac-powered rotary vacuum pumps with backup power provided to any portable CAMs used for stack monitoring. Sample airflow is indicated by flow indication devices (rotameters) on the CAMs. Large volumes of air must be drawn through the filter media to accurately determine small concentrations of airborne contaminants. Stack effluent monitoring probes are designed to be near isokinetic at the designed flowrate of the exhaust stack and CAM.

Sample probe pickup line inlet points for most CAMs in the PFP are located in exhaust ducts, stacks, or directly in the airflow path in front of room exhaust in work areas. A typical room exhaust filter located in the 2736-ZB Building is shown in Figure 8-29. How the sample pickup line is installed directly in the path of room airflow is also shown in Figure 8-29. The pickup probes are as short as possible with any required elbows or bends having as large a radius as is practical. Sample activity line loss is incorporated into air sample calculations where necessary. Sample line transmission fractions are specified in the procedures governing the calculations.

Most of the PFP CAMs are examined for proper operation each day by RCT personnel. Additional inspections and operational performance tests are completed weekly, along with the exchange of sample filters. CAMs are removed from service at 12 month intervals (normally several at a time) and replaced with units that have just been calibrated. All alpha CAMs are calibrated by the instrumentation contractor.

CAMs and their associated alarm function mitigate some potential facility worker hazards at PFP. In general, during stabilization activities, the primary boundary to release of radionuclides to occupied rooms are gloveboxes, process systems, or sealed plutonium storage containers. The primary boundaries to plutonium release inside PFP can fail through several potential mechanisms, such as improper maintenance, equipment degradation, or abnormal glovebox pressurizing events. In many cases, there is no obvious indication that a plutonium release has occurred. The CAMs serve to validate the satisfactory performance of the barriers to plutonium release. If one of these primary barriers fail and plutonium is released inside PFP, then alarms are actuated when the alarm setpoint is reached. Upon activation of the alarm, facility workers are trained to promptly evacuate the affected airspace. These actions in combination serve to reduce the potential plutonium inhalation dose received by the affected facility workers. The public and onsite non-facility workers are not significantly affected by these potential plutonium releases inside PFP because the exhaust air flow is filtered by the applicable exhaust ventilation system prior to release outside of PFP.

8.3.5.3 Miscellaneous Monitoring Devices.

8.3.5.3.1 Workstation Monitors. The CAMs and semi-portable alpha survey instruments (Poppies) are located at or near workstations and room exits because of the potential for personnel or equipment to become contaminated at the workstation. Cart-mounted units are available for use in the laboratory

and glovebox areas so that personnel may survey immediately after exiting a hood or glovebox. Cart-mounted CAMs are used to monitor as near as possible to operations that may produce airborne activity.

8.3.5.3.2 Effluent Monitors. The criteria for obtaining representative samples of effluents and the features of the sampling systems are identified in Sections 8.6.1.1 and 8.6.1.2.

8.4 ESTIMATED PERSON-REM FOR PLUTONIUM FINISHING PLANT OPERATING PERSONNEL (DOSE ASSESSMENT)

The estimated occupancy factor of the PFP radiological areas during normal operation is identified in "First Quarter ALARA Goal Status" (McQuinn 2000). The high exposure rate values are associated with the principal work station(s) in the designated rooms. The exposure rates provided are the summations of the neutron and gamma exposure rates. Workstation occupancy in high exposure areas is usually one-third or less of the indicated occupancy rate. An estimate of plant occupants in radiological areas during an anomaly is the same as during normal operation. The actual operating history of the plant shows that functional conformance to the 1 rem/yr shielding performance criteria of DOE Order 6430.1A (DOE 1989) is being achieved.

In the PFP, there are no areas with known airborne radioactivity concentrations that are easily accessible to, or normally occupied by, operating personnel. Areas with a high potential for airborne radioactivity are posted and locked. Entrance to these areas requires special authorization as well as respiratory protection. Where only a single engineered barrier exists between the process materials and the worker, multiple administrative controls and safety monitoring are provided, including air sampling and monitoring equipment, self-survey devices [Poppies and portable alpha meters (PAMs)], respiratory protection, and RCT coverage.

Many PFP personnel are provided with the Hanford Combination Neutron Dosimeter (HCND). These HCNDs are processed monthly, quarterly, or annually based on expected radiation exposure. The data from 386 personnel shows that the total exposure (beta-gamma plus neutron) for CY 1995 was 30.89 person-rem, which averages to 0.08 rem each.

A normalization to 100% vault contents was performed. The dose rates derived from this approach, when compared to current limits for occupational exposure, verify that the shielding in place is adequate. The CP and Snoopy (described in Section 8.5.2.1) are the principal instruments used for dose rate determination in the PFP facilities.

Gamma-to-neutron exposure-rate ratios are highly variable in these facilities. The observed ratios range from greater than 100:1 (gamma/neutron) to less than 1:100 with the average ratio in the 3:1 to 3:2 range. These ratios are principally dependent on shielding material used but do change with the chemical form of the source material and its specific activity and moisture content.

See Sections 5.2 and 10.5 for further information relating to physical and administrative protection of the onsite individual. Chapters 6.0 and 9.0

discuss facility capabilities for providing nuclear criticality safety for the process, the building, and the onsite individual.

8.5 RADIOLOGICAL CONTROL PROGRAM

This section addresses the Radiological Control (RC) program organization, training, equipment, instrumentation, facilities, and procedures. Where applicable, particular emphasis is placed on those aspects of the RC program directly related to the PFP operations. The radiation protection program implements the requirements of the DOE orders and regulations via the use of controlled procedures. These procedures reiterate the DOE policies and requirements, assign authorities, and provide the framework for the supporting and implementing documents. These documents are used to establish compliance with 10 CFR 835 (DOE 1993a), PHRCM (FH 2000) and DOE Order 5480.4, *Environmental Protection, Safety and Health Protection Standards* (DOE 1984) requirements. The basic program guidance is provided by 10 CFR 835, and the PHRCM, while various DOE 5480.4 documents establish the mandatory and recommended standards to be used in various components of the radiation protection program. The reference section of PHRCM lists documents or other DOE orders that are pertinent to, or provide a basis for, the implementation of the primary radiation protection regulation. Implementation of radiation protection requirements is through a series of procedures developed by the Hanford Site contractor including HNF-SP-1145, *Fluor Daniel Hanford Radiation Protection Program, Implementation of Title 10, Code of Federal Regulations, Part 835*. Hanford Site contractor documents are written so that compliance with them also means compliance with the applicable DOE regulations and orders.

DOE Order 5480.4 (DOE 1984) also lists reference standards as guidance for good work practices. These reference standards include Federal Radiation Council, ICRP, International Commission on Radiological Units and Measurements, National Council on Radiation Protection, and International Atomic Energy Agency reports; additional ANSI standards; specialty reports by the DOE, PNNL, and the Nuclear Regulatory Commission (NRC); and other documents that would contribute to the improved performance of a radiation protection program. The reference standards are used to keep the radiation protection program up to date. Modifications or additions to the PFP facilities are required to address the appropriate criteria of DOE Order 6430.1A (DOE 1989).

8.5.1 Equipment, Instrumentation, and Facilities

This section provides information on the various RC-related portable equipment, instrumentation, and facilities available to support the radiation protection program for the PFP [see PNL-MA-562, *Portable Radiation Survey Instrument Manual*, (PNL 1988c)]. The DOE has listed NRC documents as reference standards to be used when the subject area is not fully addressed in DOE documents. The guidance provided by NRC Regulatory Guides 8.4, *Direct Reading and Indirect Reading Pocket Dosimeters*, and 8.9, *Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program* (NRC 1973b and NRC 1973a, respectively) and applicable ANSI standards has been followed, with exception of the criteria for film badge performance. Thermoluminescent dosimeters (TLDs) are used for monitoring personnel dose rather than film

badges. Specific performance criteria are applied to the TLD program that meet or exceed the intent of ANSI N13.15, *Performance of Personnel Thermoluminescence Dosimetry Systems*. The TLD program participates in the DOE Laboratory Accreditation Program (DOELAP). The Hanford standard dosimeter and Hanford combination neutron dosimeter are DOELAP accredited. The present practice of DOE-RL is to contract the selection and calibration of instrumentation separately from the management and operations (M&O) contract.

The instrumentation contractor currently provides the following services for the Hanford Site:

- Operation of the portable radiation detection instrument pool
- Radiation detection instrument calibration services
- The TLD services for personnel monitoring
- Environmental monitoring and sampling services
- Compilation and issuance of the annual Hanford Site environmental report
- Consulting services related to radiation and environmental protection.

A matrix relating the PFP radiation detection instrumentation to ANSI criteria documents is shown in Table 8-17. These standards are used by the PFP and its supporting organizations to provide a quality radiation protection program. Standards applicable to radiation protection design and confinement features are identified in Chapters 4.0, 5.0, and 6.0.

The function of the instrumentation calibration contractor is to aid the facilities in obtaining the best possible instrument for the designated purpose.

8.5.1.1 Portable Survey Instruments. Most of the portable instruments used by the PFP radiation protection program are from the Hanford Site instrument pool operated by the instrumentation contractor. Instrumentation is purchased by the various Hanford Site facilities and then placed into the pool for calibration, maintenance and repair. This allows the various facilities to have calibrated specialty instruments available on an as-needed basis. The Poppy alpha-sensitive semi-portable unit is one exception. The Poppy is unique to the PFP facility and is calibrated and maintained within the facility. Instrumentation available from the Hanford Site instrument pool is described in PNL-MA-562 (PNL 1988c). This manual also contains various correction factors and other data pertinent to the physical and environmental use of the instruments. The instrument characteristics are summarized in Table 8-18. The principal routinely used instruments at PFP are the CP, PAM, Eberline Model E-140 with pancake Geiger-Mueller (GM) detectors, Snoopy, and Poppy.

8.5.1.2 Portable Airborne Radioactivity Monitoring. The use of portable CAMs for airborne radioactivity monitoring is addressed in Section 8.3.4.2.

8.5.1.3 Criteria for Selection of Portable Laboratory Equipment and Instrumentation. Portable and laboratory technical equipment and instrumentation for performing airborne radioactivity sampling, area dose rate surveys, and personnel monitoring during normal operations or anomalies are selected using criteria from the Technical Assessment of Compliance with *Workplace Air Monitoring Program* (BWHC 1997a). Additional criteria for selection of portable survey instrumentation for performing contamination surveys is provided by the HIEC.

8.5.1.4 Instrument Storage, Calibration, and Maintenance Facilities. The portable radiological monitoring instruments, with the exception of Poppies, are provided to the PFP from the instrumentation contractor. Instruments are calibrated on a rotational basis by the instrumentation contractor or the PFP Instrument Shop on a fixed calibration schedule or when operational checks indicate problems. Calibration sources used are traceable to NIST (formerly NBS) standards. Appropriate ANSI standards are used as required by DOE orders and PHRCM (FH 2000) for calibrations and record keeping.

Spare and operational instruments are stored in various locations throughout the PFP facility. The principal storage locations are in the RC office in the 234-5Z Building, room 221B and the 2736-ZB Building, room 631. Instruments are also maintained in the emergency response supply lockers, which are inventoried and sealed to prevent unauthorized use.

Portable instruments that have malfunctioned or are due for calibration are tagged, segregated, and transported to the instrumentation contractor weekly. See Table 8-18 for calibration frequencies.

The Poppy alpha contamination survey instrument is maintained and calibrated by the PFP instrument technicians. A number of Poppies are kept in a storage rack in room 158; they are connected to ac power to maintain the batteries fully charged until they are needed to replace Poppies requiring calibration.

8.5.1.5 Radiological Control Offices. The RC facilities within the PFP are located in the 234-5Z and 2736-ZB Buildings.

The office in room 221-A of the 234-5Z Building is used by the RCT supervisory personnel and RCTs who support operations. This office also serves as the central RC facility for the PFP and contains records of survey and personnel dose data. It has a computer terminal located at the access control enrollment station (ACES) that is used for tracking doses obtained from gamma pencil readings. There is also a source for checking CPs. The RC facility in the 2736-ZB Building is located in room 631. These rooms are equipped with storage cabinets for portable survey instrumentation and equipment.

A console in room 221-A provides indication of room CAM alarms for high alpha, room CAM failure, or loss of instrument vacuum for the 2736-ZA Building west and east filterbanks and the 2736-ZB Building repackaging, shipping, staging, NDA, and receiving rooms. After receiving an alarm, the operator notifies RC and PFP Facility Operations, initiating the appropriate alarm response.

The office in room 631 is used by the RCTs who support operations in the 2736-ZB Building. This office houses the survey records and other applicable radiological data and has storage for portable survey instrumentation, a source for checking CP instruments, and a counter for air samples. Room 631 also houses a control panel console for remote alarm annunciation of CAMs that monitor the room air for the repackaging, shipping, staging, NDA, receiving rooms, and corridor 625. This console also provides visual and audible alarm notification for high alpha, room CAM failure, or loss of instrument vacuum.

Instrumentation and other RCT supplies are also available at satellite locations throughout the PFP. These satellite locations contain such things as instruments, rope, labels, signs, tags, writing materials, and other items necessary for routine RCT support of plant operations in the area. Specialty items to support nonroutine operations would be obtained from the RC office/ready room area.

The PFP RCT personnel operate the mini-scaler system that is located in room 221A of the 234-5Z Building. These systems are ZnS scintillation detectors used for air sample, nasal smear, and other gross alpha contamination counting.

Air samples are normally collected by the RCTs once a week. These samples are delivered to the laboratory counting area in room 221-A of the PFP AL, 222-S Laboratory, or WSCF Laboratory. Stack samples are collected at approximately 2 week intervals. If a CAM alarm occurs (with the exception of a stack alarm), the RCTs will collect the CAM filter immediately for counting in room 221-A. Air samples collected due to a stack CAM alarm are also counted in this facility. Stack record (fixed head) environmental release samples are transported to the WSCF Laboratory for immediate analysis.

8.5.1.6 Analytical Laboratory. A Tennelec™ air sample counting system modified to perform automatic alpha spectroscopy is located in room 221-G. It is equipped with an automatic sample changer. All samples are disposed of as TRU room waste after all counting procedures have been completed. Some high-activity samples are temporarily set aside for decay and recounting to verify presence or absence of radon/thoron daughters. The laboratories provide a report to the RC personnel and retain a copy for their records. If guideline values are exceeded, the laboratories reports this information to the Duty Rad Con Manager for a following investigation by the Rad Con Organization.

8.5.1.7 Protective Clothing. Protective clothing is required in any area within the PFP where personnel can come in contact with loose surface contamination. Changerooms are provided so that personnel can change from personal clothing into protective clothing. The RC organization specifies the amount and type of protective clothing based on the level and type (e.g., particulate, liquid) of contamination. The protective clothing requirements for areas within the PFP are identified in various radiation work permits (RWPs). The requirements are determined and maintained current by a periodic review of documented survey and surveillance information.

Protective apparel includes coveralls, caps, hoods, and booties made from a paper type material or cotton cloth. Gloves may be made of latex or other materials as required by the RWP. Garments made of other materials such as plastic wear and Goretex™ are used in special applications. Items are predominantly yellow in color or are conspicuously marked.

Required protective clothing is provided for the PFP personnel in all change areas. Clean clothing is stocked in cabinets and drawers according to size and type.

Cloth protective clothing is collected after use and sent to the laundry contractor for laundering. Used paper protective clothing is discarded as radioactive waste (RW) at the step-off pad (the exit point of the contamination area). A personnel survey is performed after removing protective clothing.

8.5.1.8 Respiratory Protection. Respiratory protection is used within the PFP when entering an area with high potential for airborne contamination or having known airborne contamination, and during operations that could or would cause airborne contamination. Respiratory protection types that may be prescribed include: full-face piece air-purifying respirator, PAPR, supplied airline respirators with escape provisions, and self-contained breathing apparatus (SCBA).

The RC organization is responsible for determining respiratory protection requirements based on real or potential hazards from airborne contamination. The respirator protection factor selected is based on actual or potential expected levels of airborne contamination and the type of work to be performed. Respiratory protection factors used in selecting respiratory protection equipment are given in *Radiological Work Permits*, HNF-PRO-423, and listed in Table 8-19.

Respiratory Protection Program, HNF-PRO-120, specifies the respiratory protection requirements for hazards including radiological, chemical, particulate, and biological agents.

8.5.1.9 Decontamination Facilities.

8.5.1.9.1 Equipment Decontamination. There is one radiation detection equipment decontamination area in the 234-5Z Building, room 159. Radiation detection equipment contaminated through normal operations are transported to this area for decontamination. Radiation detection equipment that cannot be decontaminated must be kept in a radiologically controlled area at all times and are discarded if, at a job completion, they still present a contamination-control or personnel-exposure problem. Decontamination techniques and agents used at the PFP for equipment are identified in Plant Operating Procedures *Decontaminate Surfaces Outside of Processing Gloveboxes*, ZO-170-311. Sinks and floor drains from this area drain to the 241-Z Complex.

8.5.1.9.2 Personnel Decontamination. Within the PFP there is one personnel decontamination station, room 126, located in the 234-5Z Building. This room is equipped with a sink, showers, decontamination supplies, an emergency supply cabinet, and a medical supply cabinet. The sink and showers drain to the 241-Z Complex. Solid wastes generated are segregated and disposed of based on anticipated or known radionuclides, total activity, and/or hazardous material content.

The PFP RC personnel are responsible for performing skin decontaminations and the final release survey after decontamination has been accomplished. The RC Organization is responsible for preparing the chemicals and reagents

necessary for performing personnel decontamination. The approved procedures for performing personnel skin decontaminations are identified in HNF-PRO-664, *Personnel Decontamination.*

8.5.1.10 Contamination Control Equipment. The primary contamination control method is confinement. The PFP uses engineered confinement barriers (hoods, gloveboxes, and ventilation) for all routine work or processes involving plutonium. These barriers are described in Chapters 5.0 and 6.0. Temporary contamination control is provided via use of bag-outs and temporary glovebags or temporary radiological containment. Bag-out is the routine method utilized to remove items from process gloveboxes. Temporary radiological containment and glovebags are used for work situations not provided with engineered contamination barriers or when an engineered barrier must be breached. Plant operating procedures cover the use of glovebags and temporary radiological containment (see *Install/Remove Temporary Radiological Containments*, ZO-170-300).

Requirements for temporary structures are found in WHC-EP-0749, *Radiological Containment Guide* (WHC 1994d). This checklist ensures that, when exhaust ventilation is needed, at least one HEPA filter is used. If a temporary radiological containment that requires exhaust ventilation is used outside of existing facility E-3 (or E-2 in the 2736-Z Complex) ventilation zones, the requirements of WHC-SD-CP-OSR-010, *Plutonium Finishing Plant Operational Safety Requirements*, Limiting Condition for Operation 3.2.1, "Filtered Exhaust from Zones 3 and 4," must also be met. The checklist requires signoff by the Operations Management and RC Management before any temporary radiological containment work commences. A typical temporary radiological containment and exhaust system is shown in Figure 8-41.

Heat-sealed plastic bags or plastic sleeving/tubing are normally used as the contamination control barrier for routine bag-out activities. Other materials, such as reinforced plastics, may be used depending on the material or items to be removed. Temporary glovebags or temporary radiological containment are used to provide confinement based on the amount of work area needed to perform the job. Glovebags are used for small-area jobs (e.g., valve repair, small glovebox window replacement). The temporary radiological containment is used for large-area work such as glovebox panel removal and vacuum pump repair.

Temporary radiological containments are normally installed with a second, smaller temporary radiological containment (anteroom) at the entrance to the primary temporary radiological containment. Its purpose is two-fold: it serves as a buffer zone between the room and the primary temporary radiological containment, and it serves as an area for personnel to remove their outer later of protective clothing when exiting the primary temporary radiological containment.

The primary temporary radiological containment has a portable exhauster installed with an aerosol-challenged HEPA filter that causes air to flow from the room into the temporary radiological containment. The temporary radiological containment air is then exhausted through the HEPA filter providing a means for removing any radioactive particulate before discharge to an HVAC system.

8.5.1.11 Personnel Dosimetry. It is Hanford policy that all employees, visitors, or vendors who are expected to receive >100 mrem/yr be issued and use record dosimeters. The TLD provides the legal record of the individual's radiation dose history. A supplementary program uses self-reading gamma pencil dosimeters to provide a real-time tracking system for the individual to note and control their exposure totals.

There are two types of TLDs used on the Hanford Site. These are the Hanford standard dosimeter and the Hanford combination neutron dosimeter. The Hanford standard dosimeter is used for personnel not expected to be exposed to neutron radiation. The Hanford combination neutron dosimeter has an added track etch detector for determining neutron doses. For further information on the operation of the various Hanford dosimeters see HNF-PRO-379, *External Dosimetry Program.*

8.5.1.11.1 Supplemental Dosimeter. In the supplemental dosimeter program, self-reading gamma pencil dosimeters must be worn for entry to any radiation area with a dose rate greater than 100 mrem/h. This supplemental dosimeter is available to plant personnel, as specified in RWPs, for work in high radiation areas within the plant. These devices are worn in addition to the TLDs to provide short-term information on an individual's radiation dose. Low-energy gamma ray pencils are used at the PFP and have a range of 0 to 200 mrem. These pencils are returned to RC personnel for reading, recording exposure information, and zeroing the pencil setting.

8.5.1.11.2 Personnel Nuclear Accident Dosimeters. The personnel nuclear accident dosimeters (PNADs) are issued by Dosimetry to personnel who work in or visit the PFP, because a nuclear criticality accident is possible. PNADs are required to be worn anywhere an active criticality alarm system is required. A PNAD is used to estimate the neutron dose to a person carrying the device only if a nuclear criticality accident occurs.

The PNAD components consist of bare indium foil, cadmium-covered indium foil, cadmium-covered copper foil, and a sulfur tablet. In the event of a criticality or high-level radiation event, the PNADs will be collected by RC personnel and transported to PNNL External Dosimetry for analysis. The components of the PNAD are shown in Figure 8-42. The shape of the unit has been modified to allow fastening to the Hanford Combination Dosimeter.

8.5.1.11.3 Quick-Sort Evaluation. The "quick-sort" is a field measurement of ^{24}Na activity in the human body after an exposure to neutron radiation. The quick-sort is a triage technique that is used immediately following a criticality event to identify personnel who may have received high neutron doses. Measurements are made quickly by placing a GM probe count rate meter against the abdomen of a subject who is bent over during the measurement. An alternative approach is to place the GM probe in the armpit and have the individual hold it tightly against his body by exerting pressure with his arm.

8.5.1.11.4 Metal Object Analysis. Samples of metallic objects (coins, rings, belt buckles, eyeglass frames, etc.) carried by a person involved in a criticality event may be analyzed to determine the activity of any radionuclides produced by exposure to neutron radiation. A complex evaluation of the activity of the different radionuclides produced, the mass of the original metallic elements, and consideration of the geometry of the exposure

conditions can all provide valuable information regarding the neutron spectrum and the dose received.

8.5.1.11.5 In Vivo Examination. A whole-body in vivo examination provides information regarding the activity of different radionuclides in the body and the spatial distribution of these nuclides. This information provides an evaluation of the dose received and, possibly, information regarding the orientation of the body during exposure.

8.5.1.11.6 Blood Analysis. Samples of blood can be analyzed by gamma-energy analysis to estimate the concentration of ^{24}Na resulting from neutron radiation. The DNA analysis of blood cells can provide the number of chromosomal aberrations that are correlated to the whole-body dose received.

8.5.1.11.7 Hair Analysis. Samples of hair can be used to estimate the dose and spatial profile of the exposure conditions to fast neutron radiation through analysis for ^{32}P.

8.5.1.12 Nuclear Accident Dosimeter. Several types of dosimeters and steps can be used to identify the dose that personnel may have received from significant exposure to a nuclear criticality event or from a very high-level radiation source (see *External Dosimetry Emergency*, HNF-PRO-383, and *External Dosimetry Program*, HNF-PRO-379). The Hanford Site nuclear accident dosimeter (NAD) is a stationary device used in the PFP for providing neutron and gamma dose information following a criticality or high-level radiation event. This information is used to determine the neutron dose in rad and the gamma dose in the presence of neutrons from 10 to 10^4 rad. The neutron fluence in each of five energy intervals is determined, which permits calculation of the neutron quality factor (QF) and in turn allows the calculation of the dose equivalent in rem.

The NAD, which is identified in Figure 8-43, is a paraffin-filled aluminum cylinder, 9 in. in diameter and 12 in. in height, containing a polyethylene candlestick (sometimes called a wand). The candlestick has an inner and outer dosimetry package and is 13 in. in length.

The inner dosimetry package, at the center of the paraffin moderator, provides for measuring the approximate tissue dose in rad from neutron and photon exposure. It is a plastic holder containing a gold foil to measure thermalized neutrons, a TLD chip (TLD-600) to measure neutrons, and a TLD-700 chip to measure photons. The outer dosimetry package is used to measure the gamma dose (TLD-700 chip) and to calculate the neutron spectrum from analysis of neutron activation products that are found in the cadmium-shielded and nonshielded indium, gold, and copper foils, a sulfur pellet, and a TLD-700 chip located outside of the cadmium shield.

The candlestick part of the NAD is exchanged annually by PNNL. The PFP staff is sent replacement candlesticks and instructed to pull and return the old ones. The candlesticks are surveyed by PNNL, who shortly thereafter send a report listing the accumulated neutron and gamma doses to the FH Site Technical Authority for Dosimetry and the PFP Technical Authority for Dosimetry.

8.5.2 Procedures

The DOE Order 5480.4 (DOE 1984) lists reference standards, including NRC Regulatory Guides, which are to be used as good work practice guidance. The guidance provided by NRC Regulatory Guides 8.7, *Occupational Radiation Exposure Records Systems* (NRC 1973d), 8.9 (NRC 1973a), and 8.10, *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low as Reasonably Achievable* (NRC 1975), as well as by the associated ANSI standards, has been followed in the development of the Hanford Site procedures for implementing the radiation protection program. These procedures provide the authorization, guidance, and procedures for all aspects of the radiological control program. Fetal protection requirements are delineated in PHRCM (FH 2000) and 10 CFR 835 (DOE 1993a).

8.5.2.1 Methods, Frequencies, and Procedures for Conducting Radiation Surveys. The methods, frequencies, and procedures for conducting radiation surveys are described in *Required Radiological Surveillance*, HNF-PRO-435. Requirements for the procedures come from ANSI/American Society of Mechanical Engineers (ASME) NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, PHRCM, Chapter 7 (FH 2000), and DOE Order 1324.5B, *Records Management Program* (DOE 1995b). The current radiological status (contamination levels and exposure rate), both inside and outside of radiological areas, are determined by radiation surveys. These surveys make it possible to recognize off-normal conditions, initiate corrective actions, and provide a method of determining long-range trends in radiological conditions. The surveys are conducted by trained and certified RCTs. Portable ion chamber instruments, principally the CPs, are used to measure dose rates for beta-gamma radiation. The GM counter would be used to measure beta and gamma contamination. The AN/PDR-70 Snoopy is the approved instrument for measuring neutron dose rates. Portable CRMs, principally the PAM, are used for alpha contamination surveys. The CRMs are source-response checked before each use and periodically during continuous use. Requirements have been established for instrument calibration. Scheduled (routine) surveys are conducted, as well as other surveys, in support of operations (e.g., surveys of high-risk operations) and include both workplace and personnel monitoring.

The referenced manuals provide guidance to the RCT on the preparations for the survey and the techniques to be employed. Standard methods for direct and smear surveys are employed and specific procedures have been developed. For example, "Scheduled Radiation Survey Task Description," describes an area that is to be a part of the repetitive survey program. This description is completed by the supervisor for each scheduled (routine) survey and provides information specific to each survey (e.g., special conditions and minimum survey equipment to be used) as well as action levels. The RCT performs the described required actions and logs the results on the appropriate forms.

The frequencies of routine surveys are based on frequencies presented in the PHRCM (FH 2000). Routine contamination surveys are conducted in radiological buffer areas established for the control of contamination and other areas with the potential for spread of contamination. The survey frequencies range from several times per shift to once per year. Some of these examples are: step-off pads at a control point may be surveyed several times a shift; change rooms are surveyed daily; radioactive workstations are surveyed weekly; potentially contaminated ducts, some shops and offices are surveyed monthly; uncontrolled areas next to controlled areas are surveyed

quarterly; some deactivated facilities are surveyed semiannually; and some buildings adjacent to nuclear facilities are surveyed annually. (See HNF-PRO-435 for additional information). Nonroutine surveys are performed as needed to support plant activities and to maintain cognizance of the plant's radiological status. The results of each routine or nonroutine survey are documented and the reports are retained in accordance with the requirements in DOE Order 1324.5B (DOE 1995b).

8.5.2.2 Plans to Ensure that Occupational Radiological Exposure will be As Low As Reasonably Achievable. The authorities, responsibilities, requirements, policies, procedures, and guidelines for implementing ALARA are delineated in FSP-PFP-5-8, Section 14, *Radiological Control.* Work practices and facility and equipment designs are reviewed to achieve ALARA goals; for example, the need to keep personnel exposures as low as possible is reviewed in each pre-job meeting.

The plan for implementing ALARA has been discussed in some detail in Sections 8.1.1 and 8.1.2.

8.5.2.3 Physical and Administrative Measures to Control Access and Stay Times for Radiological Areas. Both physical and administrative measures have been developed for controlling access to radiological areas in the PFP. The principal emphasis is on physical measures; administrative measures are developed as needed to ensure that the level of control is consistent with the degree of hazard. The primary physical measures include the following.

- **Controlled Facility Access**--Access to the facility is controlled by Hanford Patrol with entry restricted to those with proper security credentials.
- **Exterior Door Locks and/or Alarms**--Exterior doors to zone 3 areas are locked and/or alarmed with plant management control of keys.
- **Radiological Control Technician**--A RCT located at the ACES Station will restrict those individuals who have not met the access requirements for entering radiological areas.
- **Escorts**--Visitors are escorted while in radiological areas by plant personnel.

Additional information concerning existing physical measures for access control is given in Section 8.3.1.

Administrative access controls developed to supplement the physical measures include the following.

- **Radiological Work Permits**--These permits administratively control entrance to radiation areas and provide information such as radiological status of radiation areas, dosimetry, and personal protective equipment required. RWPs are described in PHRCM (FH 2000).
- **Posting and Labeling**--A uniform system has been established for identifying radioactive materials and radiological conditions within the plant. Procedures and practices pertaining to labeling and

posting are consistent with requirements described in PHRCM (FH 2000).

- **Training**--Formal programs with attendance requirements have been developed to ensure that all personnel are provided with adequate radiological safety and radiological worker training so work can be performed in a safe manner consistent with ALARA objectives.

Those who have not met the training requirements will be denied entry into radiological areas. Minimum requirements for entry into a RBA, RA, CA, HCA, HPA, or HRA is Certified plus a trained escort. Training is discussed in more detail in Section 8.5.2.5.

- **Alarms**--Audible alarms warn of abnormal radiological conditions, which initiates the evacuation of the area where the alarm is located and warns personnel not to enter the area.

- **Pre-Job Briefing**--Before the start of any non-routine work or work having potential to exceed a PHRCM (FH 2000) trigger level, a pre-job safety meeting is conducted to discuss or identify safety concerns, hold points, evacuation routes, criticality postings, etc. The RWP, procedures to be followed, and radiological conditions are discussed. The meeting is documented.

Physical and administrative measures for controlling safety and health are described in FSP-PFP-5-8, Procedure 1.1, "Safety Policy." These measures are part of the required radiological worker training.

Administrative measures for controlling exposure include the following:

- **Self-Estimation**--Plant personnel, before entering a radiological area, must review the dose rates posted at the room entrance, the general area dose rates, and their current dose data compiled by the Dose Tracking Program; then they must estimate a stay time that will result in a dose that does not exceed the guidelines and which is consistent with ALARA objectives.

- **Pre-Job Safety Meeting**--Stay times, based on radiation conditions such as dose rates, contamination levels, and potential airborne radioactivity, are reviewed and established in the pre-job safety meeting.

8.5.2.4 Bases and Methods for Monitoring and Controlling Personnel, Equipment, and Surface Contamination. Programs for monitoring and controlling personnel, equipment, and surface contamination have been developed and are described in PFP procedure *Personnel Decontamination*, ZRC-100-101 (BWHC 1998b) and in site procedures, principally HNF-PRO-379, HNF-PRO-380, HNF-PRO-328, and HNF-PRO-435. These programs are consistent with the requirements and guidelines of the PHRCM (FH 2000) and 10 CFR 835 (DOE 1993a). Smears are taken of the contaminated area or equipment and taken to a laboratory to be counted using a scaler. Laboratory counters are used to meet the sensitivity requirement for items being shipped or unconditionally released.

HNF-IP-0718, Section 6.1, "Release Surveys for Material and Equipment," provides the basis for the release survey methods and techniques currently in

use at the PFP. In extraordinary situations, this procedure is supplemented by a release survey plan developed by the PFP Radiological Control Organization. Release survey plans are kept at the RC Office in 234-5Z. Selection of the portable survey equipment to be used is based, in part, on recommendations from the instrumentation contractor.

10CFR835 and part 5 of PHRCM (551-554) (FH 2000) provide the basis for the requirements regarding methods of monitoring and controlling radioactive contamination and is the basis of the Hanford Site program.

Personnel are protected from contamination by use of engineered controls, protective clothing, detailed training, procedural controls, and periodic work area decontamination. Containments such as hoods, gloveboxes, enclosures, temporary radiological enclosures, and cells are used to confine contamination and to minimize the area of surface contamination. Even though primary radiological protection is provided by the engineered features, secondary protection, provided through the use of administrative controls, reduces challenges to the primary systems.

When exiting contamination areas personnel receive a whole body survey for contamination with portable or semiportable count rate instruments by an RCT or by self-survey, if they are qualified. All RBA exiting personnel must undergo hand and foot surveys with alpha-sensitive detectors. Personnel cannot be released from a controlled area with detectable contamination on skin, clothing, or personal effects as determined by standard survey instruments and techniques, and properly functioning personnel survey devices. If contamination is detected on skin or clothing, decontamination procedures, under the direction of an RCT, must be performed until there is no detectable contamination. Skin decontamination procedures (i.e., washing, scrubbing, and chemical reacting) are approved or performed by the Hanford Environmental Health Foundation (HEHF), the Hanford Site medical services contractor.

For unconditional release, equipment must be free of detectable contamination. A direct survey of the equipment is required using standard battery-operated portable instruments and approved techniques. A smear survey is used to detect removable radioactive contamination and to provide information regarding approaches for decontamination. These release surveys must be performed by an RCT.

A facility surface outside of contaminated areas is maintained free of detectable contamination as determined by both dry smears and direct surveys using standard survey techniques and instruments.

Facility surfaces in contamination areas are maintained as free of contamination as feasible using regular decontamination, pre-job planning, post-job cleanup (housekeeping), and timely decontamination. The areas near engineered barriers and other physical systems for contamination confinement are provided with instruments and systems for contamination control and detection located as near to the potential sources as feasible. Training, procedures, and job direction (pre-job meetings) are other components of the contamination control program. Off-normal contamination conditions are reported promptly to permit a timely cleanup, and action levels are assigned to ensure that proper recognition and importance are given to contamination control.

A routine surveillance program has been established to assess surface contamination conditions in both radiologically controlled and uncontrolled areas. The areas to be surveyed, the frequency of the surveys, and the bases for these have been documented on the survey form or in one of the Hanford Site approved procedures.

8.5.2.5 Radiological Protection Training Programs. The radiological protection training programs are described in PHRCM, Chapter 6, "Training and Qualification" (FH 2000). The training programs, designed to be consistent with DOE requirements and ALARA, cover five categories of personnel who may be exposed to radiation or radioactive materials at the PFP: (1) all employees, (2) radiological workers, (3) visitors, (4) RCTs, and (5) other personnel.

Personnel trained as radiological workers are taught the proper response to a CAM alarm, to respond to material spills, to respond to potentially contaminated wounds, to survey when exiting a hood or gloves and, if they find they are contaminated, to minimize their movement to that needed to obtain help. All training programs are fully documented and auditable.

The retention periods for radiological protection program records are identified in the Records Inventory and Disposition System (RIDS). The established retention periods meet or exceed the guidelines of ANSI N13.6, *Occupational Radiation Exposure Records System*. Generally, the organization producing the record maintains the record in the field in accordance with requirements and retires it to the records retention facility as applicable.

Regulatory Guide 8.7 (NRC 1973d) and ANSI N13.6 provide only general guidance for the physical protection of records. ANSI/ASME NQA-1, Supplement 175-128, and applicable procedures (e.g., *ALARA Program Records*, HNF-PRO-1633 and *Documentation of Radiological Surveys*, HNF-PRO-1892) provide some specific requirements for records storage. Field storage of RC-generated records is in accordance with procedural requirements. Many records are ultimately transferred to a Seattle facility operated by the General Services Administration (GSA). The records generated and maintained include personnel occupational exposure records, radiological status of work area records, radiological program records, radiological training records, medical records, and records of the ALARA program.

8.5.2.5.1 Radiological Training Records. Radiological safety training includes radiological safety orientation, radiological worker training, RCT training, and special training, (e.g., for use of SCBA). The RC Training group trains RCTs, and Technical Training provides the other training. Immediately following the completion of the training, evidence of the satisfactory completion, (completed forms, rosters, and examinations) is sent to Technical Training Support. These records are entered into a computerized Training Records Information System. An individual's training status is also entered into another computer database that is available to managers. Approximately every quarter the records (e.g., copies of examinations and checklists) are retired to a record retention facility for 10 yr. Records such as rosters and completed training forms are retired quarterly to a records retention facility for 75 yr.

8.5.2.5.2 Radiological Program Records. The radiological protection policies and standards, developed primarily by RC, are documented in various procedures. These manuals establish the scope and organization of the

radiological protection program and program requirements (e.g., training, frequency, and techniques used in the measurement of radiological exposures, radiological and contamination control procedures, plans for emergencies, and recording and reporting requirements). Document Control maintains the record copies of the manuals and significant revisions and retires them to a records retention facility for 75 yr.

Records of maintenance and calibration of portable and semiportable radiological detection instruments are generated and maintained by PNNL. The hard copies of the service performed are retained by PNNL and then retired to a record retention facility for 75 yr.

Records generated by plant calibration of Poppies are maintained in a computer database. These data are used to document and forecast plant-installed instrument and equipment calibrations and verifications. These records relative to the radiological protection program are generated and maintained in accordance with the guidance of ANSI N13.6 by appropriate organizations. Records of criticality alarm system calibration are maintained and dispositioned as part of the plant OSR compliance program.

8.5.2.5.3 Radiological Status of Work Area Records. Records of the radiological status of work areas generated by RC include documentation such as radiological and contamination survey reports, air sample counter logs that document the results of the analysis of air samples counted by the RCTs, RWPs, and radiation problems and incident reports (RPRs). These records are maintained in the PFP for a period not to exceed 1 yr, transferred to the RC Central File for a period not to exceed 3 yr, and then retired to a record retention facility for 75 yr. The reports of the air sample analyses performed by the analytical laboratories, including engineering procedures and equipment calibration, are not being maintained and used in accordance with the Regulatory Guide and DOE requirements. A plan has been developed for implementing corrective action.

8.5.2.5.4 As Low As Reasonably Achievable Records. The Hanford Site has a formal program to ensure that radiological exposures are reduced to ALARA. In addition to the program manual, several reports are generated and maintained. These include an annual report to DOE on the ALARA goals with quarterly status reports, reports of monthly meetings of ALARA committees and teams, ALARA Management Worksheets, and ALARA Checklists. The ALARA Management Worksheets and Checklists are completed by Operations or Maintenance for all jobs requiring a job specific RWP for tasks that exceed trigger levels found in PHRCM, Article 312.3 (FH 2000). The completed worksheets and checklists are attached to the RWP for pre-job meetings and work approvals and are retained for 75 yr as part of the radiological protection records. A retention period for other ALARA reports has not been established.

8.5.2.6 Occupational Radiological Exposure Records Systems. The occupational radiological exposure records system is operated in accordance with PHRCM (FH 2000), 10 CFR 835 (DOE 1993a), and ANSI N13.6 by PNNL and HEHF for all Hanford Site employees. The systematic generation and retention of records relating to occupational radiological exposures are described in FSP-PFP-5-8, Section 6.0, Records.

The guidance provided by NRC Regulatory Guide 8.7 (NRC 1973d) and ANSI N13.6 is being followed. The generation of records is adequate to evaluate program effectiveness and enable reconstruction, for legal or medical purposes, of the situations and conditions for analysis of the radiation dose received by individuals.

Personnel occupational exposure records, along with medical and related occupational exposure records, are maintained for the lifetime of a facility plus 75 yr. The PNNL generates and maintains the current and historical occupational exposure records (OER) files. The HEHF generates and maintains the current employees' medical records. Historical medical records are transferred to PNNL for inclusion in the employee's OER file. Hanford contractor-generated OER-related records such as skin contamination reports, lost dosimetry or other reports (unusual occurrence reports, etc.) related to personnel occupational exposures are forwarded to PNNL for inclusion in the appropriate OER files. The PNNL also collects and maintains a historical file of the Hanford Site health and safety-related documents that have been generated by the various Hanford Site operating contractors.

8.5.2.6.1 Individual Occupational Exposure Record. The personnel OERs are accumulated and maintained by PNNL under its contract to DOE. These records include a prior occupational radiological dose, internal and external occupational dose (including that received at other installations during current employment), special dose evaluations, reports of unusual doses or potential dose, and other data relative to the individual's dose status such as radiological incident reports provided to PNNL by RC. A nonrecord copy of these dose records is also maintained by RC. Process management receives a copy of the monthly, quarterly, and annual TLD doses as an aid in operational planning and for ALARA purposes.

The PNNL processes the personnel dosimeters and performs the in vivo examinations. A testing laboratory, under contract to PNNL, performs the bioassay analyses and reports its findings to PNNL. The dosimetry and bioassay results are immediately entered into a database computer system for use and retention. Hard copies of dose records are temporarily stored in a protected facility. The individual's complete history is microfilmed by PNNL for retention for 75 yr. One copy is stored in an offsite record retention facility, one copy is stored in a local record retention facility, and one copy is maintained by PNNL for immediate referral. Personnel dosimetry data are also entered into a computer program (ORE) to which site contractors have access and forwarded to the National Registry. Radiological dose data are summarized in an annual Radiological Exposure Information Record, which is prepared by RC and provided to DOE. Employees are provided reports of an occupational dose at least annually and following termination; if requested, reports can be made available on the day of termination.

8.5.2.6.2 Medical Records. All PFP hazardous material and routine radiation workers receive periodic medical examinations. The examinations are performed by the HEHF under its contract to DOE. These examinations ensure that each employee is medically capable of performing assigned tasks. The medical examination program is described in *Occupational Medical Qualification and Monitoring*, HNF-PRO-111.

All hazardous waste workers are examined annually. The examinations and laboratory tests are comprehensive. The HEHF provides a report of Medical

Clearance and other reports (such as Work Restrictions) to the Hanford Site contractors. The HEHF also staffs an onsite medical treatment facility with registered nurses to provide first-aid and emergency medical treatment. Information concerning first-aid treatment is reported on a Treatment Record form. These reports are included in the individual's complete medical file. This file is microfilmed, duplicated, and transferred to a record retention facility for 75 yr. One copy of the records is retained by HEHF for reference, one copy is retained at a separate local facility, and a third copy is transferred to an offsite record retention facility.

8.5.2.7 Neutron, Gamma, and X-Ray Personnel Monitoring for Normal Operations and Criticality Accidents. The methods and procedures for implementing the personnel external dosimetry program are described in PHRCM (FH 2000), 10 CFR 835 (DOE 1993a), and *External Dosimetry Program*, HNF-PRO-379. The Hanford Combination Dosimeters (HCD) is the principal device used for personnel dose measurements at PFP. Supplemental dosimeters, such as direct-reading gamma pencils and finger rings, are used when an HCD would not adequately measure an individual's external dose. The PNADs are used by PFP personnel. These dosimeters supplement the HCD by extending the range of the dosimetry system and allowing determination of neutron energies that personnel were exposed to under accident conditions. The characteristics and methods for using these dosimeters in normal operations are discussed in Section 8.5.1.11.

After each gamma pencil use, pertinent data, including user and pencil identification, location of use, date and time of use, and dosimeter reading, are recorded in a log. Each shift, these data are entered in a computerized dose tracking system that is used to manage personnel radiological doses and operations. The HCD is evaluated monthly, quarterly, or annually, depending on the anticipated rate of dose accumulation. Extremity dosimeters such as finger rings are normally evaluated on the same frequency as the individual HCD. The PNNL processes the TLDs, reviews the data, records the data in the individual's dose records, and reports the results. The RC organization prepares a Radiological Exposure Status Report and submits it to the PFP management. Each employee receives an annual statement of occupational dose status and is informed of any occupational dose as soon as possible after involvement in a radiological occurrence. The HCD systems meet DOELAP criteria for accreditation and are accredited. The PNNL Dosimetry organization has the responsibility for maintaining the accreditation.

The methods and procedures for monitoring criticality accidents as well as the methods for recording and reporting the results are discussed in Section 8.3.4.1.5.

Both RC and plant management regularly review the personnel dosimetry results per PHRCM (FH 2000). With counsel from RC, plant management uses the dosimetric results in operational planning. Principal uses include the following.

- The dose tracking system and monthly reports of personnel external dosimetry data are used by plant management to make employee assignments to avoid exceeding personnel dose guidelines. If necessary, an employee may be restricted from work or work areas to maintain that employee's dose below administrative guidelines.

- Dosimetric results are used to determine trends and identify locations, tasks, or operations where ALARA measures such as shielding, facility redesign, or work practice revisions are needed.

- Dosimetric results are used to determine when supplemental dosimeters are needed to adequately measure doses from radioactive materials.

- Dosimetric results are also considered in scheduling operations which involve potentially high external doses so that available employees do not exceed dose guidelines.

8.5.2.8 Internal Dosimetry. The criterion for performing in vivo examinations and bioassays is described in PHRCM, Section 522 (FH 2000).

In vivo counting, whole body or chest, is used to determine the quantity and types of radionuclides inhaled or ingested by personnel. The counting equipment is designed to measure the energy and number of gamma rays entering the detectors. Through calibration and comparison to known standards, an estimate of the type and quantity of radionuclides deposited within an individual can be determined. The deposited quantity is used to calculate the dose commitment that the individual will receive. This information becomes part of the individuals' permanent record and may be used to determine future dose limitations. Bioassays, urine and fecal, are also used to track and verify past and current doses accumulated by personnel. Usually, a chest count is performed and urine collection is initiated for those personnel involved in an airborne plutonium release, while blood and urine samples would be collected for a plutonium-contaminated wound situation.

New employees, rehires, and employees returning from leave-of-absence submit a Personal Radiological Exposure History Form to RC listing any contact with radioactive materials. Visitors and vendors may also be required to submit this form. Based on this information and work assignments, RC assesses the need for baseline in vivo and bioassay assessments.

The Radiological Control section reviews the work assignment of each radiological worker and establishes an appropriate type and frequency of routine surveillance for internally deposited radionuclides. Routine in vivo and in vitro bioassays are provided for radiological workers exposed to surface or airborne radioactive contamination where the worker could receive 100 mrem/yr committed effective dose equivalent (CEDE) from all intakes of all radionuclides from occupational sources or if any organ or tissue dose equivalent could exceed 5 rem committed dose equivalent (CDE). The routine in vivo examination and bioassay frequency for plutonium are as follows:

- For jobs with high exposure risk, a urinalysis must be done annually, a chest count must be done annually, and a whole-body count is not required.

- For jobs with low exposure risk, a urinalysis must be done annually and neither a chest count or a whole-body count is required.

Special examinations and evaluations for different radionuclides at different intervals are required when a radionuclide can potentially exceed 10% of the DOE standards but can be undetected by routine evaluations. For

example, routine fecal sampling may be required for personnel working in facilities with high potential for intake of insoluble material.

Based on field information, the Radiological Control section determines if any in vivo or bioassay analyses are required when a person is suspected of having received a significant intake of radioactive material. Any person is monitored who has a potential for having received a 100-mrem annual CEDE from any intake or 10% of the tissue dose equivalent for a particular organ. The initial determination and need for an in vivo examination is usually made by field indicators, (e.g., nasal smears, air samples, or personal contamination surveys). The Radiological Control section, with the advice of the PNNL dose evaluator, determines the need for specific bioassay analyses to confirm an uptake of radioactive material. Employees give their written approval for all medical tests. Doses from internally deposited radionuclides exceeding 2% (100-mrem annual CEDE) of the applicable ALI are investigated in consultation with the PNNL dose evaluator. Table 8-21 is from *Personnel Decontamination*, ZRC-100-001, Appendix 2 (BWHC 1998b). It identifies the internal dosimetry evaluations required and the urgency of these evaluations for a range of contamination levels determined by field indicators. The HEHF physicians may be called on for medical assistance.

Internal dosimetry evaluations may also be performed when an employee reports a recent medical administration of radionuclides, at the request of the employee, to aid in the development of new techniques or programs, and at termination.

The PNNL has been assigned the responsibility for providing the facilities and services required for performing in vivo and in vitro bioassays for the Hanford Site. The PNNL has received and is maintaining its internal dosimetry program accreditation by actively participating in the DOE Laboratory Accreditation Program (DOE LAP).

8.5.2.9 Methods and Procedures for Evaluating and Controlling Potential Airborne Radioactivity Concentrations. The methods and procedures for evaluating and controlling potential airborne radioactivity concentrations are described in *Work Place Air Monitoring*, HNF-PRO-331. Line management, Nuclear Safety (NS), Industrial Safety, and RC all have responsibilities for evaluating and controlling airborne radioactivity.

The prevention of internal deposition of radionuclides is accomplished by the use of engineered systems as required by PHRCM (FH 2000) and 10 CFR 835 (DOE 1993a). A total confinement policy is in effect at the PFP. That is, all radioactive material having a potential to become airborne must be totally confined in an engineered system. If a task would deviate or potentially deviate from the total containment criteria, temporary confinement such as a temporary radiological containment must be provided, or a deviation from the policy is required.

These engineered controls include confinement of radioactive contaminants by ventilation, piping systems, gloveboxes, hot cells, temporary radiological containment, and shipping containers. When establishing radiological controls for work involving the potential for airborne radioactive materials, the first consideration is using techniques that prevent a release to the work atmosphere. Even then, to be conservative, the RWP for an operation in many

cases requires that respiratory protection be worn by personnel in the area adjacent to the work location.

Loose surface contamination in contamination control areas is controlled to levels low enough to minimize the potential resuspension of radioactive aerosols by constant attention to housekeeping and post-job cleanup. In controlling airborne radioactivity, the PFP objective is to restrict airborne radioactivity concentrations to ALARA levels and not exceed the prescribed DAC limits of 10 CFR 835, Appendix A (DOE 1993a).

Ambient air sampling and monitoring systems are placed in strategic locations to detect and evaluate potential airborne contamination at work locations. Sampling is required where airborne concentrations may exceed 2% of the applicable DAC. Locations of FHSs and CAMs are determined, documented, and periodically reviewed using HNF-PRO-331, *Workplace Air Monitoring Program* and various standards and guides; resultant document is HNF-5242, *Technical Basis for Work Place Air Monitoring for the Plutonium Finishing Plant (PFP).* Air sampling equipment and techniques used can be divided into four categories: (1) breathing zone or room air samples, (2) CAM devices, (3) stack effluent samplers and monitoring systems, and (4) portable air samplers. Breathing zone or room air samplers are used to establish average breathing zone air concentrations or to quantify chronic low-level airborne exposures.

The CAMs are used in areas where dispersible radioactive material is handled and/or the potential for airborne radiological release is high, to provide an annunciation of a changing workplace environment. As a minimum, CAMs are located at workstations where potential concentrations of radioactive airborne materials may exceed 1 DAC during the occupancy period (DOE 1994). They provide early warning of a significant release (40 DAC-h of ^{239}Pu) of radioactive material. Facility exhaust stacks are monitored by CAMs to provide rapid indication of a detectable release of airborne radioactivity. Portable air samplers are used for special or supplemental air sampling (grab sampling) when a CAM indicates an increase in radioactivity, for special evaluations of radiological conditions, or for specific tasks.

Depending on the location of the CAM and susceptibility to interference from radon at particular locations, the alarm set points may be reduced from the maximum value based on RC assessment of false alarm frequency. One of the primary objectives when calculating the CAM alarm set point is to allow personnel sufficient warning of a significant release or potential environmental release of airborne radioactivity, while attempting to minimize spurious alarms. Alarm set points are determined by calculating the meter reading equivalent to a predetermined air concentration accumulation in a given amount of time. Normally this is calculated as a set number of DAC hours exposure.

Naturally occurring radon and thorium daughters interfere with the ^{239}Pu measurement. At CAM sample locations where wide fluctuations in the natural activity occur, the set point may be adjusted to compensate for the increased natural activity. For locations where the natural activity fluctuations are both frequent and severe, it may be necessary to calculate an average background value into the alarm set point. The background values for Radiological Control CAMs are derived in accordance with HNF-PRO-5675, *Radiaiton Protection Real-time Air Monitoring.*

The RCTs exchange the air sample filters and record all applicable sample data weekly. There are approximately 390 samples exchanged every week. Some environmental sample filters are exchanged monthly. Air sample filter (fixed head samplers) exchanges may be performed on a daily or shift basis where the potential for airborne contamination is high. In addition to the weekly schedule, the CAM filters are exchanged after an alarm occurs to allow identification and evaluation of the alarm-causing material. The criteria for sample filter exchange frequency include radiological history, nature of operations, and frequency and length of personnel occupation. The RCT submits the filter to the PFP AL for counting.

Approximately 390 filters per week are submitted to the PFP AL, room 221-G, for counting and inclusion in a computer program used for tracking/trending air sample data. Printouts are distributed to RC for review. If an abnormal condition occurs, such as a CAM alarm or a high concentration of radon, the RCT counts the filter on RC field equipment before submitting it to the counting laboratory. The PFP Lab logs the results of the analysis of the radioactivity on the filter. Results of the analysis of samples taken during an abnormal condition, or of samples indicating abnormal conditions, are immediately reported to Operations and RC for action. For normal conditions, the logged information is reported to RC quarterly unless guideline values are exceeded. Daily inspections and weekly sample exchanges performed by the RCTs are incorporated into the Scheduled Radiological Survey Program, and the results are recorded per approved procedure.

Calibrations of equipment and instruments or air sampling system components are performed by Plant Maintenance or PNNL. Calibration procedures follow the requirements of ANSI N323, *Radiological Protection Instrumentation Test and Calibration*. The RCTs perform scheduled efficiency and performance checks of counting equipment they operate.

Additional information on the air sampling equipment is provided in Section 8.3.4.2.2.

Areas subject to rapidly changing airborne contamination conditions or where airborne concentrations are (or are likely to be) greater than 0.1 DAC are posted as airborne radioactivity areas. Appropriate protecting clothing and respiratory protection are required for entry.

8.5.2.10 Use of Respiratory Protective Devices. The use of respiratory protective devices, including the respiratory protective equipment fitting programs and training of personnel, is discussed in Section 8.5.1.8. The respiratory protection program meets the requirements of *Respiratory Protection*, HNF-PRO-120.

8.5.2.11 Decontamination and Decommissioning. The radiological protection program at the PFP has the flexibility to provide the services necessary to support D&D activities.

8.6 ESTIMATED PERSON-REM OFFSITE DOSE ASSESSMENT

The effluent streams from the PFP are sampled and analyzed for radioactivity in accordance with the requirements of approved procedures including HNF-PRO-2364, *Radioactive Airborne Effluent Sampling*, HNF-PRO-455,

Solid Waste Management, and HNF-PRO-456, *Water Quality*. The Environmental Compliance Manual establishes limits on the quantities of radioactive material that can be released to the environment from airborne, liquid, and solid waste streams. These limits are set such that the requirements of federal, state, and local regulations are met and releases from facilities are maintained ALARA. For specific information regarding effluent sources and sampling refer to Chapter 7.0. This section addresses the estimated radiation dose to offsite individuals from activities at PFP, which produce gaseous and liquid effluents. The contribution to an offsite dose from solid waste will not be addressed since this waste form is not released to the public from the PFP.

The contribution of the PFP effluents as offsite dose to the public is assessed in the following manner:

- Identify the waste streams of concern
- Sample for specific radionuclides to determine routine releases
- Monitor for radioactivity to detect off-normal or transient levels of radioactivity that may exceed established limits
- Perform environmental monitoring of specific media (flora, fauna, soil, water, etc.) to evaluate pathways of specific radionuclides to man.

Chapter 7.0 of this safety analysis report (SAR) provides a detailed description of all waste streams. Chapters 5.0, 6.0, and 9.0 provide additional details of design features that provide attenuation of postulated accidents and off-normal situations. Offsite environmental monitoring is provided by PNNL under their DOE contract. Onsite environmental monitoring is performed by Hanford Site contractors. The onsite monitoring program is used to evaluate the long-term effect (if any) of the PFP (and other facilities) effluent on the adjacent environs.

The gaseous effluents of interest to offsite dose estimation are from the 291-Z-1 main stack, 296-Z-3 stack, 296-Z-5 stack, 296-Z-6 stack, and the 296-Z-14 stack. The PFP's main stack exhausts filtered process and ventilation air from gloveboxes and hoods (zone 4) in the 234-5Z, 236-Z, and 242-Z Buildings as well as zone 3 (personnel occupied) process areas. The 296-Z-3 stack exhausts filtered air from the sumps and vessels of the 241-Z and 241-ZA/ZB Buildings. The 296-Z-5 stack exhausts filtered process and ventilation air from the 2736-ZB Building. The 296-Z-6 stack services the 2736-Z storage vaults and the 2736-ZA. The 296-Z-14 stack services the process areas and glove boxes of the 232-Z Incinerator Building (which is now undergoing TCO).

The radionuclides of concern in gaseous PFP effluents are the various isotopes of plutonium. Radionuclide effluent sampling is conducted for gaseous effluent emission points in a manner that meets requirements defined in *Radioactive Airborne Effluent Sampling*, HNF-PRO-2364. Various federal [DOE/Environmental Protection Agency (EPA)], state, local, and Hanford procedures define the basis for the air quality requirements. The effluent sampling emission measurement system is designed to sample the effluent at near-isokinetic conditions to provide sample data that are representative of

the actual emissions. The data provide the basis for the PFP annual effluent environmental release reporting.

Effluent streams are monitored to detect off-normal transient conditions that could lead to a release in excess of applicable limits. The monitoring is adjusted to alarm at release concentrations as low as possible, without generating spurious alarms, but having the range capability to alarm at a minimum of 5,000 times the DCG over a 4-h release.

Environmental monitoring data are used to detect trends in quantities of radionuclides released to the environment. The sampling and monitoring methods are of sufficient sensitivity to allow corrective actions before applicable limits or guidelines are exceeded. Specific types of media are sampled to track the migration of radionuclides in the environment, especially in those pathways of exposure to man. The environmental monitoring program serves to assess the performance of the various effluent control mechanisms.

The following approach was used to estimate offsite doses as a result of routine operations of the PFP.

- **Collect Release Data**--Effluent monitoring and sampling data were assembled to evaluate annual routine releases from the facility.

- **Exposure Pathways**--The possible exposure pathways to man have been determined. These include inhalation of airborne contaminants, ingestion of waterborne contaminants or airborne contaminants that have been deposited on foodstuffs, and direct exposure from airborne or deposited radionuclides.

- **Assemble Parameters for Calculation**--Assemble values for the parameters necessary for calculating the dose to man from a given release, including meteorological, geological, and hydrological data; site characteristics; resource-use information; and population studies.

- **Calculate Offsite Dose**--The data and other parameters are used in a validated mathematical model for calculating the offsite dose. The calculation for this SAR employs the computer code GENII, as developed by PNNL (PNL 1988a).

Collective doses are calculated for the population surrounding the site, as well as those for the maximum exposed individual (MEI), based on the highest annual release data within the last five years. Radiation exposures to the public from anticipated off-normal and accident conditions are provided in Chapter 9.0.

Meteorological data for determining dispersion coefficient ($\bar{\chi}$/Q') values are obtained from the PNNL Atmospheric Sciences Department Hanford Meteorological Station (HMS) 622R. Joint frequency meteorological data from 33 ft and 200 ft elevations (1983 through 1991) were averaged to obtain $\bar{\chi}$/Q' values used in the onsite and offsite personnel and population exposure calculations.

8.6.1 Effluent and Environmental Monitoring

This section describes the basic effluent and environmental monitoring programs for estimating the PFP contribution to radioactivity in the environment. See Chapter 3.0 for details of the meteorological conditions of the Hanford Site from which the joint frequency meteorological data was obtained.

8.6.1.1 Gaseous Effluent Sampling and Monitoring. This section describes the basic effluent and environmental monitoring programs for estimating the PFP contribution to radioactivity in the environment. The PFP developed a monitoring program in accordance with the requirements of *Environmental Notification and Reporting*, HNF-PRO-453, to implement DOE Order 5400.1, *General Environmental Protection Program* (DOE 1988a), requirements. The monitoring program contains the rationale, design, and operational criteria for monitoring and sampling programs, the extent and frequency of monitoring and sampling, procedures for laboratory analysis, the Quality Assurance (QA) requirements, and the verification and direction for the preparation and disposition of reports.

The operational objective for the management of airborne effluents is to control the annual average concentrations of radionuclides released to the environment (under routine operating conditions) to ALARA levels. This objective is in conformance with the DOE Order 6430.1A, Section 1300-9 (DOE 1989) design requirements. See HNF-PRO-2364, *Radioactive Airborne Effluent Sampling*, for additional information relating to airborne effluents.

8.6.1.1.1 Record Sampling Capabilities. See Chapter 7.0, Section 7.1.2.1.1.

8.6.1.1.2 Monitoring Capabilities. See Chapter 7.0, Section 7.1.2.1.2.

8.6.1.1.3 Analysis Continuity and Integrity. See Chapter 7.0, Section 7.1.2.2.

8.6.1.1.4 Monitoring and Sampling Criteria. See Chapter 7.0, Section 7.1.2.1.

8.6.1.2 Liquid Effluent Sampling and Monitoring. Condensates, cooling water, and other "normally cold" streams from the PFP are routed to the 200 East Area TEDF. The streams that have a potential to be contaminated are routed through the LLWTF before discharging to TEDF. The "normally cold" streams historically were released to the 216-Z-20 Crib and 216-Z-21 Trench that are now inactive and blanked off. Both sampling and monitoring are conducted on this waste stream (see Chapters 5.0 and 7.0 for additional details).

Liquids discharged to the TEDF are sampled using an online grab sampling unit. A sample aliquot is removed from the sample collection container and sent to the WSCF for isotopic analysis, and other analyses, for verification of compliance with TEDF acceptance requirements.

The PFP and WSCF procedures delineate the sampling frequency, specific analyses to be performed, analytical methods to be used for specific contaminants, record keeping, action levels, and QA methods to be used for the samples removed from the PFP effluent streams.

Radioactive liquid waste streams discharged to the 241-Z Building collection tanks are ultimately transferred to the TK-D5 tank, which is sampled, analyzed, treated (neutralized), and subsequently transferred via 244-TX to underground tank storage.

8.6.1.2.1 Sampling and Monitoring Capabilities. The sampling equipment is located in 225-WC. Sampling is achieved by two composite samplers (see Figure 8-44 for a diagram of a composite sampler). The liquid is drawn into a 5-gal receiver container. A 2-L sample is removed from the receiver and sent to the WSCF for analytical processing. The MDL for plutonium using this sampling technique is 0.4 pCi/L.

8.6.1.2.2 Analysis Continuity and Integrity. Sample integrity is maintained through implementation of procedural requirements by the sample collecting and laboratory personnel involved. Sample data are noted on the sample container by the collector and via a hand-held bar code scanner. These data and the sample are logged in at an assembly point (RCT Office, Operations desk, Control Room, etc.) and then transferred to the appropriate analytical facility. At the analytical facility, the samples are logged in by the transporter and the analytical facility representative on an inventory sheet, at which time possession of the samples is transferred to the laboratory. The laboratory then implements its routine chain of custody procedures during sample analysis. The laboratory sends copies of the analytical results to the concerned parties and maintains a copy in its own files. The analytical results are used to evaluate compliance with DOE requirements and are usually summarized in monthly, quarterly, or annual reports. The concerned parties (PFP Operations, Environmental Protection, RC Operations, etc.) perform tracking and trending of the results based on their individual needs and requirements. The methods used meet the requirements of HNF-PRO-456, *Water Quality*.

8.6.1.2.3 Sampling and Monitoring Criteria. The requirements for liquid effluent sampling and monitoring used at PFP are defined in ANSI N42.18 and *Water Quality Program*, HNF-PRO-456, which implement DOE Orders 5400.5 (DOE 1993b) and 5480.11 (DOE 1988b).

The liquid effluent sampling and monitoring systems were designed and are operated to meet the above criteria. The flow proportional sampler is installed per the manufacturer's instructions.

8.6.1.3 Solid Waste Sampling and Monitoring. The solid waste generated at the PFP is packaged for storage and/or disposal at other Hanford Site or offsite facilities and therefore does not impact the offsite population. To ensure that the offsite population is not exposed to radiation or radioactive materials during transport, all solid waste packages are carefully monitored for external radiation levels and removable contamination using standard radiological survey techniques before being released from the PFP. All solid waste packages must conform to the shipping criteria established in *Radioactive Material/Waste Shipments*, HNF-PRO-157, and 49 CFR 173, Subpart I (DOT 1994) before release for shipment. See Chapter 7.0, Section 7.3 for further information relating to solid waste handling.

8.6.1.4 Environmental Monitoring. It is the goal of Hanford site contractors to manage and conduct site activities in an environmentally responsible and cost-effective manner that is in compliance with the applicable environmental

statutes, regulations, and standards of DOE, Washington State Department of Ecology (Ecology), and EPA. In addition, Hanford site contractor policies ensure that its activities are conducted to protect employees, government property, and the public.

The PFP participates in the onsite environmental monitoring by supplying power to nearby air monitoring stations and by supplying personnel for performance of surveys and sample collection. The PFP provides data to this program via quantification of its liquid and gaseous effluents as annually summarized in WHC-EP-0141-1 (WHC 1990).

8.6.1.4.1 Environmental Monitoring Plan for PFP Environs. Operational environmental monitoring for PFP consists of samples taken in or near the 200 West Area. Additional environmental samples are collected by PNNL to assess the total Hanford Site contribution to environmental radioactivity.

8.6.1.4.2 Special and Emergency Sampling. Special and emergency sampling is conducted in the operations areas to augment the routine sampling program, support construction projects, and verify near-field waste containment. Special sampling is undertaken to clarify results from the analysis of routine samples.

8.6.1.4.3 Annual Reports--An annual report of the environmental conditions in the 200 West Area is issued every calendar year (examples are WHC 1990 and WHC 1994a). The report includes the results from the analyses of all environmental media, as applicable, and fulfills the requirements of *Environmental Notification and Reporting*, HNF-PRO-453.

8.6.2 Estimated Exposures

The estimated exposures presented in this section are based on the routine operating releases from PFP. The gaseous effluent releases arise from stacks 291-Z-1, 296-Z-3, 296-Z-5, 296-Z-6, 296-Z-14, and 296-Z-15. Of the six stacks used to exhaust gaseous effluents from PFP, only the 291-Z-1 rises above roof level and is considered an elevated release. The other vents are treated as ground level releases.

To derive the source term from PFP, the release data for the years 1989 through June of 1995 were obtained from the laboratory to determine the year that would represent the greatest release. It was determined that 1993 had the highest concentration for elevated releases (291-Z-1 stack). The beta-emitting radionuclide ^{241}Pu was not included in the source term. This is because the concentrations of ^{241}Pu are several orders of magnitude less than the alpha emitters. Therefore, beta particle emitters do not contribute significantly to the total dose from plutonium when compared to alpha particle emitters.

The primary pathway of exposure to plutonium in gaseous effluents is by inhalation; however, ingestion of foodstuffs contaminated with radionuclides via deposition is also a credible, albeit minor, contributor to the total offsite dose. Also, the doses from inhalation and ingestion are cumulative, which means that the offsite individual continues to grow food and live off the land for an assumed 50 yr after the release.

The exposures to the MEI as well as the cumulative population are calculated. The MEI is assumed to live at the site boundary at the location of highest radionuclide concentration. For gaseous effluents following Gaussian dispersion kinetics, this location is the point where the dispersion coefficient, $\bar{\chi}/Q'$, is greatest. The worst case $\bar{\chi}/Q'$ for maximum individually chronic (annual average) ground and stack level releases at offsite locations are 5.02 E-08 s/m^3 and 1.03 E-08 s/m^3, respectively. The highest annual average $\bar{\chi}/Q'$ is at 17.7 miles in the west offsite boundary (Nguyen 1995).

To calculate exposure to the population, average annual $\bar{\chi}/Q'$ values were calculated for a series of rings at varying distances from PFP in 16 directional sectors. The rings corresponding to the transport distances evaluated are listed in Nguyen (1995). The effects of the PFP airborne effluents are calculated for the midpoints of each of 16 sectors, each 22.5° wide and at 10 specified distances representing the 0 - 50-mi radius area surrounding the facility. The directional sectors are defined by midpoint. The annual average $\bar{\chi}/Q'$ values are based on 1983 to 1991 meteorological data. The population-weighted worst case $\bar{\chi}/Q'$ for chronic (annual average) ground and stack level releases at offsite locations are 1.36 E-03 s/m^3 and 4.55 E-04 s/m^3, respectively. The highest annual average $\bar{\chi}/Q'$ is at 50 miin the southeast (Nguyen 1995).

8.6.2.1 Identification of Sources. The mission of the PFP Complex includes recovery and/or processing of various forms of plutonium-bearing materials, conversion of plutonium-bearing materials to a stable form, and storage of recoverable and/or processed plutonium-containing materials. The various ventilation systems serve as the source of radionuclide releases. Although several different TRU radionuclides can be detected in the waste streams, by far the most significant contributors to an offsite dose are the plutonium isotopes. See Chapter 7.0, Section 7.2 for source descriptions.

A detailed description of radioactive gaseous waste streams is presented in Chapter 7.0, Section 7.2.1. The short stacks are treated as ground-level releases, while the 291-Z-1 stack is treated as an elevated (200 ft) release.

8.6.2.2 Analysis of Effects and Consequences. The offsite doses to the MEI and the cumulative population are shown in Table 8-23. The effective dose equivalent (EDE) and maximum organ doses are also presented in the Table 8-23. The maximum organ dose in all cases is to the bone surface as a result of the modeled plutonium intake. The dose to the MEI and the population was calculated by GENII using the dispersion coefficients presented in Nguyen (1995). The MEI is assumed to reside at the site boundary location possessing the highest value of $\bar{\chi}/Q'$ (Nguyen 1995). In the case of the population dose calculation, the 1990 population within 50 mi of the PFP was considered, which is 375,860 persons. The average $\bar{\chi}/Q'$ values were calculated by GXQ 4.0 and used for the dose determination using GENII. Average consumption values for farm produce was assumed for determining the average population dose.

The dose to the MEI from PFP operations is several orders of magnitude less than either the EPA limit [40 CFR 61, *National Emission Standards for Hazardous Air Pollutants*, Subpart H (EPA 1995)] of 10 mrem/yr EDE or the DOE EDE limit of 100 mrem/yr.

The dose equivalents listed in Table 8-23 may be compared to the estimated per capita background EDE of 300 mrem/yr from natural background and

65 mrem/yr from manmade sources (medical X-rays, diagnostics, consumer products, etc.) for a total of 365 mrem/yr. It is unlikely that the release has any measurable impact on the population based on latent cancer fatality (LCF) to the exposed.

For example, the CEDE for offsite chronic ground level release is calculated to be 8.0×10^{-4} person-rem (Table 8-23). The ICRP has determined that the nominal cancer fatality coefficient for a population of all ages for a low dose (low dose-rate whole body irradiation) is approximately 5.0×10^{-4} LCF/person-rem EDE (ICRP 1991).

Assuming the chronic ground level release occurs during 99.5% meteorology, the health effect to the exposed offsite population is given by:

$$(8.0 \times 10^{-4} \text{ person-rem}) \ (5.0 \times 10^{-4} \text{ LCF/person-rem}) = 4.0 \times 10^{-7} \text{ LCF}.$$

To place this in perspective, the exposed offsite population of 114,734 persons within 50 mi and located to the SE of PFP (including the Tri-Cities) would normally be expected to have approximately 225 LCFs per year (NSC 1990) from causes other than chronic PFP emissions.

The difference is approximately a factor of 1.13×10^{10} higher from non-PFP causes. This indicates that the risk to the exposed offsite population of a cancer fatality from all causes is 11,300 million times greater than the risk of a cancer fatality resulting from routine PFP emissions. The population and health effect for chronic ground and stack level releases are shown in Table 8-23.

8.6.3 Liquid Effluents

The offsite MEI and population exposures resulting from PFP liquid effluent discharges were not calculated as there are no radioactive exposure pathways from PFP liquid effluents to the public.

Waste liquids containing radioactive materials are transferred to other Hanford Site facilities for volume reduction and/or other treatment prior to storage in underground tanks. Therefore, the general public is not exposed to liquid radioactive effluents from the PFP. Small quantities of specialty liquids not compatible with the liquid waste system are processed to achieve compatibility or are solidified for disposal. Most of the decontamination processes are based on the use of dampened material to minimize the generation of liquid wastes. Therefore, decontamination efforts usually produce a much larger volume of solid rather than liquid wastes.

8.6.4 Solid Effluents

Solid wastes from PFP operation and facilities are either transferred to the Hanford Site solid waste burial facilities or placed in retrievable storage (TRU only) areas for ultimate shipment to a geologic repository.

Since solid wastes are not released to the environment, there is no onsite or offsite impact within the scope of this document. Solid wastes that may contain TRU are assayed to determine the disposal category: geologic repository or low-level.

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HNF-PRO-379, *External Dosimetry Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-380, *Internal Dosimetry Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-383, *External Dosimetry Emergency*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-423, *Radiological Work Permit*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-430, *Safety Analysis Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-435, *Required Radiological Surveillance*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-436, *Radiation Protection Instrument Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-450, *Air Quality Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-453, *Environmental Notification and Reporting*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-455, *Solid Waste Management*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-456, *Water Quality*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-546, *Criticality Alarm System*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-664, *Personnel Decontamination*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-704, *Hazard and Accident Analysis Process*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1618, *ALARA Management Commitment and Policy*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1619, *ALARA Organization and Responsibilities*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1620, *ALARA Program Scope*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1622, *Radiological Design Review Process*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1630, *Radiological Performance and ALARA Goals*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1633, *ALARA Program Records*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-1892, *Documentation of Radiological Surveys*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-2364, *Radioactive Airborne Effluent Sampling*, Fluor Daniel Hanford, Inc., Richland, Washington.

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Table 8-1. Shield Design Criteria.

Area category	Access time allowed	Initial design level (mrem/h)	Maximum (mrem/h)
Uncontaminated area	Full time	0.05	0.1
Contaminated area 1	Full time	0.2	0.5
Contaminated area 2	Less than 1 h/day	2.0	5.0
Contaminated area 3	Less than 1 h/week	10.0	20.0
Contaminated area 4	Less than 10 h/yr	50.0	100.0
Contaminated area 5	No normal access permitted	>100	--

Note: Section 5.2 of Chapter 5.0 discusses natural phenomena hazard design criteria from U.S. Department of Energy Order 6430.1A (DOE 1989). This section describes the special features that were incorporated into the design and ultimately built into the facilities to make the facilities appropriate for processing and handling large quantities of special nuclear material. Chapter 4.0 discusses the principal design criteria used at the PFP.

Table 8-2. Potential Radiation Sources in Plutonium Reclamation Facility. (4 sheets)

Equipment number	Location	Function*	Description	Working volume (L)	Former process chemical form
TK-32 (CA column)	Process cell	Extracts plutonium from aqueous feed	4-in. x 45-ft stainless steel and Pyrex™	144	$Pu(NO_3)_4$[a]
TK-33 (CC column)	Process cell	Strips plutonium from organic feed	4-in. x 45-ft stainless steel and Pyrex™	144	$Pu(NO_3)_4$[a]
TK-WS-1 (CO column)	Process cell	Plutonium scrubbing	6-in. x 19-ft 10-in. stainless steel, Teflon™-lined	90	$Pu(NO_3)_4$[a]
TK-123 (CU column)	Process cell	Uranium stripping	4-in. x 23-ft stainless steel	65	$Pu(NO_3)_4$[a]
TK-69 (CX column)	Process cell	DBP scrubbing	6-in. x 12-ft 7-in. stainless steel, Teflon™ lined	70	Trace plutonium[a]
TK-48 (OA column)	2nd floor west section	Organic reacidification	5-in. x 4-ft 6-in. stainless steel, Teflon™-lined	18	Trace plutonium
TK-15	Process cell	S&C Product receiver	5-in. x 3-ft 9-in.[b] stainless steel	45	$Pu(NO_3)_4$
TK-16	Process cell	Miscellaneous storage	5-in. x 15-ft 4-in.[b] stainless steel	185	$Pu(NO_3)_4$[a]
TK-17	Process cell	Feed makeup tank	5-in. x 15-ft 4-in.[b] stainless steel	185	$Pu(NO^3)_4$
TK-18	Process cell	Feed transfer to CA column	5-in. x 15-ft 4 in.[b] stainless steel	185	$Pu(NO^3)_4$
TK-19	Process cell	CAW receiver cell	5-in. x 15-ft 4-in.[b] stainless steel	185	$Pu(NO^3)_4$
TK-126	Process cell	Miscellaneous storage	5-in. x 15-ft 4-in.[b] stainless steel	185	$Pu(NO^3)_4$
TK-127	Process cell	Miscellaneous storage	5-in. x 15-ft 4-in.[b] stainless steel	185	$Pu(NO_3)_4$[a]
TK-36	Process cell	CAIS pump tank to CA column	5-in. x 45-in.[b] stainless steel	45	$Pu(NO_3)_4$

Table 8-2. Potential Radiation Sources in Plutonium Reclamation Facility. (4 sheets)

Equipment number	Location	Function*	Description	Working volume (L)	Former process chemical form
TK-37	Process cell	CAX pump tank	5-in. x 15-ft 4-in. stainless steel[b]	185	TBP and CCl4
TK-38	Process cell	CAX pump tank	5-in. x 48-in. stainless steel[b]	185	TBP and CCl4
TK-39	Process cell	CAW receiver tank (waste)	5-in. x 15-ft 4-in. stainless steel[b]	185	$Pu(NO_3)_4$
TK-40	Process cell	CXP receiver tank (waste)	5-in. x 13-ft. 8-in. stainless steel[b]	185	$Pu(NO_3)_4$
TK-41	Process cell	CUU receiver tank (waste)	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-42	Process cell	Concentrator feed tank	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-43	Process cell	Product concentrator	4-in. x 10-ft 9-in. stainless steel with annular steam jacket	5	$Pu(NO_3)_4$
TK-44	Process cell	Condenser	6-in. x 3-ft 8-in. stainless steel	N/A	N/A
TK-45	Process cell	PR tank	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-46	Process cell	PR tank	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-20	Process cell	Evaporator	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-21	Process cell	Evaporator feed	6-in. x 72 in. stainless steel with shell & tube heat exchanger	25	$Pu(NO_3)_4$
TK-22	Process cell	Condenser for Evaporator TK-21	6-in. x 44-in. stainless steel	N/A	N/A
TK-23	Process cell	Evaporator receiver for TK-21	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-24	Process cell	Evaporator receiver for TK-21	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$
TK-25	Process cell	Mt receiver tank	5-in. x 45-in. stainless steel[b]	45	$Pu(NO_3)_4$

Table 8-2. Potential Radiation Sources in Plutonium Reclamation Facility. (4 sheets)

Equipment number	Location	Function*	Description	Working volume (L)	Former process chemical form
TK-26	Process cell	MT receiver tank	5-in. x 45-in.,[b] stainless steel	45	$Pu(NO_3)_4$
TK-27	Process cell	CAR supply to CA column	5-in. x 45-in.,[b] stainless steel	45	$Pu(NO_3)_4$
TK-29	Process cell	CAS pump tank to CA column	5-in. x 45-in.,[b] stainless steel	45	N/A
TK-30	Process cell	CCX pump tank to CC column	5-in. x 45-in.,[b] stainless steel	45	N/A
TK-128	Process cell	PR tank	5-in. x 45-in.,[b] stainless steel	45	$Pu(NO_3)_4$
TK-49	Process cell	Miscellaneous transfer tank	5-in. x 45-in.,[b] stainless steel	45	$Pu(NO_3)_4$
TK-52.1 & TK-52.2	East glovebox	East drain header receiver tanks	6-in. x 2-ft 6-in. glass pipe	20	$Pu(NO_3)_4$
TK-52.3 & TK-52.4	West glovebox	West drain header receiver tanks	6-in. x 2-ft. 6-in. glass pipe	20	$Pu(NO_3)_{4a}$
TK-70	Process cell	CXX pump tank	5-in. x 45-in.,[b] stainless steel	45	$Pu(NO_3)_4$[a]
TK-58	Room 50 glovebox	Organic deentrainment	4-in. x 2-ft. 6-in. glass pipe	10	$Pu(NO_3)_4$
TK-120	Process cell	CAP pump tank	5-in. x 45-in.,[b] stainless steel	45	a
TK-WM-1	Process cell	CAW receiver		185	$Pu(NO_3)_4$
D centrifuge	West glovebox	Solids removal from product	5.6-in. x 14-ft 4-in. stainless steel, 3 tubes	2.7	$Pu(NO_3)_4$
B1 & B2 centrifuges	MT-6 glovebox	Solids removal from waste stream (CAW)	Stainless steel	2.7	$Pu(NO_3)_4$
Filter 16.1	East glovebox	Solids removal from feed solution	Stainless steel	N/A	$Pu(NO_3)_4$[a]
Filter 16.2	East glovebox	Solids removal from feed solution	N/A	N/A	$Pu(NO_3)_4$
Filter 5.1	West glovebox	Filter for solids removal	N/A	N/A	$Pu(NO_3)_4$

Table 8-2. Potential Radiation Sources in Plutonium Reclamation Facility. (4 sheets)

Equipment number	Location	Function*	Description	Working volume (L)	Former process chemical form
TK-C1	MT-6 glovebox	Vacuum catch tank for TK-C2 and TK-C3	4-in. x 1-ft. 6-in. stainless steel	5.6	$Pu(NO_3)_4$
TK-C2	MT-6 glovebox	Receiver tank for MT solutions	Glass	13.9	$Pu(NO_3)_4$
TK-C3	MT-6 glovebox	Receiver tank for MT solutions	Glass	14.4	$Pu(NO_3)_4$
C centrifuge	MT-6 glovebox	Solids removal from liquid feed for solvent extraction	Stainless steel	2.7	$Pu(NO_3)_4$

[a] $Pu+4.2TBP.4NO_3$.
[b] Equals four tubes per tank.
[c] Solid.
*S&C = slag and crucible
DBP = dibutyl phosphate
•CA = first column of PRF solvent extraction process
CAW = column aqueous waste
•CAIS= plutonium rich reflux stream
•CAX = column organic extract
CXP = solvent cleanup waste
CUU = column uranium waste
PR = product receipt
•CCX = .04M hydroxylamine nitrate, .2 M nitric acid, & .05 M hydrazine
•CXX = dispersed aqueous solution ascending through downward flow of organic in CX column
•CAP = CA column product stream

Table 8-3. Potential Radiation Sources in Remote Mechanical C Line. (3 sheets)

Equipment type*	Location	Function	Description	Working volume (L)	Former process chemical form
VDF & Pan	HC-9B	Plutonium oxalate solids are separated from the filtrate	5-in. x 11-in.-dia 8-in. x 7-in. 8.25-in. x 10-in. 0.5-in.	222.2	$Pu(NO_3)_4$
Calciner	HC-9B	Discomposes plutonium oxalate solids to PuO_2	6-ft 9-in. stainless steel through x 4-in.-dia. screw	N/A	PuO_2 **
Fluorinator	HC-9B	Conversion of PuO_2 to PuF_4	5 ft 6 in. long x $\frac{1}{4}$ in. high made of inconel™ with platinum-iridium liner	N/A	PuF_4
Powder pans	HC-1* HC-11	Interim storage and transport of PuF_4 powder	7-in. x 6-in. high pans	1.7	PuF_4
Mixer/dumper (abandoned in place)	HC-13MD	Mixing calcium metal, iodine crystals with PuF_4 powder (abandoned in place) Glovebox is used for seal-in/seal-out of material to/from thermal stabilization processes	10-in.-diameter x 3-in. high Lexan™ mixer that tapers conically to 7 in.	6.5 N/A	PuF_4 PuO_2 (current process chemical form)
Induction furnaces (3)	HC-15	Firing of reduction charge	3/8-in. OD, 0.035-in. wall thickness copper tubing coiled around a heat-resistant type with an 8-in. OD and 1/8-in. wall thickness	N/A	PuF_4
PV	HC-1* HC-12S HC-13MD HC-15 HC-16CC HC-17DC	Contains PuF_4 charge along with chemicals for reduction, crucible, and MgO sand	7-in. x 12.7-in Hastelloy™ X	4.3	PuF_4, plutonium metal, plutonium S&C
Damper hammer mill	HC-17DC	Separate the plutonium metal and grind up the sand, S&C	N/A	N/A	Plutonium metal, plutonium S&C
B valve	HC-9B	Transfer PuO_2 from calciner to flourinator	N/A	N/A	PuO_2

Table 8-3. Potential Radiation Sources in Remote Mechanical C Line. (3 sheets)

Equipment type*	Location	Function	Description	Working volume (L)	Former process chemical form
Reactor	HC-9B	Formation of oxalate slurry	6-in. schedule-10 stainless steel	2.7	$Pu(NO_3)_4$
VRT	HC-9B	Supplies vacuum to the VDF	6-in. x 2-ft glass tank	11	$Pu(NO_3)_4$
CRT	HC-9B	Receives offgases from the calciner	6-in. x 1-ft glass tank	5.5	$Pu(NO_3)_4$
OT	HC-9B	Catch tank for overflow of VDF pan	6-in. x 1-ft glass tank	5.5	$Pu(NO_3)_4$
Batch tanks	HC-227S	Blending and sampling	6-in. x 8-ft. glass tank (3)	44.5	$Pu(NO_3)_4$
Vacuum trap	HC-227S	Prevent solutions from entering 26-in. vacuum system	6-in. x 1-ft 5-in. glass tank	8.3	$Pu(NO_3)_4$
Load-out tank	HC-227S cell	Product staged for loadout	6-in. x 2-ft glass tank	11	$Pu(NO_3)_4$
Storage tanks	HC-4	Interim product storage	6-in. x 4-ft glass tank	22	$Pu(NO_3)_4$
ACT	HC-7	Receiver tank for miscellaneous solutions	6-in. x 4-ft glass tank	22	$Pu(NO_3)_4$
Vacuum trap and E-4 vent trap	HC-7	Prevent solutions from entering 26-in. vacuum system	6-in. x 1-ft glass tank	5.5	$Pu(NO_3)_4$
Vacuum tank	HC-7	Prevent solutions from entering 26-in. vacuum system	6-in. x 1-ft glass tank	5.5	$Pu(NO_3)_4$
PMT	HC-7	Meter H_2O_2	3-in. x 1-ft 10-in. stainless steel tank	1.4	H_2O_2

Table 8-3. Potential Radiation Sources in Remote Mechanical C Line.
(3 sheets)

Equipment type*	Location	Function	Description	Working volume (L)	Former process chemical form
PRT	HC-7	Plutonium valence adjustment	6-in. x 3-ft glass tank	16.7	$Pu(NO_3)_4$ H_2O_2
THT	HC-7	Feed tank	6-in. x 3-ft glass tank	16	$Pu(NO_3)_4$
FKT/FCT	HC-7	$KMnO_4$ used to eliminate $C_2H_2O_4$	5-in. interconnected glass tank	22	$Pu(NO_3)_4$
FST	HC-7	Sampling and transfer of filtrate solution to PRF	6-in. x 6-ft glass tank	33-36	$Pu(NO_3)_4$

* The HC-1 conveyor glovebox is currently utilized in the thermal stabilization process.
** They may still exist in process vessel.

VDT = vacuum drum trap
*VDF = vacuum drum filter
PV = pressure vessel
VRT = vacuum receiver tank
CRT = condensate receiver tank
OT = overflow tank
ACT = aqueous catch tank
PMT = peroxide measuring tank
PRT = pre-reduction tank
THT = transfer head tank
FKT = filtrate kill tank
FCT = filtrate catch tank
FST = filtrate storage tank

Table 8-4. Liquid Effluent Waste Ranges.*

Activity (normal range)	Source	Collection point
<2 E-10 Ci/L	Cooling and seal water 234-5Z HVAC drains, steam condensate drains, roof drains (west end), cold chemical drains, 2736-ZB HVAC condensate drains	Manhole Z-1
<2 E-10 Ci/L	The 234-5Z storm drains, ventilation condensate, and Manhole 1 drain	Manhole Z-2
<2 E-10 Ci/L	The 234-5Z D-1, D-2 drain headers. Roof drains (east end), 242-Z D-1 drain header and 291-Z sump	Manhole Z-3
<2 E-10 Ci/L	The 236-Z condensate drains, drain headers D-1, D-3, and Manhole Z-3 drain	Manhole Z-4
<2 E-10 Ci/L	Manholes S-7 and C-1	Manhole C-2

*Liquid effluent waste system is discussed in Chapters 5.0 and 7.0.

Table 8-5. Potential Plutonium Sources Contained in Gloveboxes and Hoods. (3 sheets)

Glovebox /hood	Location	Description	Physical form	Nominal chemical form
HC-60	Room 230-C	Framed glovebox with Lexan™ panels and 40.8-in. gloveports	Liquid/solid (sludge)	$Pu(NO_3)_4$ Organic
HA-40F	Room 169	Stainless steel glovebox	Solid	Plutonium ash
HA-46F	Room 170	Stainless steel glovebox with Lucite™ panels and lead shielding	Solid	Plutonium ash
Glovebox 636	Room 636, 2736-2B	Stainless steel glovebox with Lucite™ panels impregnated with lead	Solid	PuO_2, plutonium metal, PuF_4
HA-20MB	Room 235-B	Stainless steel glovebox with Lucite™ panels	Solid	PuO_2, plutonium metal, PuF_4
HA-21I	Room 235-B	Stainless steel with Lucite™ panels and lead shielding	Liquid/solid (sludge)	Plutonium process residues, plutonium ash, non-organics
HA-22B	Room 235-B	Stainless steel with Lexan™ or Lucite™ panels and lead shielding	Liquid/solid (sludge)	Plutonium process residues
HA-23S	Room 235-B	Stainless steel glovebox with water walls for shielding	Liquid/solid (sludge)	Plutonium process residues
H-7A	Room 235-A1	Stainless steel glovebox with Lucite™ panels	Liquid	$Pu(NO_3)_4$
H-9E	Room 235-A1	Stainless steel gloveboxes with lead glass	Solid	PuO_2
Gloveboxes 1,2,3	Room 221-C	Open-faced hoods (2). Glovebox storage cabinet	Liquid/solid	$Pu(NO_3)_4$ PuO_2
Gloveboxes 1,2,3	Room 221-D	Open-faced hood	Liquid/solid	$Pu(NO_3)_4$ PuO_2
Gloveboxes 4,5	Room 221-D	Open-faced hood, Glovebox	Liquid/solid	$Pu(NO_3)_4$ PuO_2
MT-1	Room 41	Stainless steel glovebox, lead glass panels, and 16 gloveports	Solid	Plutonium scrap
Transfer hood	Room 41	Stainless steel glovebox, lead glass windows, 12 gloveports	Solid	PuO_2, plutonium scrap
MT-3	Room 41	Stainless steel glovebox with lead glass windows, 52 gloveports	N/A	N/A
MT-4	Room 41	Stainless steel glovebox with lead glass windows, top/bottom sections, 72 gloveports	Solid	PuO_2
MT-5	Room 41	48 gloveports, stainless steel glovebox, lead glass windows	Liquid/solid sludge	NaF, PuO_2, scrap oxide
MT-6	Room 41	Stainless steel glovebox with 56 globe ports, lead glass windows	Liquid/sludge	PuO_2

Table 8-5. Potential Plutonium Sources Contained in Gloveboxes and Hoods. (3 sheets)

Glovebox /hood	Location	Description	Physical form	Nominal chemical form
Canning/ loading	Room 43	Stainless steel glovebox with lead glass windows, 11 gloveports	Solid	plutonium scrap
Charging hood	Room 43	Stainless steel glovebox with lead glass windows, 8 gloveports	Solid	plutonium scrap
Hoods 1,2,3	Room 131	Glovebox	Solid/liquid	$Pu(NO_3)_4$ PuO_2 plutonium metal
Hoods 1,2,3,4	Room 134	Open-faced hood	Liquid	$Pu(NO_3)_4$
Hoods 1,2,3,4	Room 135	Open-faced hood	Liquid	$Pu(NO_3)_4$
Gloveboxes 1,2,3	Room 136	Glovebox	Solid/liquid	$Pu(NO_3)_4$ PuO_2 plutonium metal
Gloveboxes 1,2,3	Room 137	Glovebox	Solid/liquid	$Pu(NO_3)_4$ PuO_2 plutonium metal
Gloveboxes 1,2,3,4	Room 139	Glovebox	Solid	PuO_2 plutonium metal
Hood 5	Room 139	Storage cabinet	Solid	PuO_2 plutonium metal
Hood 6	Room 139	Glovebox	Solid	PuO_2 plutonium metal
Vaults 1,2,3,4	Room 142	Glovebox (4) and open-faced hoods	Liquid	$Pu(NO_3)_4$
Hoods 1,2,3	Room 143	Glovebox and open-faced hoods	Solid/liquid	$Pu(NO_3)_4$ plutonium oxalate
Hoods 4,5	Room 143	Glovebox and open-faced hoods	Solid/liquid	$Pu(NO_3)_4$ Plutonium Oxalate
Hoods 1,2,5,6,7,8,9	Room 144	Glovebox (4) and open-faced hoods	Liquid	$Pu(NO_3)_4$
Hoods 3,4	Room 144	Glovebox (4) and open-faced hoods	Liquid	$Pu(NO_3)_4$
Glovebox 1	Room 145	Glovebox	Solid	
Hoods 1,2,3,5 glovebox 4	Room 146	Open-faced and glovebox (5)	Liquid	$Pu(NO_3)_4$
Hoods 1,2	Room 148	Open-faced hood	Liquid	$Pu(NO_3)_4$
Hood 1	Room 149	Glovebox and open-faced hood	Solid/liquid	$Pu(NO_3)_4$
Hood 1	Room 152	Hood	Liquid	$Pu(NO_3)_4$
Glovebox 552	Room 152	Glovebox	Liquid	$Pu(NO_3)_4$
Hoods 1,2,3,4	Room 153	Open-faced hood	Solid/liquid	$Pu(NO_3)_4$ PuO_2

Table 8-5. Potential Plutonium Sources Contained in Gloveboxes and Hoods. (3 sheets)

Glovebox /hood	Location	Description	Physical form	Nominal chemical form
Glovebox 5	Room 153	Glovebox	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Gloveboxes 1,2,3	Room 154	Glovebox	Solid	PuO_2 Plutonium metal
Hoods 1,2,3,4	Room 155	Open-faced hood	Liquid	$Pu(NO_3)_4$
Hoods 1,2,3,4	Room 156	Open-faced and glovebox	Liquid	$Pu(NO_3)_4$
Gloveboxes 1,2,3,4	Room 157	Glovebox	Solid/liquid	$Pu(NO_3)_4$ Plutonium metal
Gloveboxes 10,12	Room 179-B	Glovebox	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Hood 11	Room 179-B	Hood	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Gloveboxes 4,6	Room 179-C	Open-faced hood	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Glovebox 9	Room 179-C	Open-faced hood	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Vault	Room 190	-	-	-
Hoods 1,2	Room 221-C	Open-faced hood	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Glovebox 3	Room 221-C	Glovebox	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Hoods 1,2,3	Room 221-D	Open-faced hood & glovebox (5)	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Hood 4	Room 221-D	Open-faced hood & glovebox (5)	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Glovebox 5	Room 221-D	Open-faced hood & glovebox (5)	Solid/liquid	$Pu(NO_3)_4$ PuO_2
Hoods 1,2,3	Room 221-E	Open-faced hood	Liquid solid	$Pu(NO_3)_4$ PuO_2
Vault	Room 225	Locked cubicle storage	Solid	PuO_2
H-9A[a]	Room 235-A1	Stainless steel glovebox with Lexan™ panels	Liquid solid	$Pu(NO_3)_4$ PuO_2

*Radiological limit based on internal guidelines.

Table 8-6. Radioactive Material Packaging Configuration in Vaults.

Material type	Location	Container type	Description	Nominal plutonium (g)	Nominal volume (L)	Physical form	Chemical form
Polystyrene recoverable material	2736-Z Building	7-in. cans, slip-lid cans	4-1/2-in x 7-in tin can	138	1.5	Power encased in solid matrix	PuO_2
Plutonium solutions	2736-Z Building room 236 and room 192-A	PR can	Stainless steel PR can container inside a 55-gal drum	178 to 300 g/L maximum	9.5 to 10.0 (controlled to 8.5L)	Solution	$Pu(NO_3)_4$
		L-10, 10-L, FL-10	Polybottle inside two 55 drums welded together end to end		9.5 to 10.0		
		PR container drum	Polybottle inside SS sleeve in a 55 gal drum		3.0		
Incinerator ash	2736-Z Building room 192-B	Lard cans	15-in. 12-in. 10-3/4-in. tin container	36	27	Solid	Plutonium ash
S&C*	2736-Z Building	Lard cans	15-in. 12-in. 10-3/4-in. tin container	249	27	Solid	Plutonium S&C*
Metal/ alloys with uranium	2736-Z Building room 236 and room 192-B	Lard cans, 7-in. cans	4-1/4-in. 7-in. can	163	1.5	Solid	Pu-U
			4-in. 3-1/4in. can	163	0.9		
Metal/ alloys with thorium	2736-Z Building room 236	7-in. cans, tin can	4-1/4-in 7-in. can	1604	1.5	Solid	Pu-Th
Metal/alloys with zirconium	2736-Z Building room 236	7-in. cans, tin can	4-1/4-in. 7-in. can	7	1.5	Solid	Pu-Zr
Miscellaneous samples	2736-Z Building room 192-B	7-in. cans, tin can	4-1/4-in. 7-in. can	40	1.5	Solid	PuO_2
Recoverable plutonium metal	2736-Z Building	7-in. cans	4-1/4-in. 7-in. can	1,700 to 2,200	1.5	Solid	Plutonium metal
Scrap oxide	2736-Z Building	7-in. cans	4-1/4-in. 7-in. can	400 to 800	1.5	Solid	PuO_2

* S&C = slag and crucible

Table 8-7. The X-Ray and Gamma Energy Groups (photons from the decay of plutonium isotopes and their daughters). (3 sheets)

Energy (keV)	Abundance (gammas/1E6 disintegrations)	Energy (keV)	Abundance (gammas/1E6 disintegrations)	Energy (keV)	Abundance (ppm)
^{238}Pu					
U-N-x[a]	2,000	U-K-x	2	743	0.09
U-M-x	27,000	43.5	380	767	0.35
U-L3-x	70,000	100	80	786	0.06
U-L2-x	78,000	153.1	10	854	0.05
U-L1-x	3,100	203	0.04	1,001	0.008
^{239}Pu					
U-N-x	3,800	144.2	2	367.4	0.64
U-M-x	50,000	161.4	0.9	368.7	0.56
U-L3-x	28,000	171.4	0.7	375.2	10
U-L2-x	32,000	179.1	0.5	380.4	2
U-K-x	45	195.6	0.8	393.5	4
13	3	203.5	3.6	413.7	10
38.6	60	255.5	0.6	422.6	0.6
46.2	6.4	264	0.24	426.7	0.12
51.6	160	297.6	0.36	451.6	1.4
56.6	6.4	311.8	0.2	639	0.17
68.6	5.6	321.1	0.32	645	0.2
77.6	4.4	323.9	0.36	652	0.13
98	10	333	3.2	659	0.16
103	1.6	336.3	0.72	718	0.04
116	7.2	341.7	0.48	758	0.06
129.3	40	345.1	3.5	771	0.18
^{240}Pu					
U-N-x	1,800	U-L1-x	2,700	160	12
U-M-x	24,000	U-K-x	2	642	0.14
U-L3-x	59,000	45.3	500	688	0.04
U-L2-x	70,000	103.6	120	--	--

Table 8-7. The X-Ray and Gamma Energy Groups (photons from the decay of plutonium isotopes and their daughters). (3 sheets)

Energy (keV)	Abundance (gammas/1E6 disintegrations)	Energy (keV)	Abundance (gammas/1E6 disintegrations)	Energy (keV)	Abundance (ppm)
^{241}Am					
Np-N-x	4,400	165	0.4	427	0.3
Np-M-x	59,000	169	1	570	0.1
Np-L3-x	100,000	208	6	597	0.1
Np-L2-x[b]	280,000	222	0.4	619	0.8
Np-L1-x	160,000	268	0.3	641	0.1
Np-K-x	40	293	0.2	653	0.5
26.4	25,000	312	0.3	662	5
33.2	300	323	1.6	680	0.06
42.6	6	332	1.8	689	0.4
43.4	700	335	6	695	0.1
55.6	260	338	0.1	710	0.09
59.54	360,000	369	3	722	2.8
67.5	10	317	1.3	737	0.12
99	240	377	1.6	757	0.13
103	190	384	0.3	767	0.08
125	50	420	0.4	771	0.1
146	2	--	--	--	--
^{242}Pu					
U-N-x	1800	U-L3-x	59,000	U-L1-x	2700
U-M-x	24000	U-L2-x	70,000	44.7	500
^{241}Pu					
U-N-x	0.03	U-L2-x	0.56	U-K-x	17
U-M-x	0.4	U-L1-x	2.8	145	1.6
U-L3-x	0.23	--	--	--	--
^{237}U					
Np-N-x	1.3	33.2	0.019	221.8	0.022
Np-M-x	17	43.4	0.074	234.4	0.021
Np-L3-x	16	51	0.2	267.5	0.76
Np-L2-x	11	59.5	36	332.4	1.3
Np-L1-x	14	64.8	1.3	335.4	0.1

Table 8-7. The X-Ray and Gamma Energy Groups (photons from the decay of plutonium isotopes and their daughters). (3 sheets)

Energy (keV)	Abundance (gammas/1E6 disintegrations)	Energy (keV)	Abundance (gammas/1E6 disintegrations)	Energy (keV)	Abundance (ppm)
Np-K-x	56	103	0.6	337.7	0.027
13.8	0.001	164.6	2	368.6	0.05
26.4	2.4	208	23	370	0.12

[a]U-N-x = Uranium N shell transition X-rays Energy group.
[b]Np-L2-x = Neptunium, L shell, 2nd level transition X-rays Energy group.

Table 8-8. Potential Plutonium Sources Contained in Filter Boxes. (3 sheets)

Filter box	Location	Function	Physical form	Chemical form
15	308	Primary exhaust filter for glovebox in rooms 134 and 137	Powder	PuO_2
DPI 37	636/ 2736-ZB	Primary exhaust filter for part of glovebox 636	Powder	PuO_2
DPI 38	636/ 2736-ZB	Primary exhaust filter for part of glovebox 636	Powder	PuO_2
50	Room 50	Primary exhaust filter for column and MT gloveboxes	Powder	PuO_2
10	Corridor 10	One of four primary exhaust filters for the PRF process canyon	Residue	PuO_2
10W	Corridor 10	One of four primary exhaust filters for the PRF process canyon	Residue	PuO_2
20	Corridor 20	One of four primary exhaust filters for the PRF process canyon	Residue	PuO_2
20W	Corridor 20	One of four primary exhaust filters for the PRF process canyon	Residue	PuO_2
C-6	263	Primary exhaust filter for glovebox in room 221-C	Residue	PuO_2
C-5	263	Primary exhaust filter for glovebox C-6	Residue	PuO_2
D-8	263	Primary exhaust filter for glovebox in rooms 221-D	Powder	PuO_2
D-7	263	Primary exhaust filter for glovebox D-8	Powder	PuO_2
IN	308	Primary exhaust filter for part of gloveboxes in rooms 132,134, and 135	Powder	PuO_2
2	308	Primary exhaust filter for part of gloveboxes in rooms 148 and 149	Powder	PuO_2
3	308	Primary exhaust filter for part of gloveboxes in rooms 152 and 154	Powder	PuO_2
4	308	Primary exhaust filter for part of gloveboxes in rooms 136, 137, 145, and 146	Powder	PuO_2
5	308	Primary exhaust filter for part of gloveboxes in rooms 154 and 155	Powder	PuO_2
6	308	Primary exhaust filter for part of gloveboxes in rooms 132 and 139	Powder	PuO_2

Table 8-8. Potential Plutonium Sources Contained in Filter Boxes. (3 sheets)

Filter box	Location	Function	Physical form	Chemical form
7	308	Primary exhaust filter for gloveboxes in rooms 142 and 143	Powder	PuO_2
9	308	Primary exhaust filter for gloveboxes in room 166	Powder	PuO_2
10	308	Primary exhaust filter for gloveboxes in rooms 170 and 174	Powder	PuO_2
11	308	Primary exhaust filter for gloveboxes in rooms 179-B and 179-C, and corridor 9	Powder	PuO_2
12	308	Primary exhaust filter for gloveboxes in rooms 188, 189, and 190	Powder	PuO_2
13	308	Primary exhaust filter for gloveboxes in room 183	Powder	PuO_2
14	320	Primary exhaust filter for gloveboxes in rooms 228-A, 228-B, 228-C, 235-A1	Powder	PuO_2
15	308	Primary exhaust filter for gloveboxes in room 185	Powder	PuO_2
16	308	Primary exhaust filter for gloveboxes in room 143	Powder	PuO_2
16W	308	Primary exhaust filter for gloveboxes in room 144 east	Powder	PuO_2
17	308	Primary exhaust filter for gloveboxes in room 144 west	Powder	PuO_2
18	308	Primary exhaust filter for gloveboxes in rooms 156 and 157	Powder	PuO_2
19	308	Primary exhaust filter for gloveboxes in room 144 west	Powder	PuO_2
20	320	Primary exhaust filter for gloveboxes in rooms 228A,228-B, and 228-C	Powder	PuO_2
21	320	Primary exhaust filter for gloveboxes in rooms 228-A, 228-B, 228-C, and 235-A3	Powder	PuO_2
22	320	Primary exhaust filter for gloveboxes in rooms 228A,228-B, and 228-C	Powder	PuO_2
25	308	Primary exhaust filter for 17-in. vacuum system	Powder	PuO_2
26	308	Primary exhaust filter for gloveboxes in rooms 185 and 186	Powder	PuO_2

Table 8-8. Potential Plutonium Sources Contained in Filter Boxes. (3 sheets)

Filter box	Location	Function	Physical form	Chemical form
27	264	Primary exhaust filter for glovebox H-7A, room 235-A3	Powder	PuO_2
E-6	263	Primary exhaust filter for gloveboxes in room 221-E	Powder	PuO_2
E-5	263	Primary exhaust filter for filterbox E-6	Powder	PuO_2
1	241-Z	Filters for 241-Z	Powder	PuO_2
2	241-Z	Cells	Powder	PuO_2
3	241-Z	Cells	Powder	PuO_2
4	241-Z	Cells	Powder	PuO_2

Table 8-9. Estimated Quantities of Radiation Sources Located in Plutonium Finishing Plant E-4, 26-in. Mercury Process Vacuum and Exhaust Manifold Systems.

System	Location	Description content	Estimated plutonium content	Plutonium form	Chemical
E-4 Exhaust	Rooms 262,263, 264, 308, and 302	Approximately 4,000 linear ft of 2-in. to 68-in. duct work	4.1 kg[a]	Solid	PuO_2 residues
26-in. vacuum	Room 265	The 0.75-in. piping drops from first floor to main heater. Approximately 825 ft of 2-,3-, and 4-in. schedule-40 stainless steel piping	4.3 kg[b]	Solid	PuO_2 residues
Exhaust manifold	Rooms 262, 308, and down to base of 291-Z stack	Approximately 42,000-ft^2 132-in.x 132-in. (nominal size duct work)	0.01 kg[c]	Adhered solid	PuO_2 residues

[a]Westsik 1999.
[b]Westsik 1989.
[c]Westsik 1989a.

Table 8-10. Criteria for Posting.

Radiation areas	
Area	Dose rate criteria
Radiation area	>0.005 rem/h and <0.1 rem/h at 30 cm
High radiation area	>0.1 rem/h at 30 cm and ≤500 rad/h at 100 cm
Very high radiation area	>500 rad/h at 100 cm
Hot Spot	5 times general area dose rate and >0.1 rem/h
Contamination areas	
Contamination	Contamination levels >1 time but ≤100 times 20 dpm/100 cm^2 (transuranic)
High contamination	Contamination levels >100 times 20 dpm/100 cm^2 (transuranic)
Fixed contamination	Removable contamination levels < 20 dpm/100 cm^2; total contamination levels > 500 dpm/100 cm^2 (transuranic)
Soil contamination	Contaminated soil not releasable in accordance with DOE Order 5400.5
Airborne radioactivity	Concentrations ($\mu Ci/cm^3$) >10% of any DAC value

Table 8-11. Hanford Site Radiological Administrative Control Levels.

Maximum dose equivalent (annual; mrem)				
TEDE	Skin and extremity[a]	Lens of eye[a]	Any organ[a]	Approval required to exceed this level[b]
500	15,000	4,500	15,000	Level 3 line manager and RCM[c]
1000	22,500	6,750	22,500	Level 2 line manager and RCM
1500	30,000	9,000	30,000	Contractor senior site executive
2000				DOE PSO
Age x 1,000 = lifetime TEDE				Level 1 line manager and RCM

Source: Project Hanford Radiological Manual (HNF-5173, Rev. 0, FH 2000).
[a] The values are based on the nonstochastic limit and are calculated as committed doses.
[b] Approvals are sequential.
[c] Approval may be delegated within the Radiological Control Organization.

DOE - U.S. Department of Energy.
PSO - Program Secretarial Officer.
RCM - Radiological Control Manager.
TEDE - total effective dose equivalent.

Table 8-12. U.S. Department of Energy Radiation Protection Standards Limiting Values for Assessed Dose from Exposure of Occupational Workers to Radiation.

Type of exposure	Dose (rem)
Stochastic effects	5.0 (annual TEDE*)
Nonstochastic effects	
Lens of eye	15.0
Extremity	50.0
Skin of the whole body	50.0
Organ or tissue	50.0
Unborn child Entire gestation period	0.5

Source:* From 10 CFR 835, Section 835.202 (DOE 1993a).
TEDE - total effective dose equivalent

Table 8-13. Shielding for Chemical Processing Areas and Gloveboxes in the Plutonium Finishing Plant. (2 sheets)

Glovebox/area	Room/location	Type of shielding
HC-227T	227	1-in.-thick lead
HC-227S	227	1/2-in.-thick lead; 1/4-in.-thick lead
HC-4	166	1/4-in. lead glass
HC-6	166	1-in.-thick lead glass; 6-in.-thick lead/masonite wall in front of tanks
HC-7	228-A	1-in.-thick lead glass
HC-9B	228-A	1-in.-thick lead glass and water shield at midlevel
HC-1	228-A, B, C	1-in.-thick lead glass
HC-10	228-A	1-in.-thick lead glass
HC-2	228-A, B, C; 230-A, B, C	1-in.-thick lead glass; and an additional layer or 0.3-in.-thick lead glass at the north and south faces.
HC-3	230-C	1-in.-thick lead glass
HA-28	235-B	1-in.-thick lead glass
HC-11	228-A	1-in.-thick lead glass
HC-12S	228-B	1-in.-thick lead glass
HC-13MD	228-B	1-in.-thick lead glass
HC-15A,-B, -C	228-B	1-in.-thick lead glass
HC-16CC	228-B	1-in.-thick lead glass
HC-17DC	228-C	1-in.-thick lead glass
HC-17P	228-C	1-in.-thick lead glass
HC-17SSB	228-C	1-in.-thick lead glass
HC-18M	228-C	1-in.-thick and 0.3-in.-thick lead glass
HC-18BS	228-C	1-in.-thick lead glass
HC-21A	230-B	1/2-in.-thick lead; 1/4-in.-thick lead glass
HC-21C	230-A	1/2-in.-thick lead; 1/4-in.-thick lead glass
HC-46F	170	1/2-in.-thick; 1/4-in.-thick lead glass
HA-46	232	1-in.-thick lead glass
H-7A	235-A3	1/2-in.-thick lead glass
H-9A	235-A3	1/2-in.-thick lead glass
H-8	235-A3	1/2-in.-thick lead glass
H-9E	235-A3	1/2-in.-thick lead; 1/4-in.-thick lead glass
HA-21I	235-B	1/2-in.-thick lead; 1/4-in.-thick lead glass
HA-20MB	235-B	1/2-in.-thick; 1/4-in.-thick lead glass
HA-23S	235-B	1/2-in.-thick lead; 1/4-in.-thick lead glass
Process cell	236-Z	2-ft-thick concrete walls
Maintenance cell	236-Z	1/2-in.-thick lead
Process cell	236-Z	1-ft 9-in.-thick water windows

Table 8-13. Shielding for Chemical Processing Areas and Gloveboxes in the Plutonium Finishing Plant. (2 sheets)

Glovebox/area	Room/location	Type of shielding
PMP process line	228-A,-B,-C	1-ft 3-in.-thick water
Control room	229	Windows

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
234-5Z Building			
100-A	RADTU filter room	0.2	1/4 h/month
110-A	Women's laundry hampers	<0.05	1/4 h/month
126	Personnel decontamination facility	<0.05	1/2 h/day
131	Plutonium assay	<0.05	2 h/day
132	Mass spectrometry	0.07	6 h/day
133	Darkroom	<0.05	1 h/week
134	Mass spectrometry	0.1	2 h/day
135	Mass spectrometry	0.2	2 h/day
136	Emission spectrometry	0.4	2 h/day
137	Emission spectrometry	0.5	1 h/week
139	PUO_2 sample storage	5	16 h/day
140-A	Analytical support services	<0.05	12 h/day
140-B	Laboratory manager	<0.05	8 h/day
140-C	Laboratory staff chemist	<0.05	8 h/day
141	Nonradioactive solution preparation	<0.05	2 h/day
142	Miscellaneous storage	3	1 h/day
143	Waste process	4	4 h/day
144	Process support	0.5	24 h/day
145	Physical test	3	1 h/week
145-A	Stockroom	0.02	8 h/day
146	WIPP repackaging and sample analysis	0.5	1 h/day
147	Waste packaging and analysis manager	<0.05	16 h/day
148	Sample analysis	0.5	1 h/day
149	Sample dissolution	0.4	< 1h/week
150	Laboratory shift manager	<0.05	8 h/day
151	Miscellaneous counting room	<0.05	8 h/day
152	Waste concentrator (inactive)	4	2 h/day
153	Product specification analysis	5	1 h/day
154	Product specification analysis	0.5	1 h/day

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
155	Infrared spectrometer	0.05	1 h/day
156	S&C analysis	0.03	1 h/day
157	Product specification analysis	0.03	1 h/week
158	Instrument shop	<0.05	Full-time
159	Instrument shop	<0.05	Full-time
159-A	Instrument shop	<0.05	4 h/day
161	RMC Line Shift Operations	0.05	16 h/day
162	Solid Waste Operations	0.05	4 h/day
163	Storage	<0.05	8 h/day
164	RMC Line shift office	0.06	16 h/day
165	Storage	0.1	1 h/week
166	Inactive RMC Line batch tanks /SWO drum operations	4	1 h/day
167	RMC Line operations storage	0.15	Full-time
168	RMC Line ready room/storage	0.2	Full-time
169	Ash stabilization (inactive)	2	0.5 h/week
170	Ash dissolution (inactive)	0.2	1 h/day
171	Corridor	<0.05	Full-time
172	PR can storage	0.5	1 h/week
173	PR can storage	0.2	0
174	Plutonium material storage vault	5	6 h/week
175	Plutonium material storage vault	0.4	0.5 h/week
179	Process support laboratory	1	16 h/day
180	Isotopic research	0.1	2 h/day
182	Process support (microscope)	<0.05	2 h/day
183	Specialized processing	<0.05	2 h/day
185	Miscellaneous storage	<0.05	1 h/day
187	Open-faced hoods	2	16 h/day
188	Glovebox/chemical storage	2	16 h/day
189	Equipment storage	2	2 h/day

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
190	Radioactive material storage	0.5	1 h/week
191	Product support cold laboratory	0.1	3 h/day
192	Drum staging area	0.05	4 h/day
192-A	FFTF fuel pin storage	5	1 h/week
192-B	Plutonium material storage vault	90	1 h/week
192-C	Plutonium material storage vault	8	1 h/week
192-D	PR can storage	0.06	1 h/week
192-S	Storage	<0.05	1 h/week
192-W	NDA storage	<0.05	16 h/day
193	Airlock	<0.05	1/4 h/week
196	Waste drum storage	0.05	1/4 h/week
197	Waste drum storage	0.05	1.4 h/week
197-A	Mixed waste drum storage	0.05	1/4 h/week
221-A	RC office	<0.05	24 h/day
221-B	Sealer repair shop	<0.05	8 h/day
221-C	Radiochemical standards laboratory	3	2 h/day
221-D	Radiochemical standards laboratory	1	2 h/day
221-E	Radiochemical standards laboratory	1	2 h/day
225	Product handling vault	10	<1 h/week
227	Product LI/LO	1	8 h/day
228-A	RMC production line (inactive)	15	1 h/day
228-B	RMC production line (inactive)	1.5	1 h/day
228-C	LOI sampling glovebox; Storage glovebox	4	1 h/day
230-A	Thermal stabilization furnace glovebox; process control station	1	16 h/day
230-B	Product handling and sampling glovebox	2	16 h/day
230-C	Glovebox HC-60 hydrolysis (inactive)	1	4 h/day
232	HF scrubber cell (inactive)	0.5	1 h/day
233	RMA Line control room	0.1	8 h/day
234	Trash compactor	0.05	1 h/week

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
234-A	NDA Measurement of drums	0.1	4 h/week
235-A1	RMA oxide line (inactive)	5	1 h/week
235-A2	RMA oxide line (inactive)	15	1 h/week
235-A3	RMA oxide line (inactive)	30	1 h/week
235-B	Thermal stabilization furnace glovebox; process staging glovebox	1.5	8 h/day
235-C	Waste repackaging	1	8 h/day
235-D	Waste drum storage	0.3	4 h/week
236	PR can storage vault	8	2 h/week
245	Corridor	0.5	1/2 h/week
262	Duct level	0.1	4 h/day
263	Duct level	1.5	4 h/day
264	Duct level	1	4 h/day
308	Duct level	0.5	4 h/day
309	E-4 filter room	0.3	<1 d/yr
310	E-4 filter room	0.3	<1 d/yr
311	E-3 filter room	0.3	<1 d/yr
312	E-3 filter room	0.3	<1 d/yr
313	E-3 filter room	0.3	<1 d/yr
314	E-3 filter room	0.3	<1 d/yr
315	E-3 filter room	0.3	<1 d/yr
316	E-3 filter room	0.3	<1 d/yr
318	E-3 filter room	0.3	< 1 d/yr
320	Filterboxes	1	1 h/week
2736-ZB Building			
616	Women's changeroom	<0.05	3 h/day
622	Men's changeroom	<0.05	3 h/day
623	UPS room	<0.05	1/4 h/week
624	Corridor	0.1	1/2 h/week
625	Corridor	0.1	1/2 h/week

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
626	Janitor closet	<0.05	1/4 h/week
627	Women's restroom	<0.05	1/4 h/day
628	Men's restroom	<0.05	1/4 h/day
629	Matrix	<0.05	9 h/day
630	Decontamination room	<0.05	1/4 h/week
631	RC office	<0.05	8 h/day
632	Applied technology chemist's office	0.1	8 h/day
633	Corridor	<0.05	1/2 h/week
634	Shift manager	<0.05	8 h/day
635	Operator ready room	<0.05	2 h/day
636	Repacking glovebox	0.5	2 h/week
637	NDA laboratory	0.5	8 h/day
638	Packaging glovebox	1	6 h/week
639	Safety shower room	0.5	1/4 h/week
640	Supply storage	0.5	1/4 h/week
641	Receiving room	1.5	2 h/week
642	Shipping room	0.7	2 h/week
643	Personnel entry	<0.05	1/4 h/week
644	Material passageway	<0.05	1/4 h/week
236-Z Building			
10	Corridor/filterboxes	0.5	1 h/week
11	Corridor	2	1 h/week
12	Process cell	150	1 h/week
13	Corridor	3	1 h/week
14	Corridor	3	1 h/week
15	Welding shop	0.05	1 h/week
16	Maintenance shop (PRF)	0.05	1 h/week
17	Maintenance manager's office	0.05	1 h/week
18	Elevator access/storage	0.05	1 h/week
19	NDA counting room	0.3	1 h/week

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
20	Corridor/filterboxes	1	1 h/week
21	West corridor	2	1 h/week
25	East corridor	2	1 h/week
26	Filter room	0.2	1 h/week
27	Maintenance glovebox	2	1 h/week
30	Corridor	0.1	1 h/week
31	West corridor	0.2	1 h/week
33	East corridor	0.1	1 h/week
34	Instrument shop	0.05	1 h/week
35	Electrical room	0.05	1 h/week
36	Compressor room	0.05	1 h/week
37	Storageroom	<0.05	1 h/week
38	Restroom	<0.05	1 h/week
40	Chemical preparation	0.1	4 h/week
41	MT	4	1 h/day
42	Column room	1	1/4 h/day
43	S&E gloveboxes	0.5	1/4 h/day
44	Control room	0.05	1 h/week
45	Shift manager's office	<0.05	1 h/week
46	Shift engineer's office	<0.05	1 h/week
47	Corridor	0.5	1/4 h/day
50	Column glovebox	2	1/2 h/day
60	Column glovebox	1.5	1/2 h/day
291-Z Building			
500	Electrical room	<0.05	4 h/week
501	Compressor room	<0.05	4 h/week
502	Exhaust plenum	<0.05	0
509	Fan room	<0.05	2 h/week
232-Z Building			

Table 8-14. Area Occupancy Factors of Plant Radiation or Potential Radiation Areas. (7 sheets)

Room number	Operation/description	Normal field readings (mrem/h)	Area occupancy
Operating area	Storage	<0.05	1/2 h/week
Changeroom	Laundry (SWPs)	<0.05	2 h/day
Storage area	Used filters	<0.05	1/4 h/week
2736-Z Building			
1	Storage of product/recoverable plutonium materials	10	2 h/week
2	Lard can/cubicle plutonium materials storage	100	1 h/week
3	Storage of product/recoverable plutonium materials	10	2 h/day
4	Storage of product/recoverable plutonium materials	55	2 h/week
241-ZA Building			
Sumps	Sump tank waste storage	NA	1 h/month
241-Z Building	Ventilation/operating area	<0.05	1 h/month
241-ZA Building	Sampling glovebox	<0.05	1 h/month

Table 8-15. Summary of Annual Doses in the Plutonium Finishing Plant for Calendar Year 1995.

Dose from individual monthly dosimetry			
Functional group	Average whole body (rem*)	Total person-rm	Average number of personnel
Plutonium process support laboratory	0.23	2.28	10
Maintenance	0.04	2.33	56
Operations	0.12	16.95	147
RCTs	0.11	4.39	40
Safety	0.02	0.15	9
QA	0.01	0.10	8
Analytical lab	0.13	3.14	24
Engineering	0.02	1.19	63
Work Control	0.01	0.36	29
Annual Estimate		31	386

* Values are total of beta-gamma and neutron components.

Table 8-16. NOT USED

Table 8-17. Minimum Applicable American National Standards Used by the Plutonium Finishing Plant for Radiation Detection Instrumentation.

Instruments	ANS 8.3[a] (N16.2, N2.3)	N13.1	N13.3	N13.4	N13.5	N13.6	N13.15	N42.18	N317	N319	N320	N322	N323	N545
Count rate meters (GMX, PAMs, poppies, bench monitors, etc)				X		X			X				X	
Cutie pie and related units (Cp, LPC, XCP, HRCP,etc)				X		X			X				X	
Snoopy				X		X			X				X	
Air sample counter (canberra unit)						X			X				X	
CAMs (workplace)		X				X							X	
CAMs (effluent)		X				X		X			X		X	
Hanford standard dosimeter						X	X							X[b]
Hanford combination dosimeter						X	X		X					X[b]
Pocket dosimeters					X	X						X	X	
Criticality alarm system	X					X					X		X	
Nuclear accident dosimeters			X			X								
Personal nuclear accident dosimeters			X			X								

[a] Previous designation.
[b] The units used as environ monitors are modified versions of the asic + HMTD units.
[c] Only parts applicable to nuclear facilities implemented.

Table 8-18. Plutonium Finishing Plant Portable Radiation Monitoring Instruments. (2 sheets)

Name (nominal)	Detection type	Range	Minimum detectable energy (without β shield)[a]	Calibration		Linearity	Accuracy (as calibrated)
				Frequency	Method		
CP	Air-filled ionization	0-5,000 mrem/h	β≥65 keV Y≥5 keV	Annual	Uniform field ^{137}Cs	±5	+10% -5
LPC	Air-filled ionization	0-5,000	β≥0.3 keV Y≥5 keV	Annual	Uniform field ^{137}Cs	+10 -5	+10% -5
EGM	Pancake GM	0-100,000 counts/min	β≥70 keV Y≥5 keV	Annual	^{14}C ^{90}Sr-^{36}Cl Y, ^{230}Th	±5	N/A
PAM	ZnS Scintillation	0-100,000 counts/min	α±4 Mev[a]	Annual	^{230}Th	±5	N/A
XCP	Air-filled ionization	0-5,000 mrem/h	β±70 keV Y≥5 keV	Annual	Uniform field ^{137}Cs	±5	+10 -5
Bumble bee	Air-filled ionization	0-5,000 mrem/h	β≥65 keV Y≥5 keV	Annual	Uniform field ^{137}Cs, ^{230}Th, U_{pat}	±5	+10% -5
Snoopy	BF^3 Proportional	0-2,000 mrem/h	Neutrons thermal to 15 Mev[a]	Quarterly	^{252}CF source ^{60}Co	±10	+10% -5
Ludlum 177-8	Pancake GM	0-500,000 counts/min	β≥70 keV Y≥5 keV	Annual	^{14}C ^{36}Cl, ^{90}Sr-^{36}Y, ^{230}Th	±2	N/A
Poppy	Air-filled proportional	0-500,000 counts/min	α≥4 Mev[a]	Annual	^{230}Th ^{239}Pu	±1.5	N/A
HRCP	Air-filled ionization	0-50,000 rem/h	β±44 keV Y≥5 keV	Annual	Uniform field ^{137}Cs and ^{60}Co	±10	+10% -5

Table 8-18. Plutonium Finishing Plant Portable Radiation Monitoring Instruments.
(2 sheets)

Name (nominal)	Detection type	Range	Minimum detectable energy (without β shield)[a]	Calibration		Linearity	Accuracy (as calibrated)
				Frequency	Method		
Alpha CAM (Eberline Alpha-5)	Silicon diffused junction	1-10,000 counts/min	α≥1.5 MeV	Annual	^{239}Pu	±10	±15%

Source: PNL-MA-562 (PNL 1988c).
[a]Where applicable.
[b]NIST (formerly NBS) traceable.
[c]Designed to 8 DAC-h for ^{239}Pu (achievable under laboratory conditions) but these are the practical field use values.
α = Alpha.
β = Beta.
γ = Gamma.

Table 8-19. Respiratory Protection Factors.

Respirator type	Protection factor
Full-face mask	100
Duo flow, air purifying	100
Powered air purifying	1,000
Duo flow, supplied air	1,000
Consistent flow without egress air	1,000
Pressure demand air line	1,000
Content flow hood	1,000
Pressure demand air line with egress air	10,000
SCBA	10,000

Table 8-20. Not Used

Table 8-21. Notification Criteria for PFP.

Criteria for Notifying Radiological Central Standards Group		
Indicator	Alpha Emitters (dpm)	Beta/Gamma Emitters (dpm)
Nasal or Mouth smears	>BKG	>BKG
Facial contamination[b]	>200	>4,000
Head/neck contamination	>2,000	>40,000
Contamination Inside Respirator	>DL	
Airborne contamination	Acute exposure >10 DAC-hours[b] (after incorporating respiratory protection factor)	
Hands, Forearms, clothing[a] (spotty, loose)	>10,000	>200,000

(a) Clothing contamination levels apply to exposure without respiratory protection, such as contamination levels on inner coveralls while undressing.

(b) DAC-hours = time-integrated exposure to airborne contamination.

Criteria for Notification to Medical (First Aid or HEHF Physician)		
Indicator	Alpha Emitters (dpm)	Beta/Gamma Emitters (dpm)
Nasal or Mouth Smears	>1,000	>100,000
Facial contamination	>25,000	>500,000
Head/neck contamination	>100	>20,000

NOTE; HEHF EMERGENCY CONTACT, FDH Radiation Protection Central Standards Group, PNNL Exposure Evaluator AND PATROL OPERATIONS CENTER.

Table 8-22. Not Used

Table 8-23. Offsite Doses for Ground and Stack Level Releases from PFP Based on Annual $\overline{\chi}/Q$'s (Chronic release).

Release type	EDE		Maximum Organ[a]
Maximum individual			
Ground level	3.0 E-08 rem		5.5 E-07 rem
Stack level	1.0 E-06 rem		1.9 E-05 rem
Population	Unit in person-rem	Health effect	Unit in person-rem
Ground level	8.0 E-04	4.0 E-07 LCF[b]	1.5 E-02
Stack level	4.4 E-02	2.2 E-05 LCF[b]	8.2 E-01

[a]The maximum organ for all cases is the bone surface.
[b]Latent cancer fatality.

Figure 8-1. Containers for Packaging Plutonium.

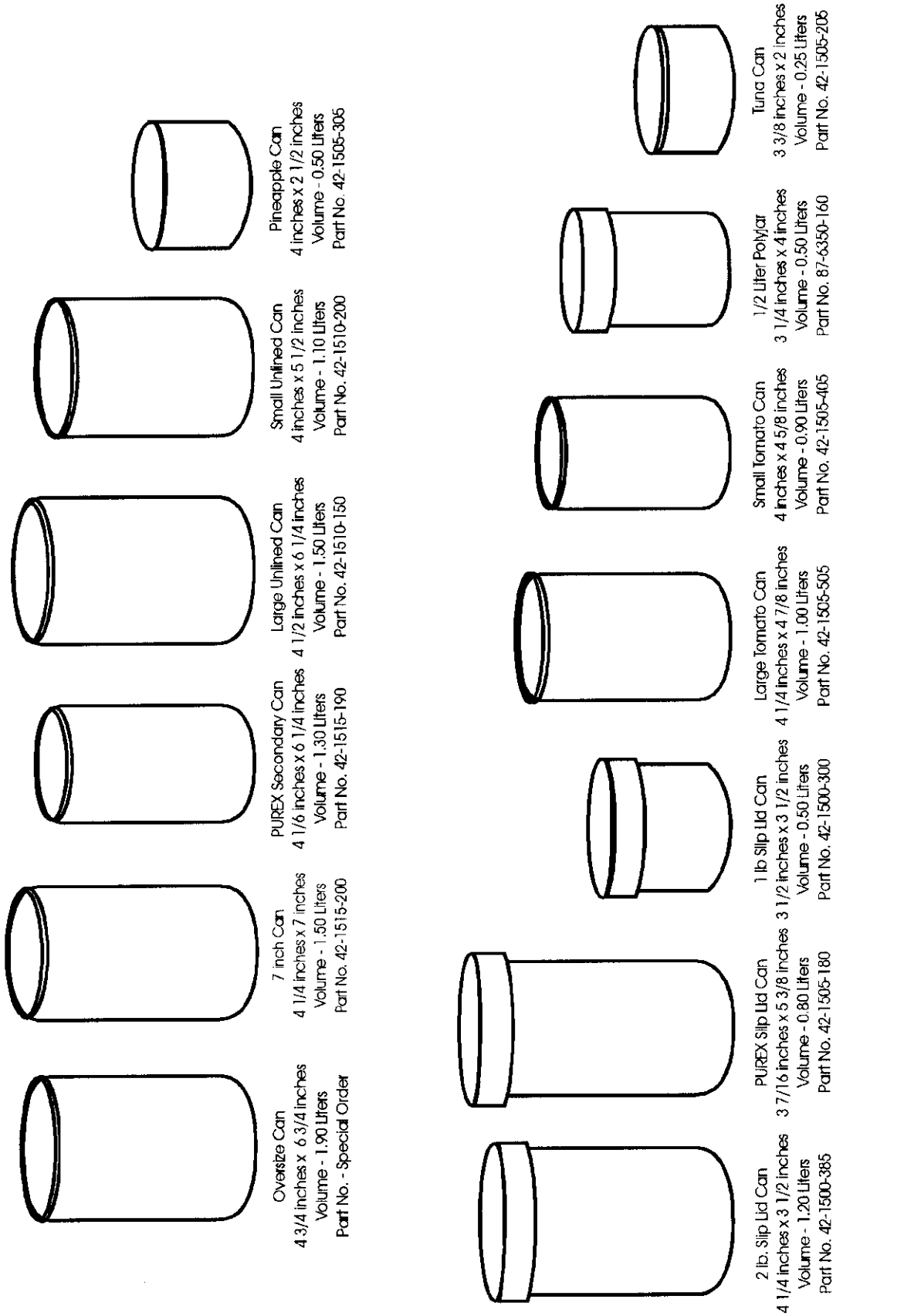


Figure 8-2. U.S. Department of Transportation 6M Shipping Container.

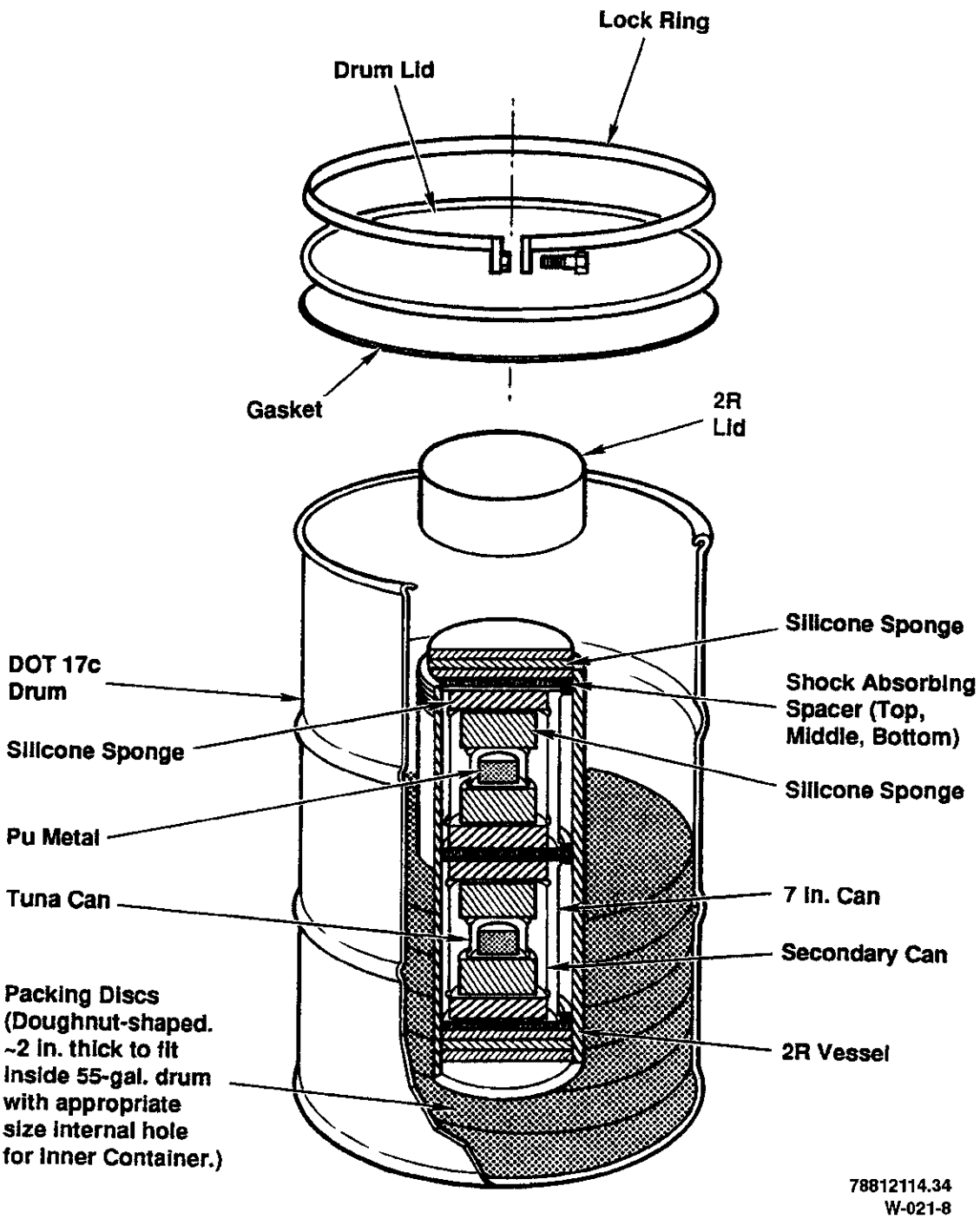


Figure 8-3. Typical Product Receiver Can Assembly.

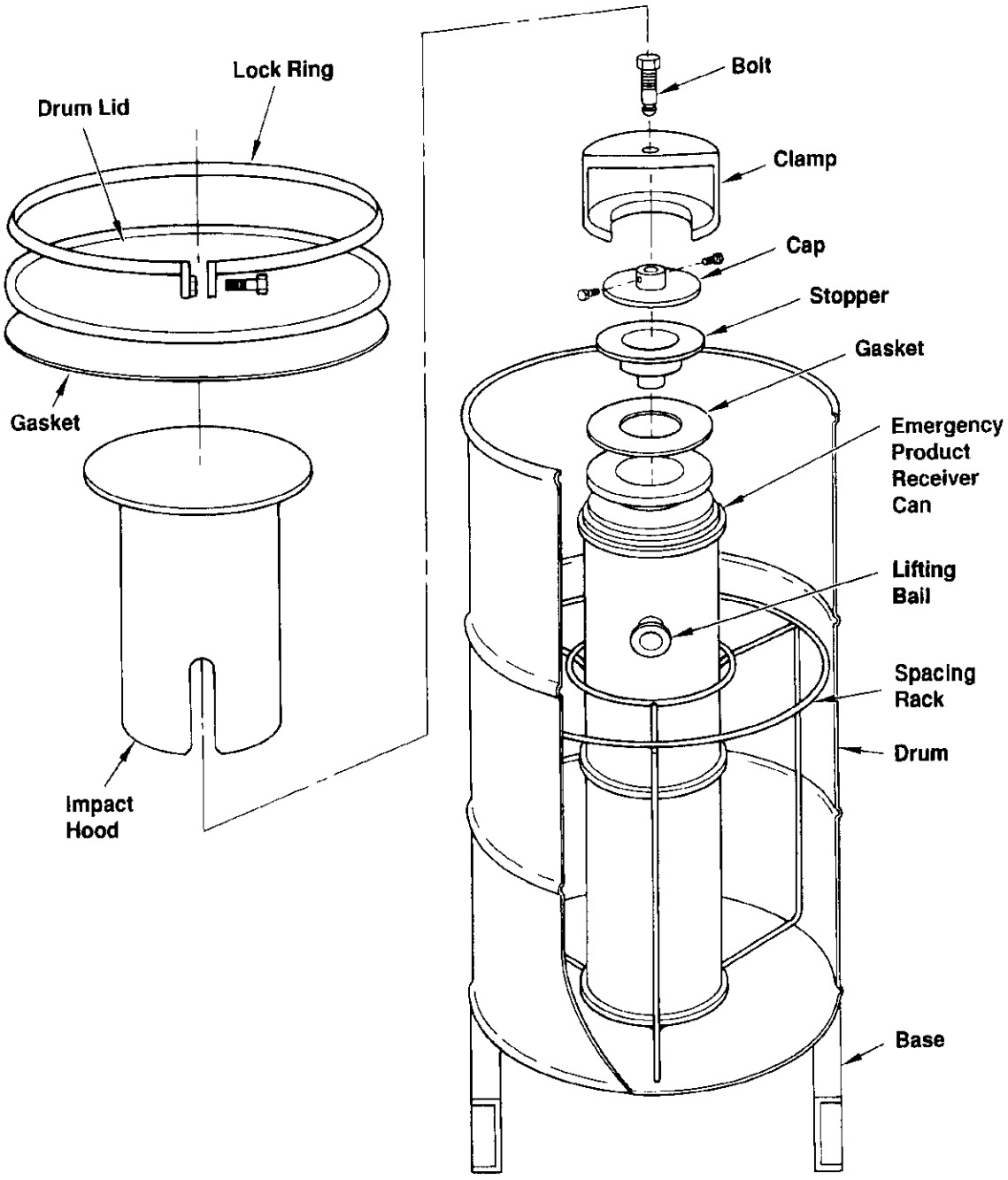


Figure 8-4. Plutonium Reclamation Facility Shielding Design.

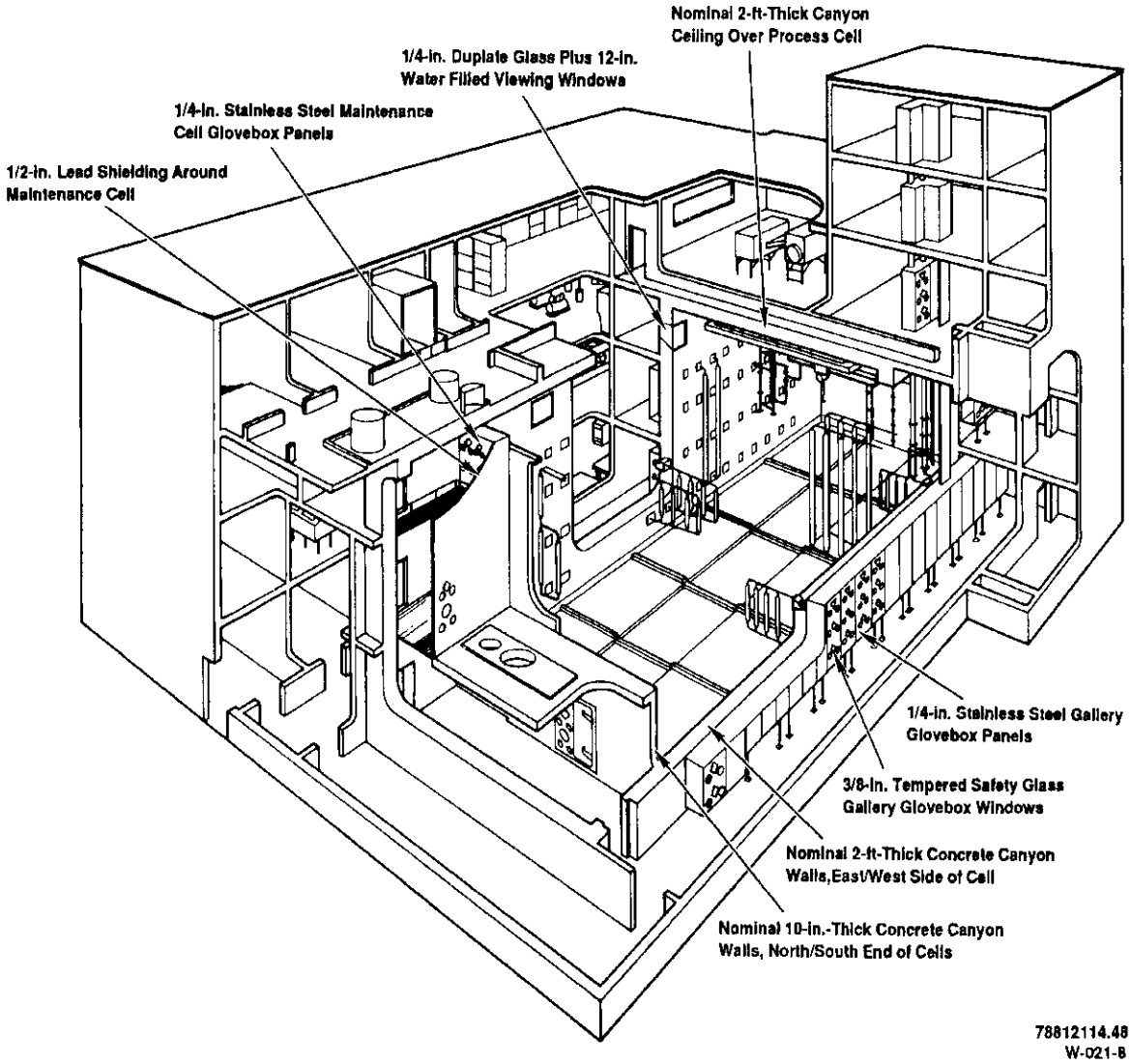


Figure 8-5. Repackaging Glovebox.

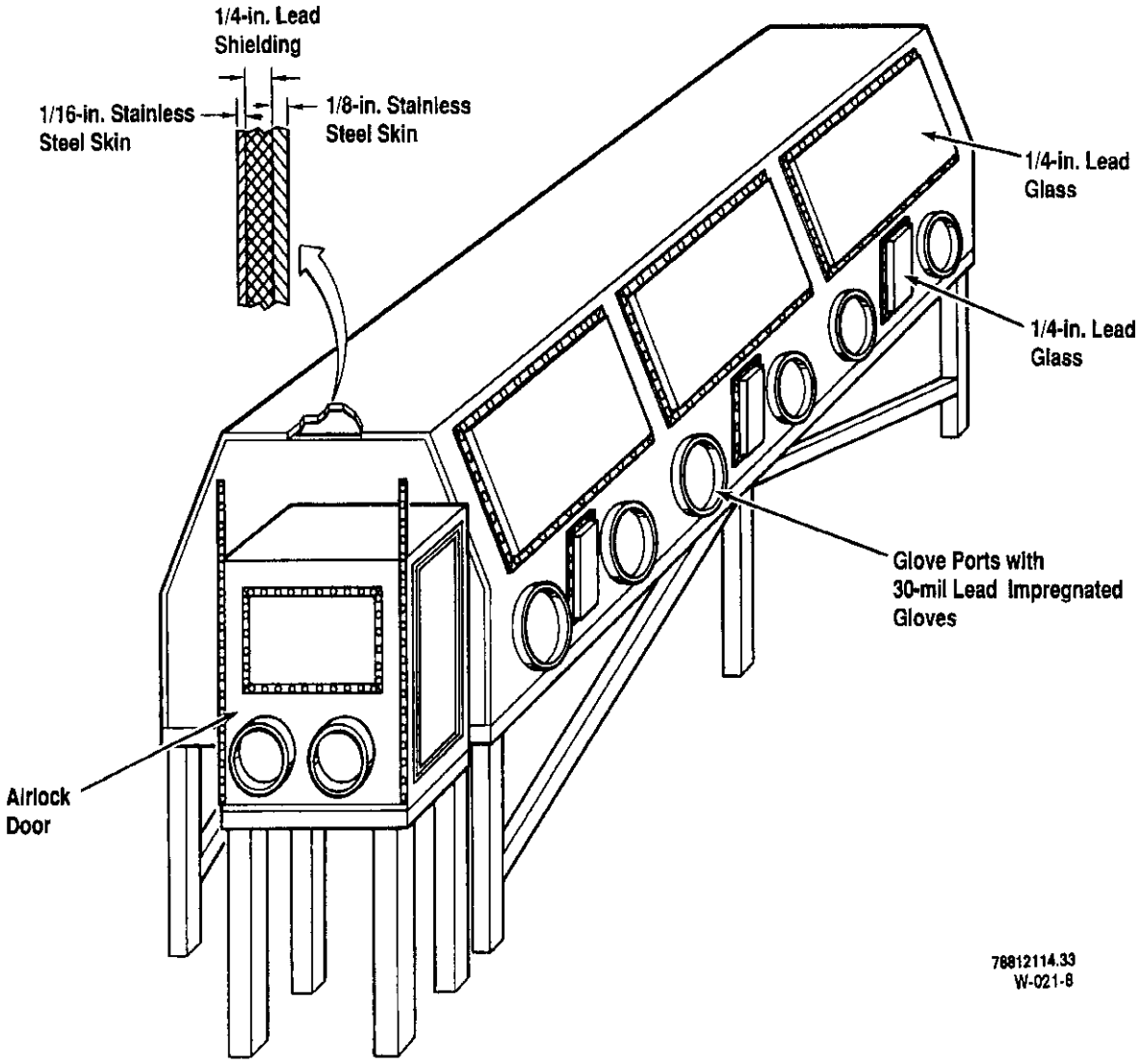
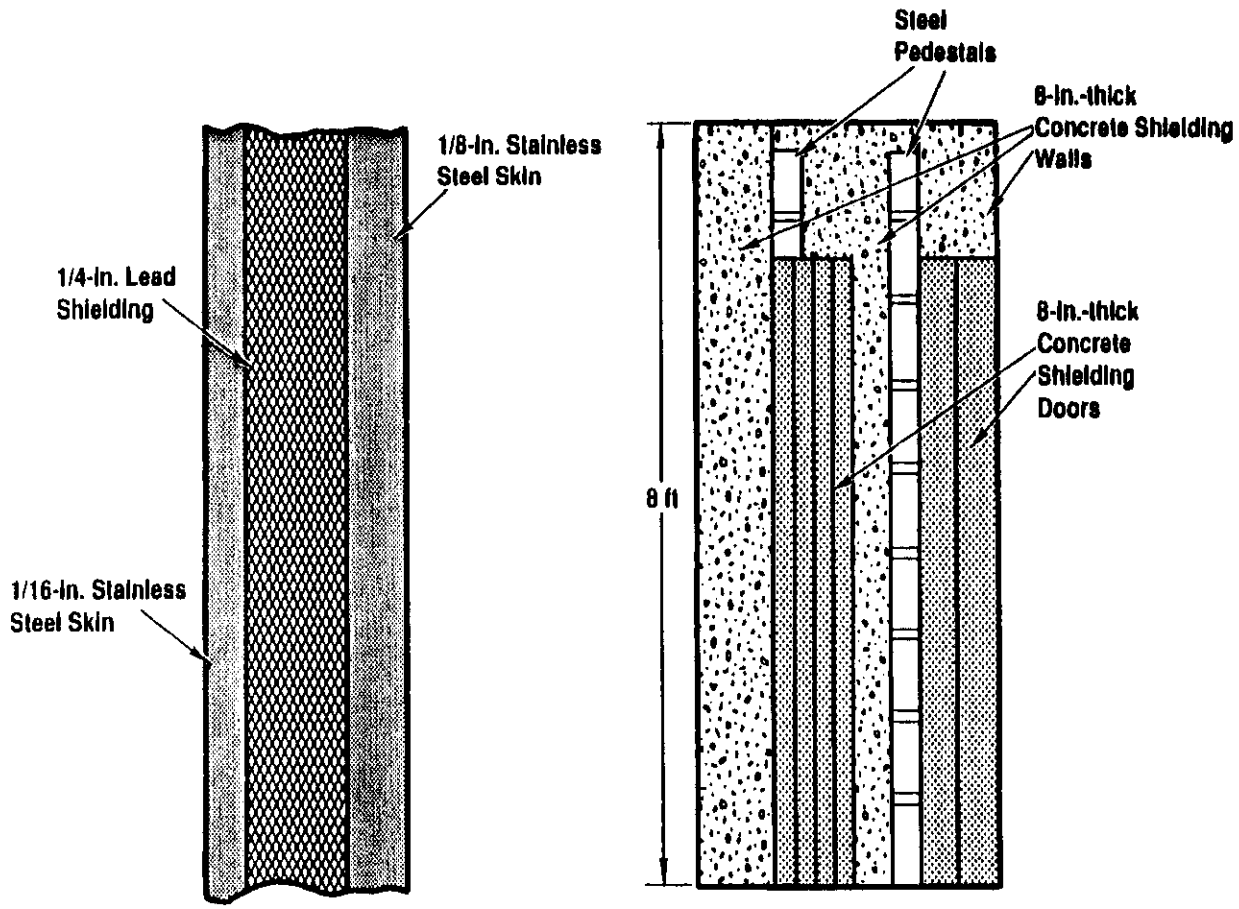


Figure 8-6. Not Used

Figure 8-7. Examples of Shield Wall Thickness in 2736-ZB and Other Plutonium Storage Facilities.



1/4-in. lead shielding enclosed between two smooth stainless steel layers on the repackaging glovebox in 2736-ZB

8-in.-thick concrete shielding used for shielding cans of radioactive materials in storage cubicles. Pedestals with cans of material are surrounded by the concrete shielding. The doors are made of concrete 8-in.-thick.

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Figure 8-8. Not Used

Figure 8-9. Not Used

Figure 8-10. Not Used

Figure 8-11. Not Used

Figure 8-12. Not Used

Figure 8-13. Continuous Air Monitoring System
(3 sheets)

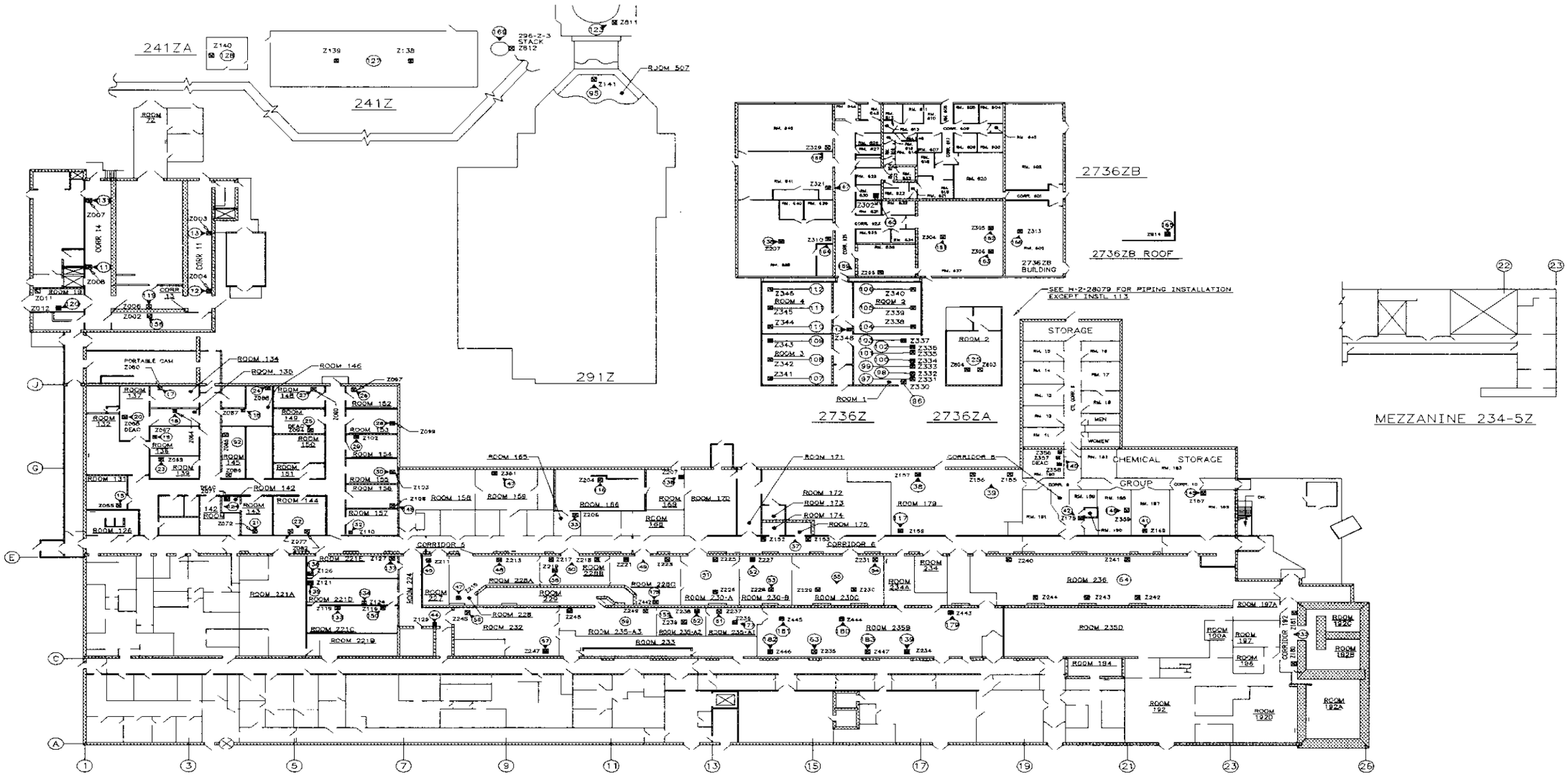


Figure 8-13. Continuous Air Monitoring System
(3 sheets)

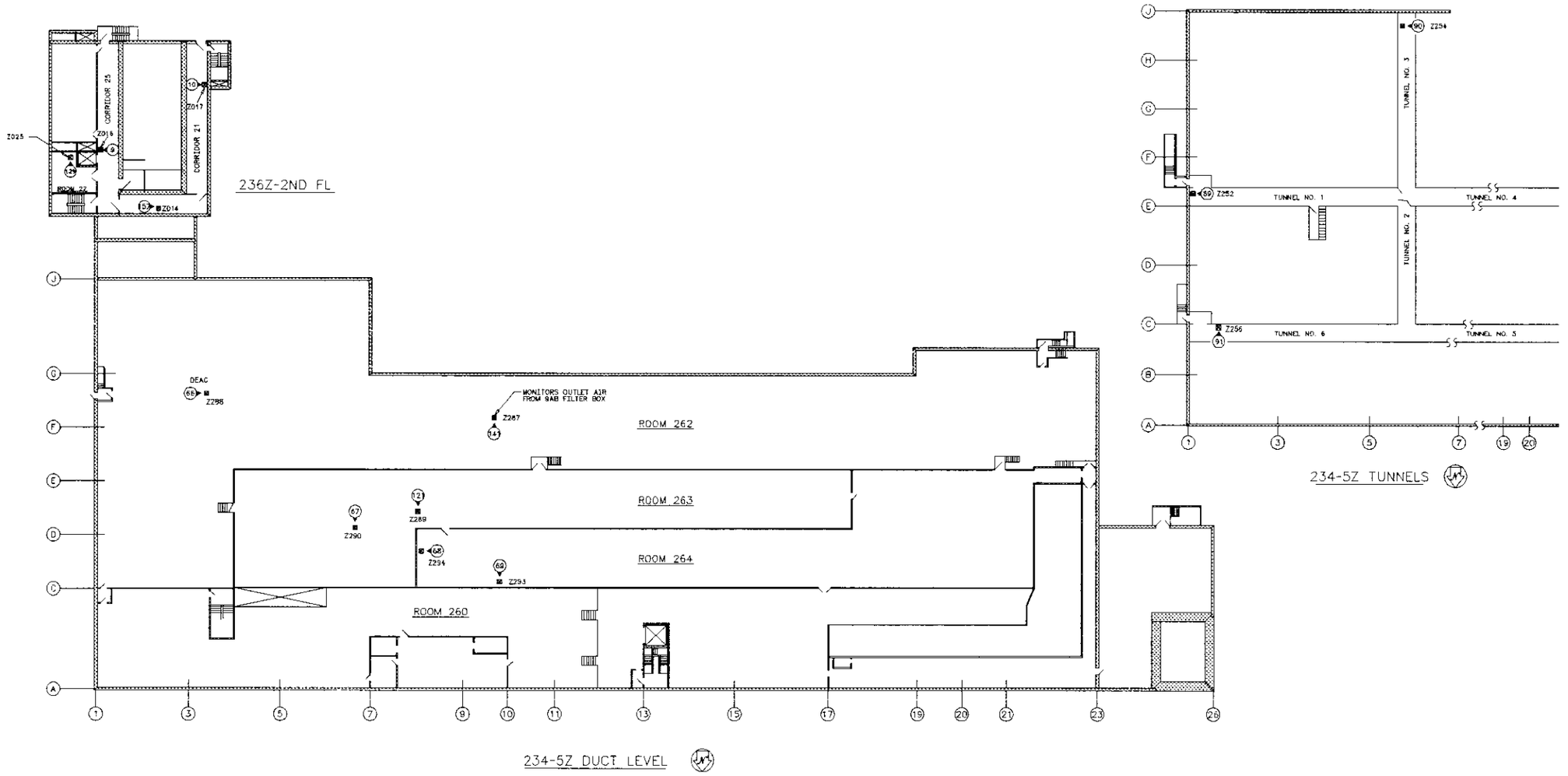
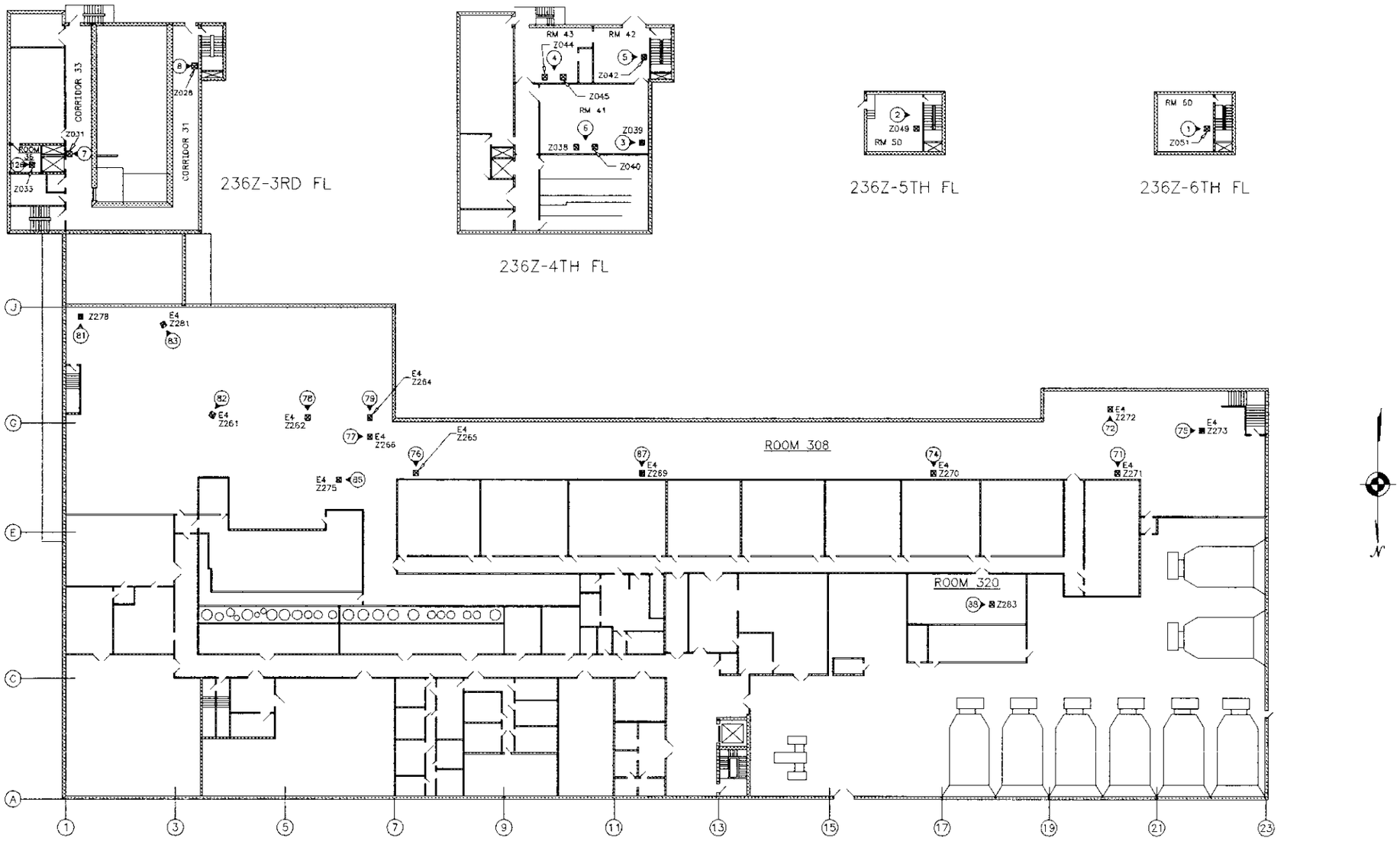


Figure 8-13. Continuous Air Monitoring System
(3 sheets)



2ND FL 234-5Z; 3RD, 4TH, 5TH & 6TH FL 236Z

Figure 8-14. Survey Instrumentation/Emergency Equipment.
(Sheet 1 of 5)

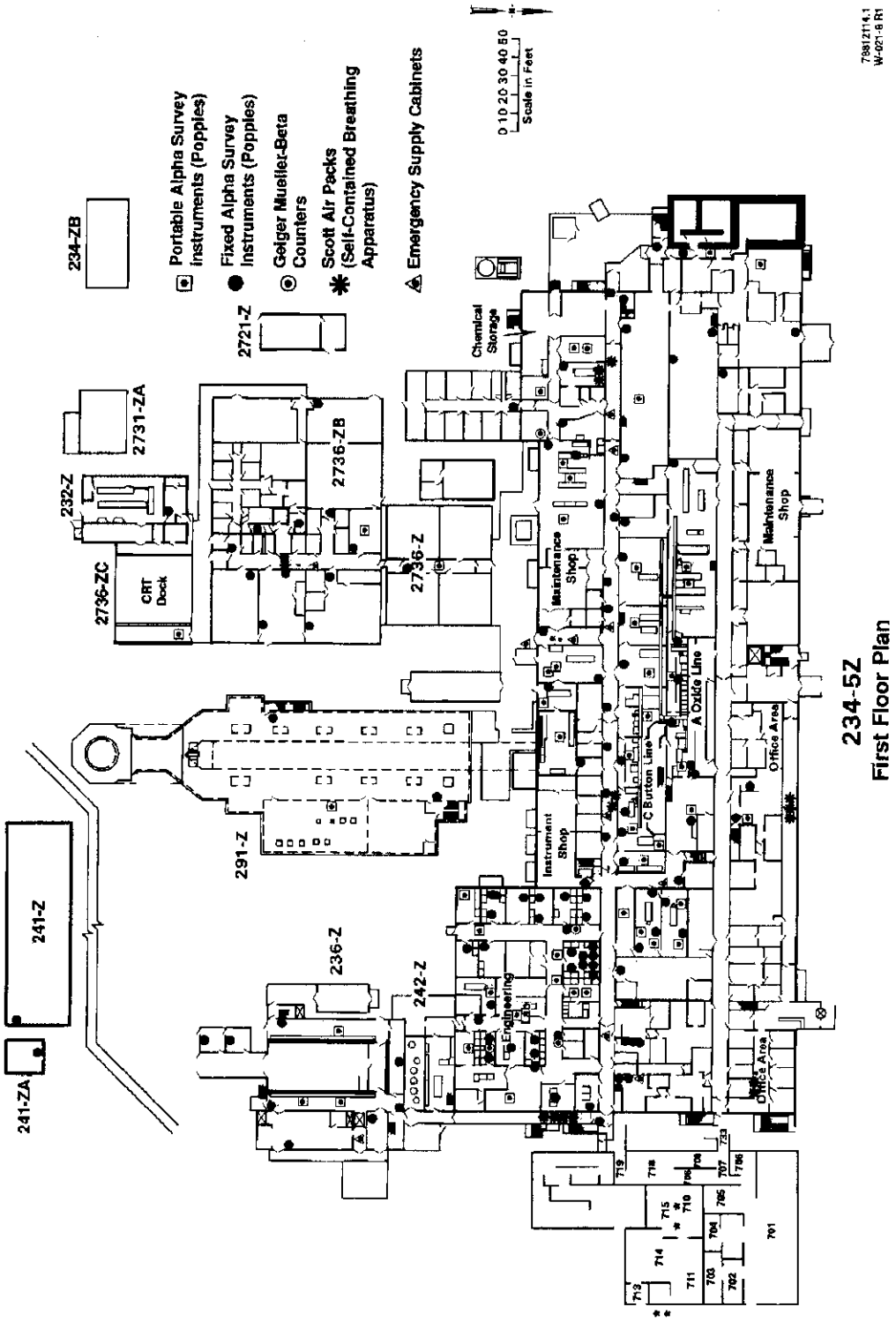


Figure 8-14. Survey Instrumentation/Emergency Equipment.
(Sheet 2 of 5)

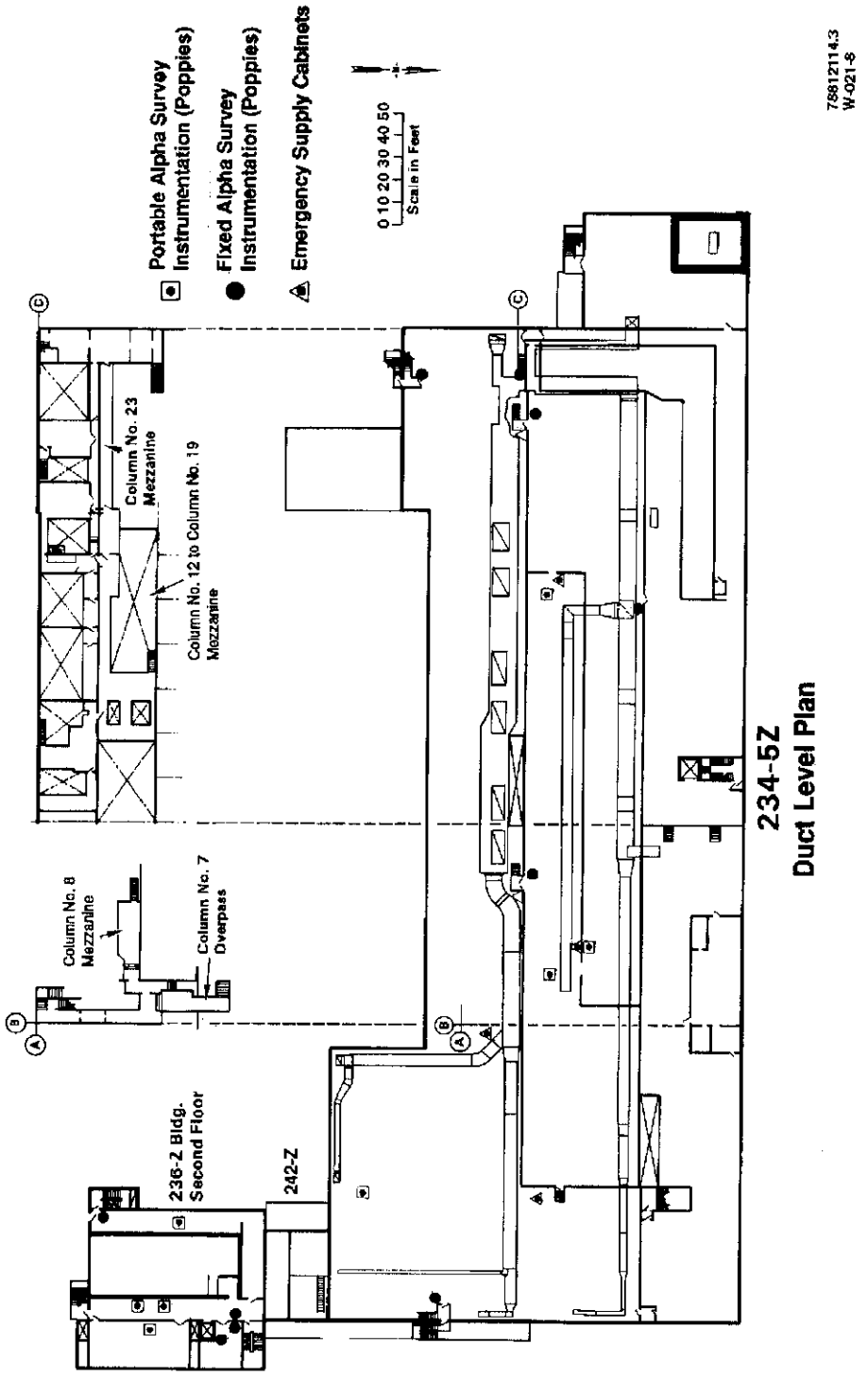


Figure 8-14. Survey Instrumentation/Emergency Equipment.
(Sheet 3 of 5)

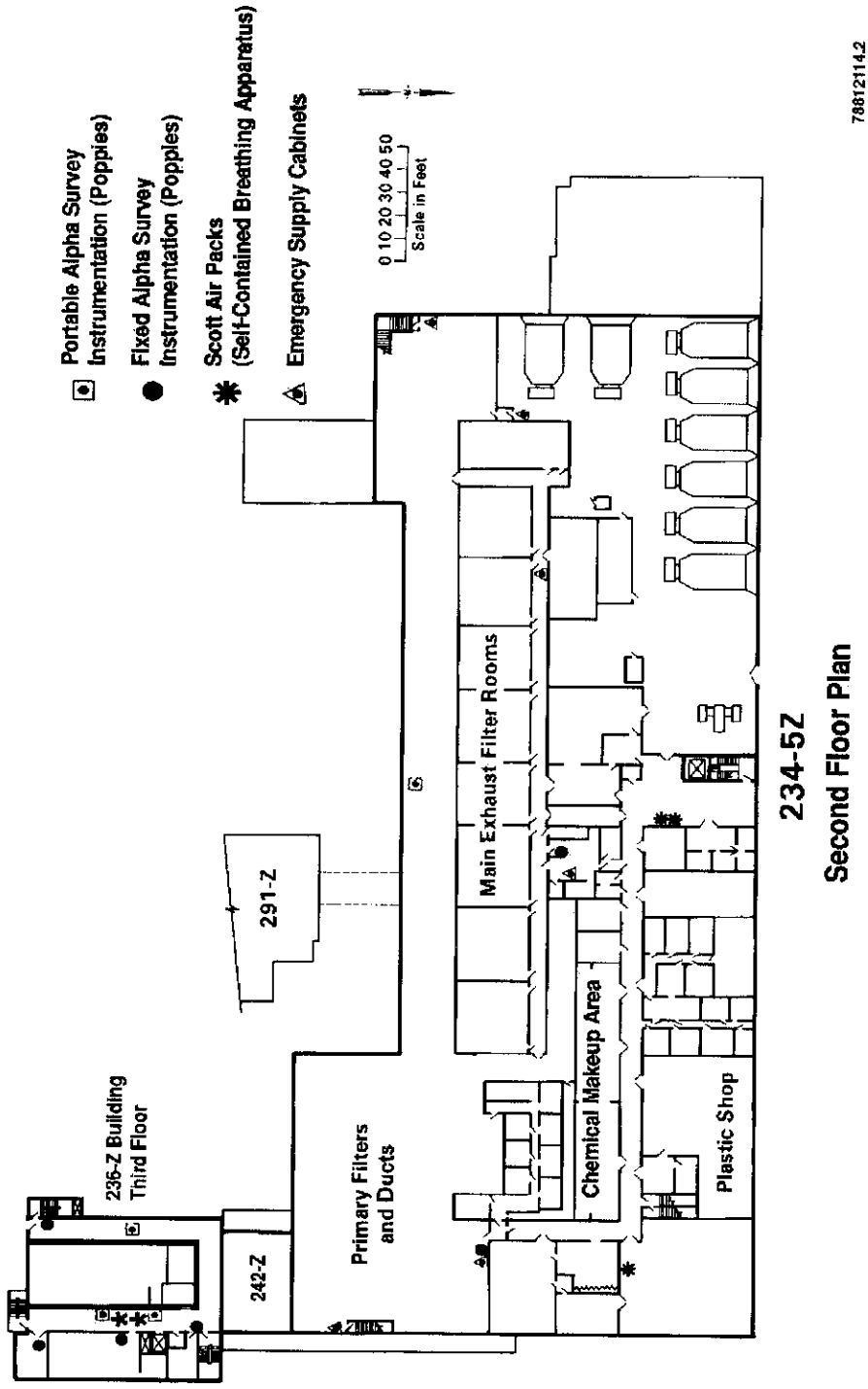


Figure 8-14. Survey Instrumentation/Emergency Equipment.
(Sheet 4 of 5)

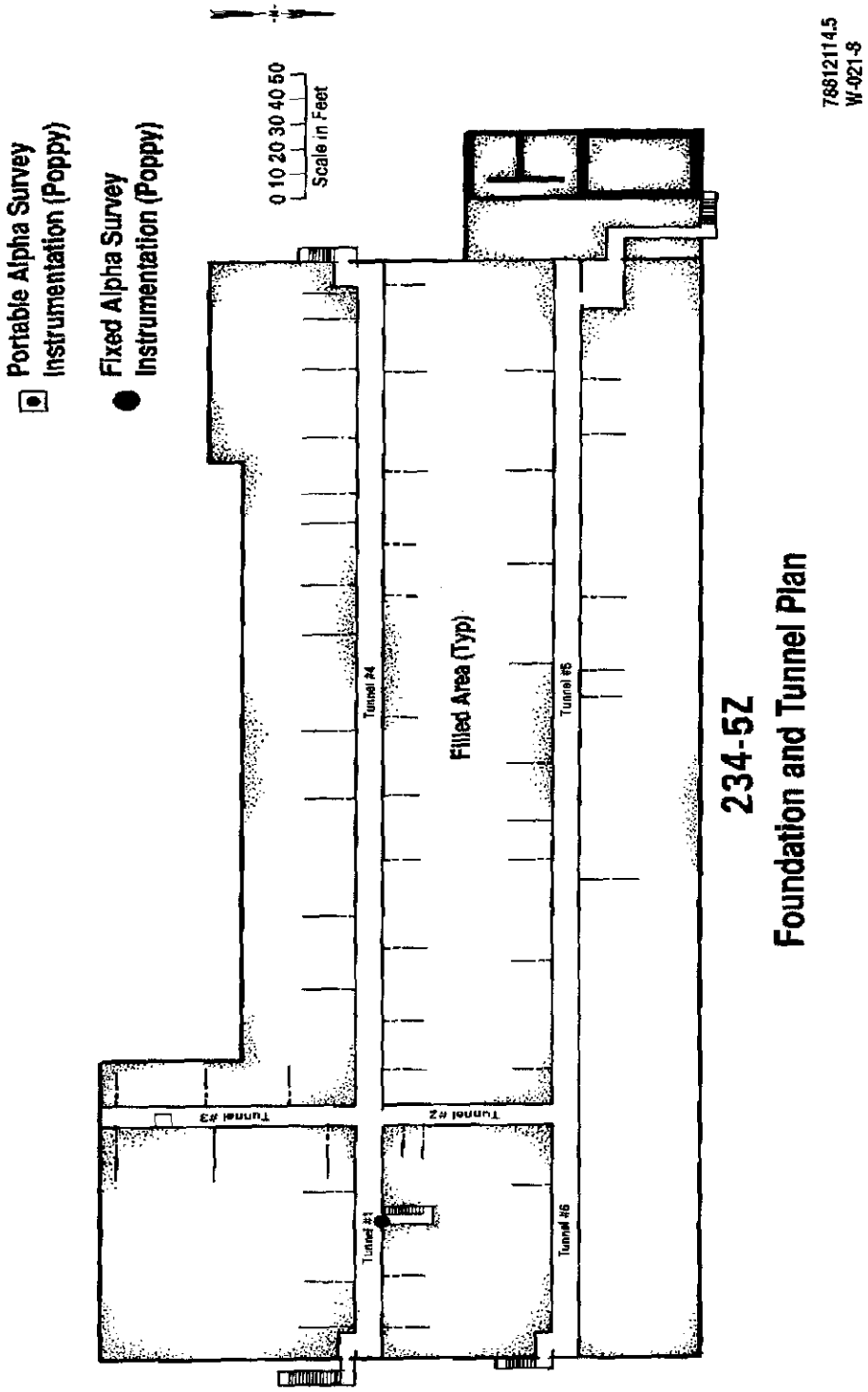


Figure 8-14. Survey Instrumentation/Emergency Equipment.
(Sheet 5 of 5)

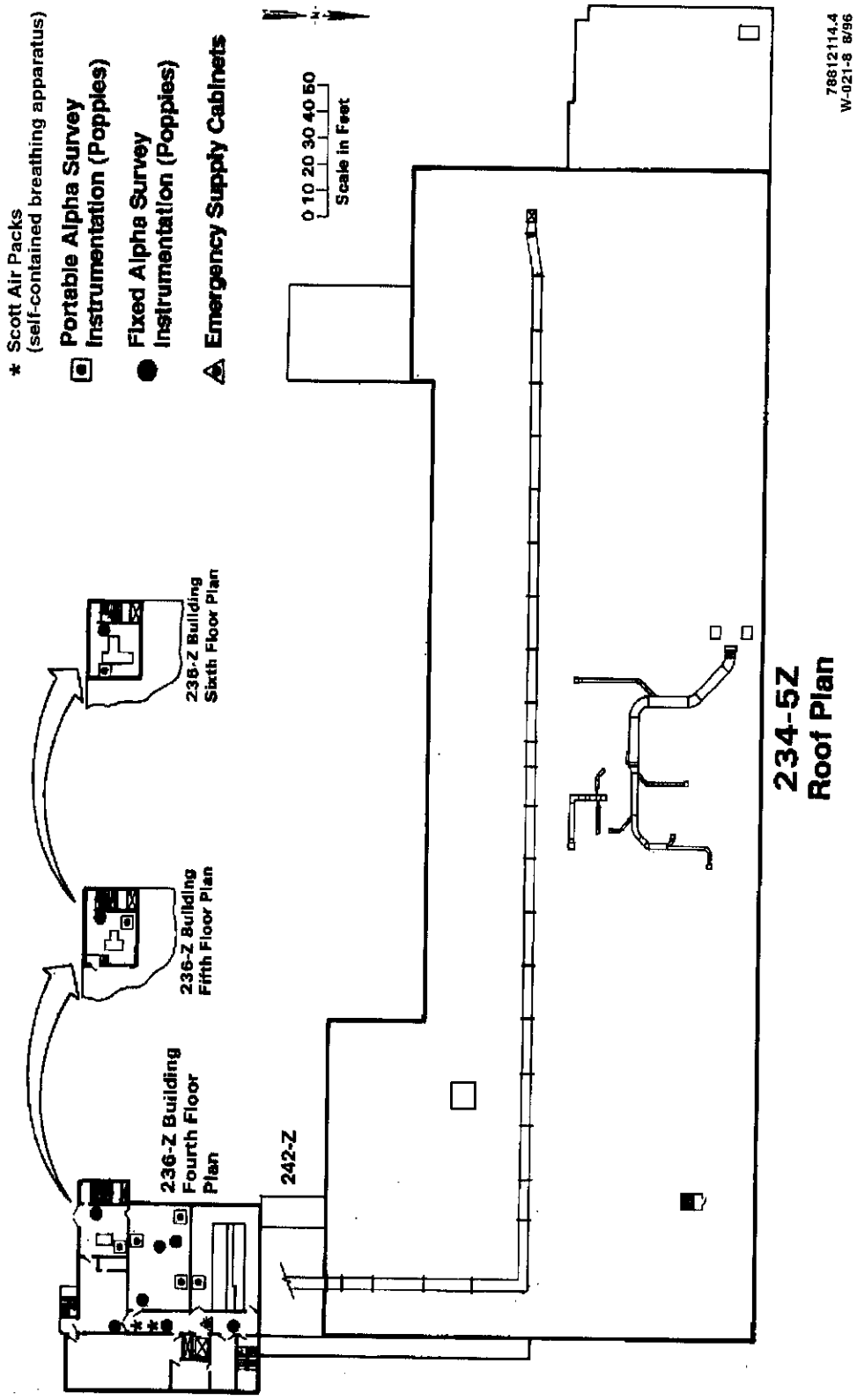


Figure 8-15. The 2736-Z Building Overview and Vault Storage Shielding.

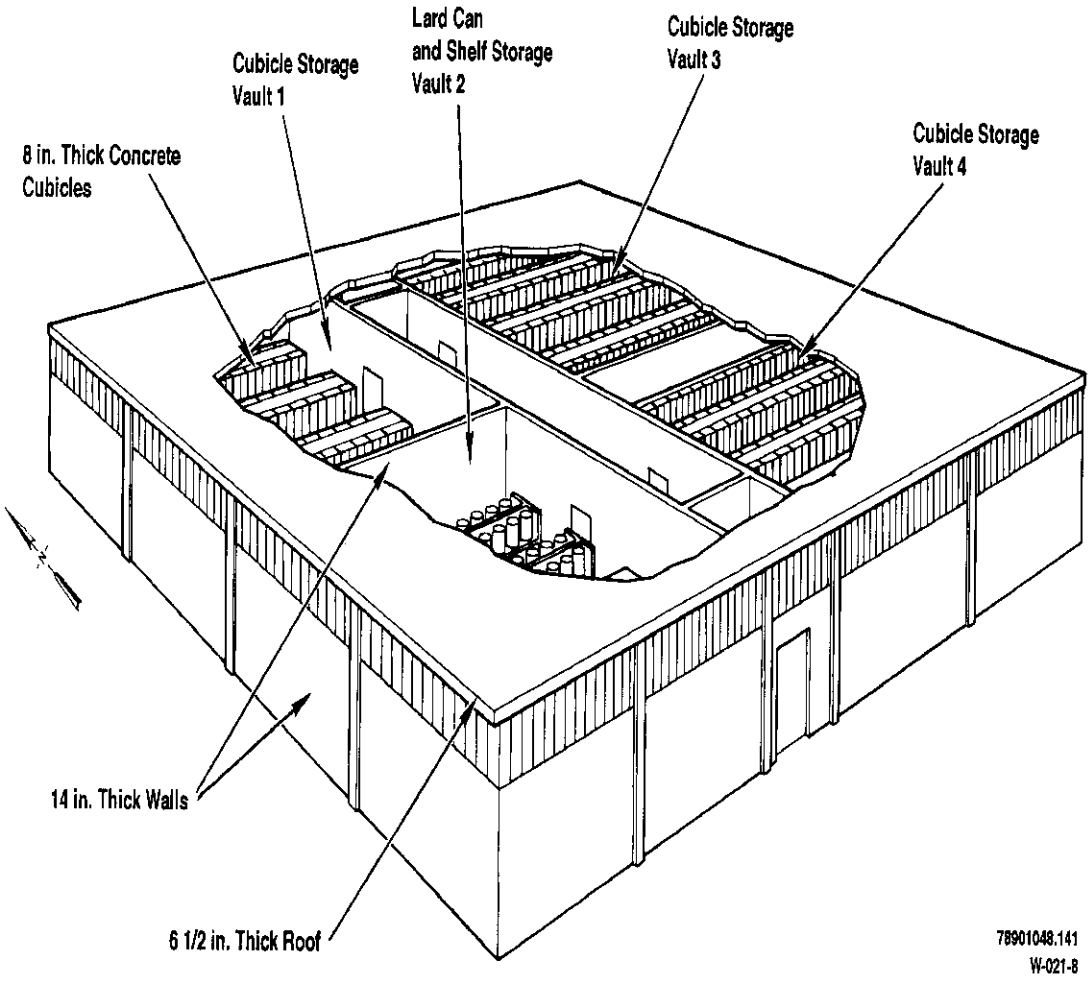


Figure 8-16. Example Building 2736-Z Vault 1 Field Dose Rate and Cubicle Readings.

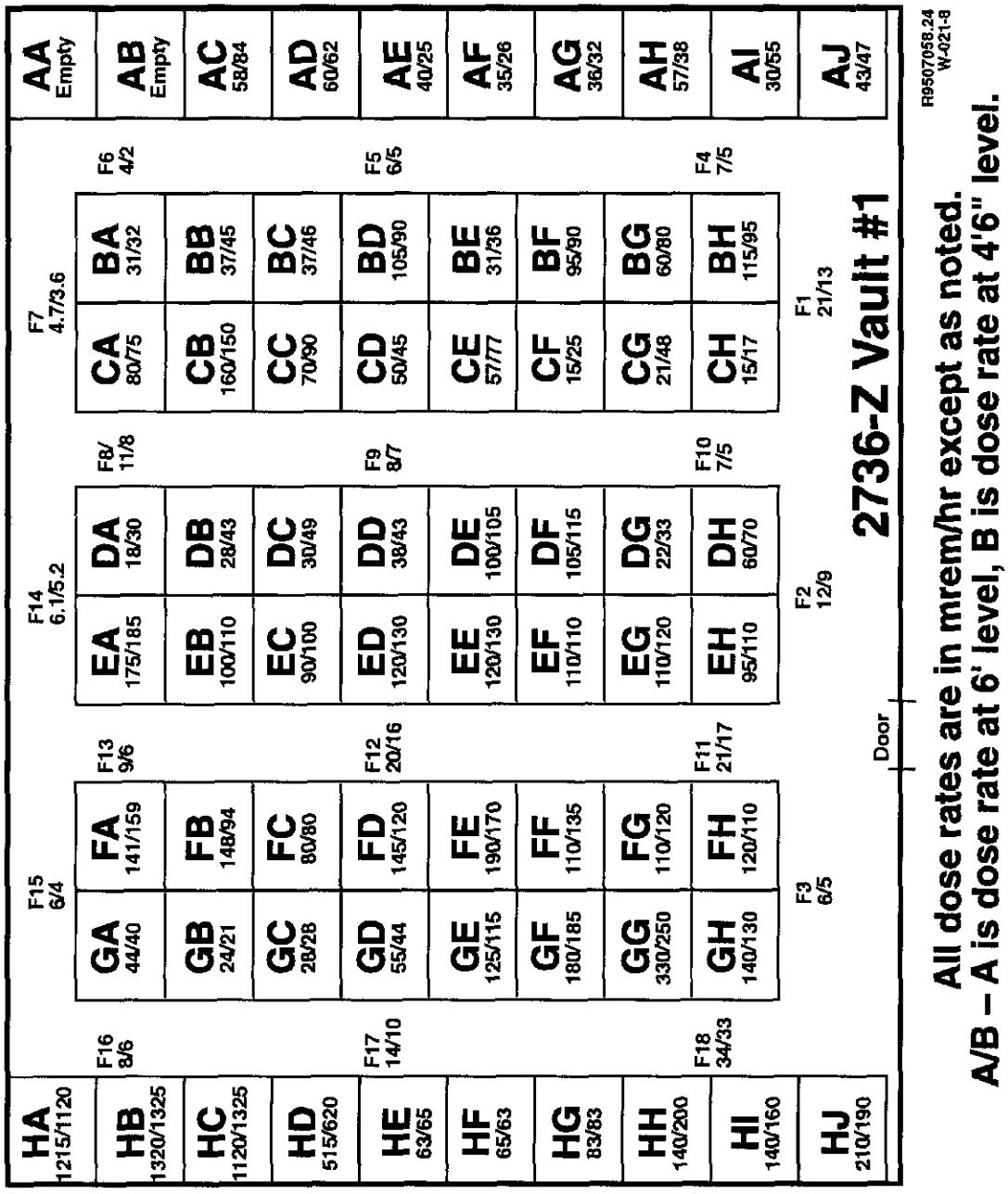


Figure 8-17. Not Used

Figure 8-18. Not Used

Figure 8-19. Not Used

Figure 8-20. Typical Fixed-Array Wagon.

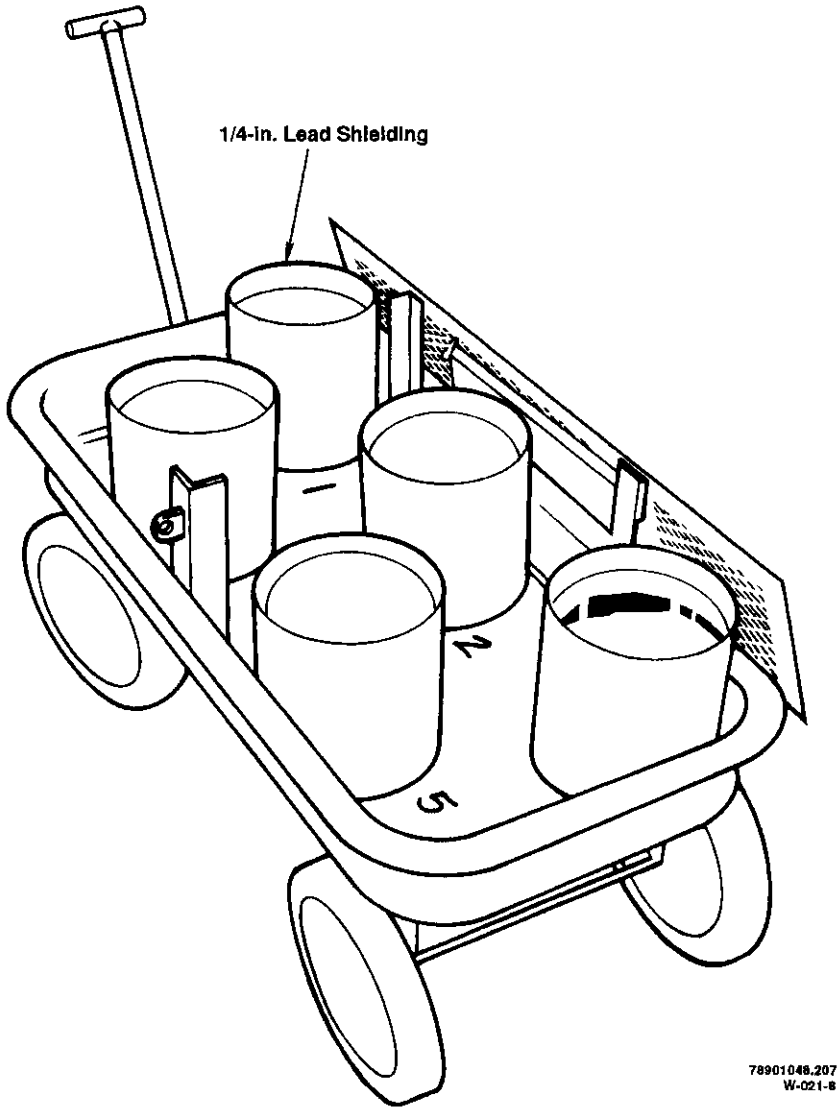


Figure 8-21. Mettler Balance with Lead Glass Shielding.

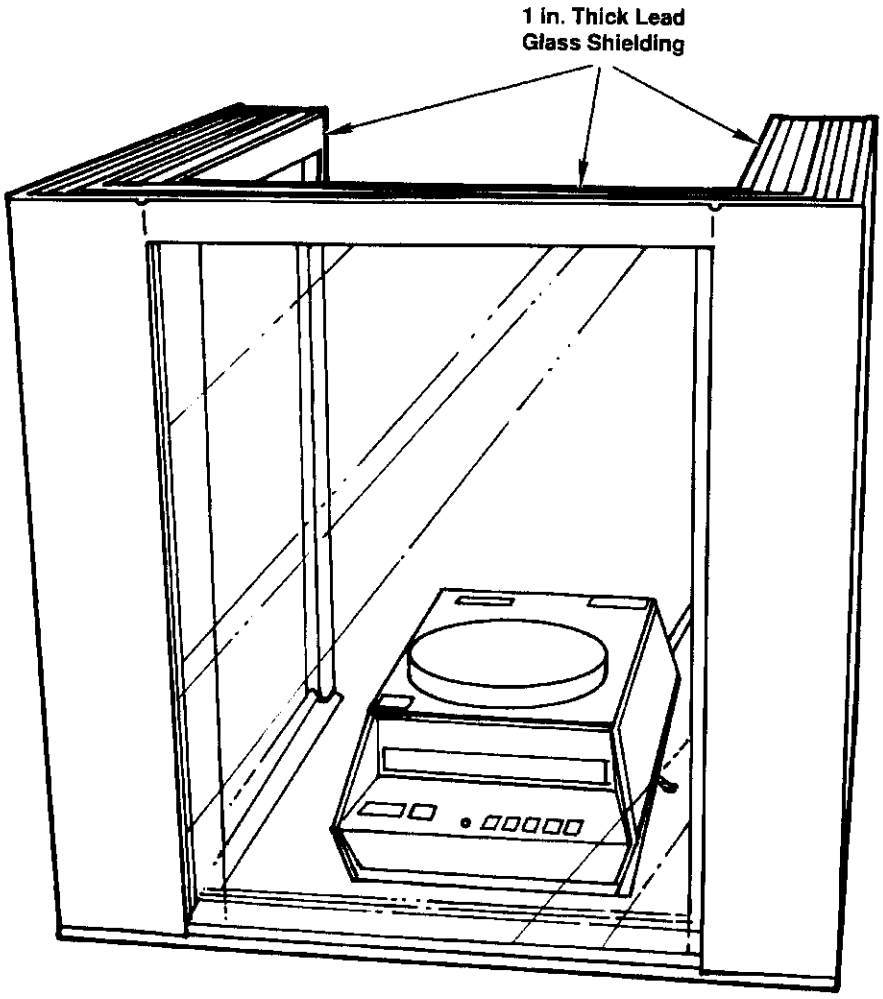


Figure 8-22. Criticality Alarm Panel.

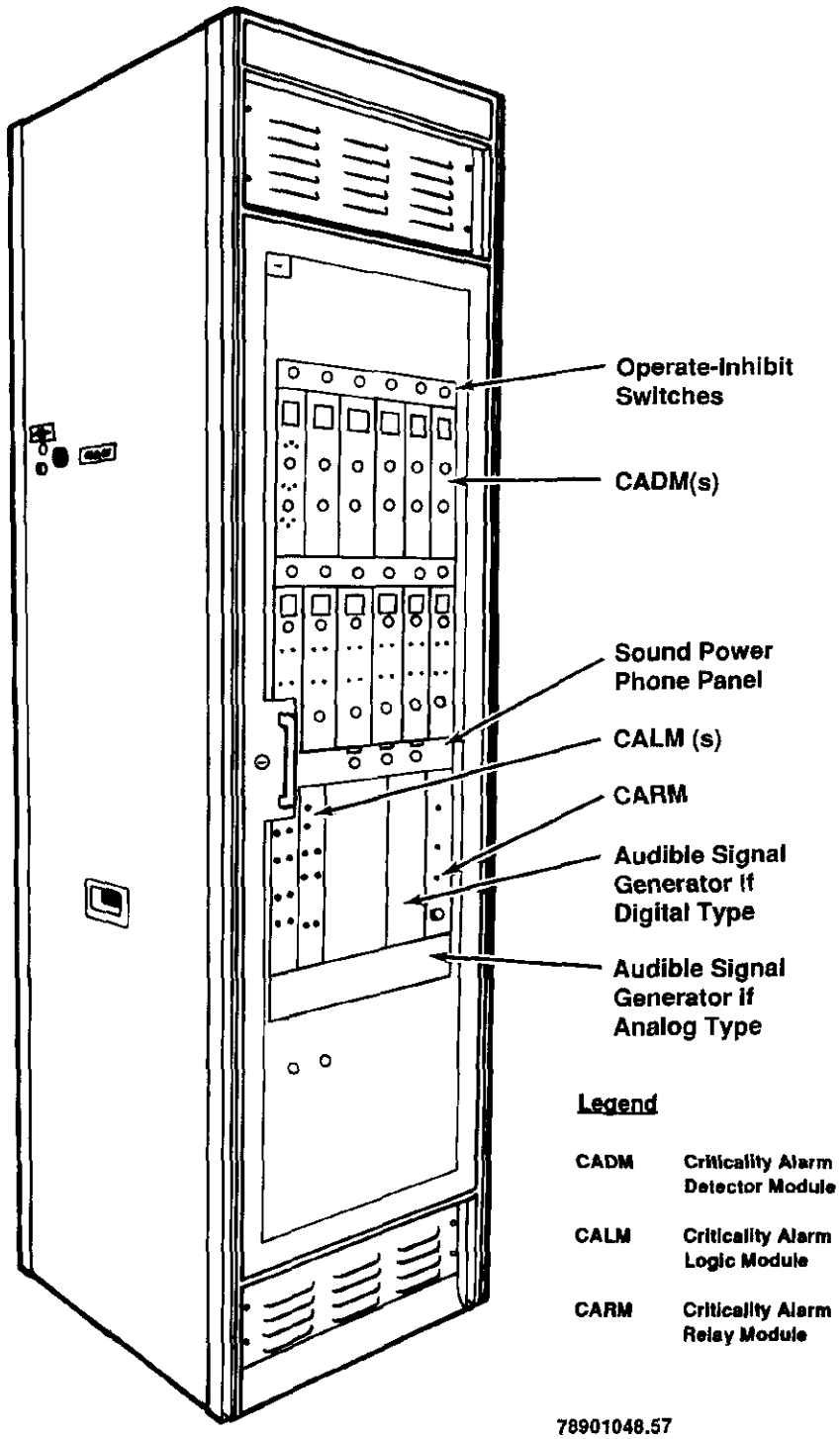


Figure 8-23. Criticality Alarm Detector on Mounting Assembly (Side View).

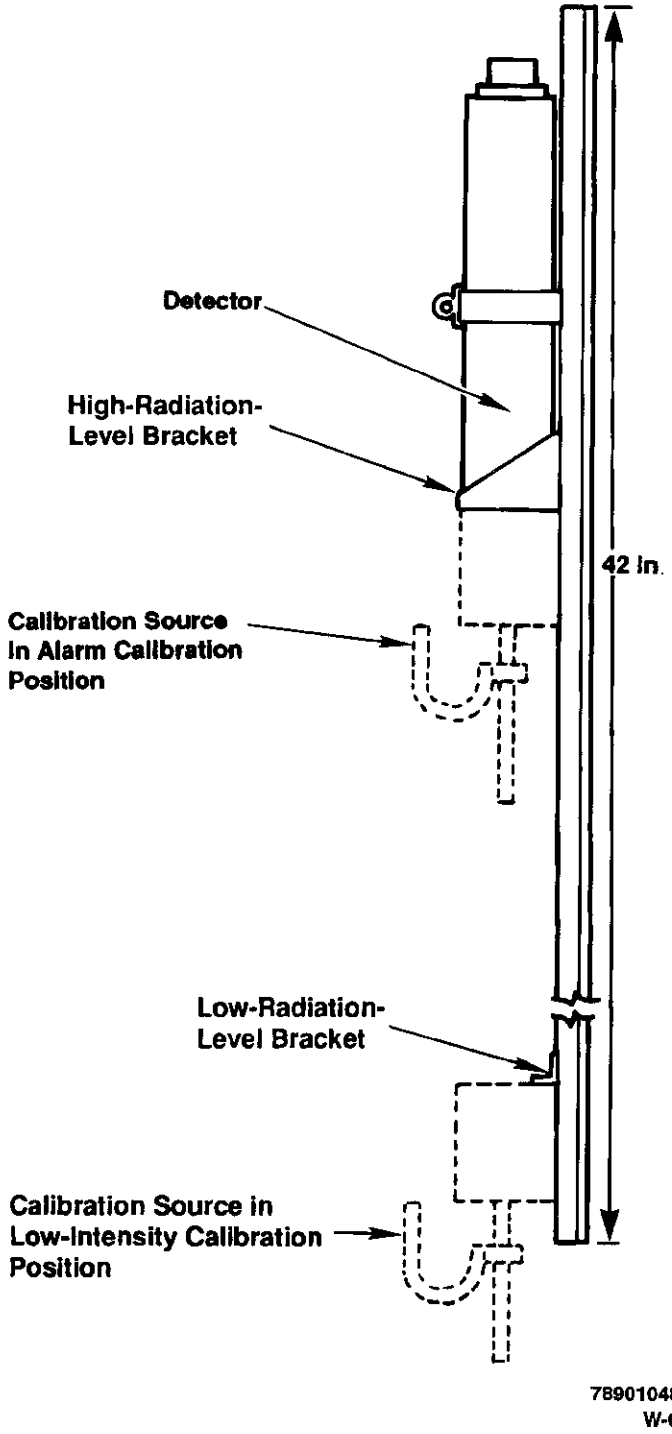


Figure 8-24. Criticality Alarm Detector Module.

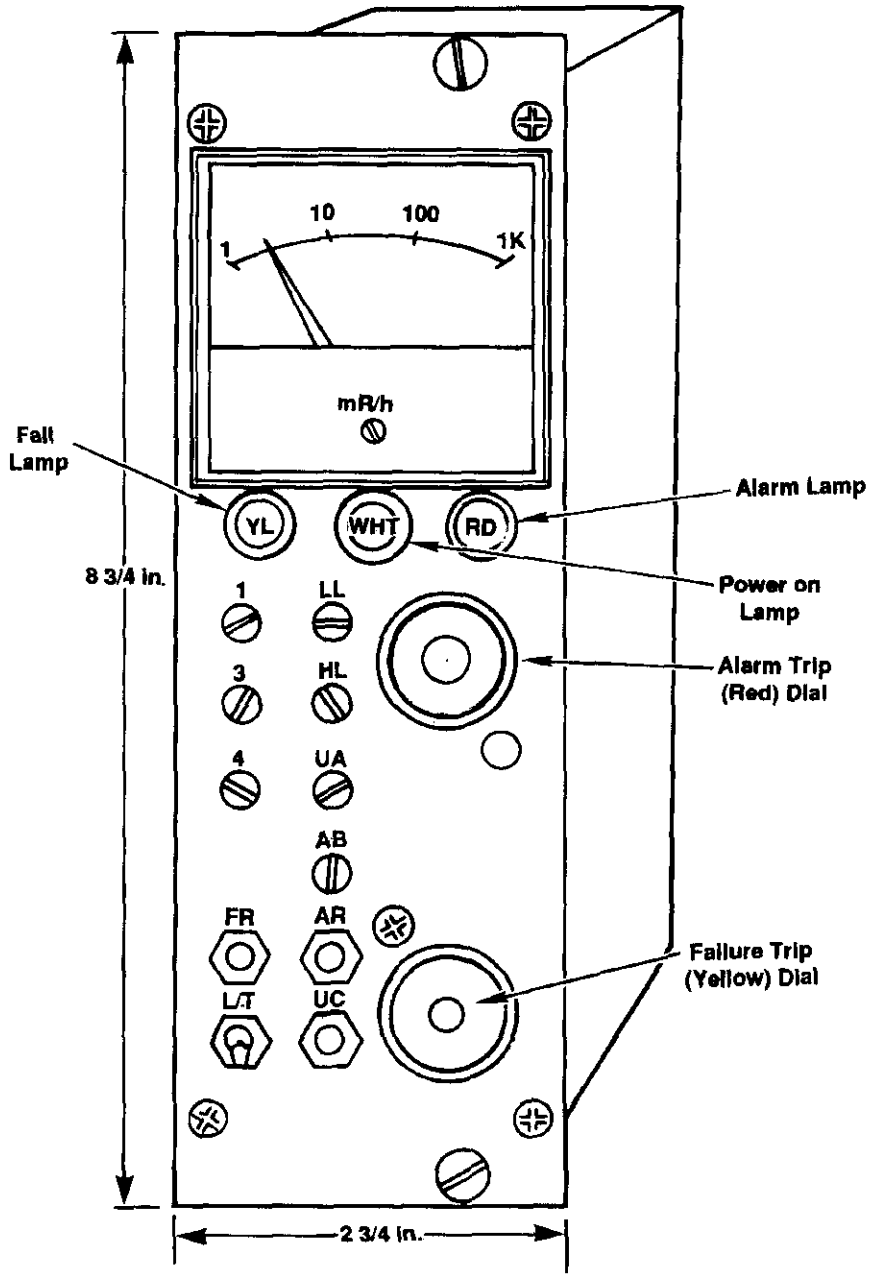


Figure 8-25. Criticality Alarm Logic and Alarm Relay Modules.

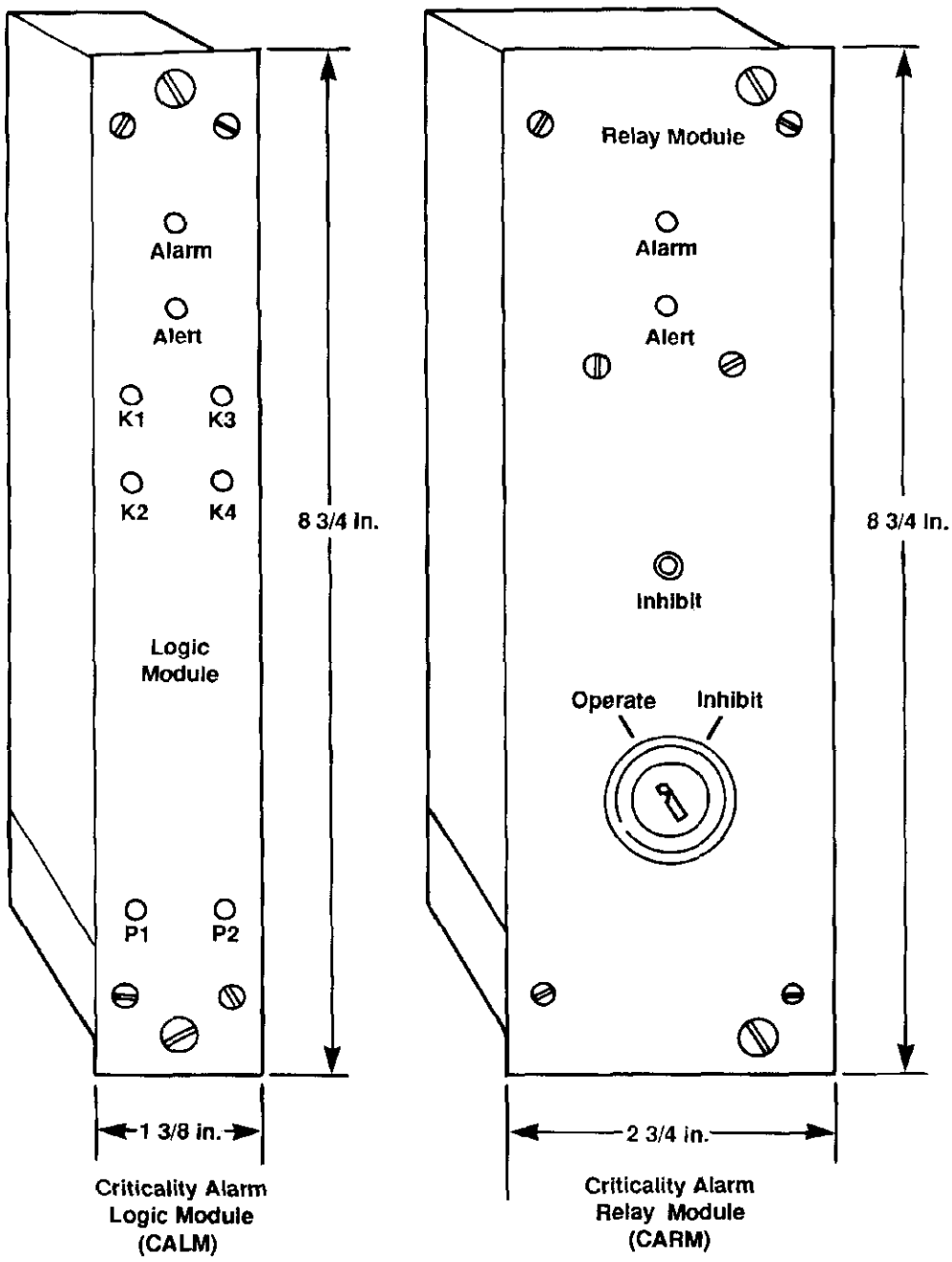
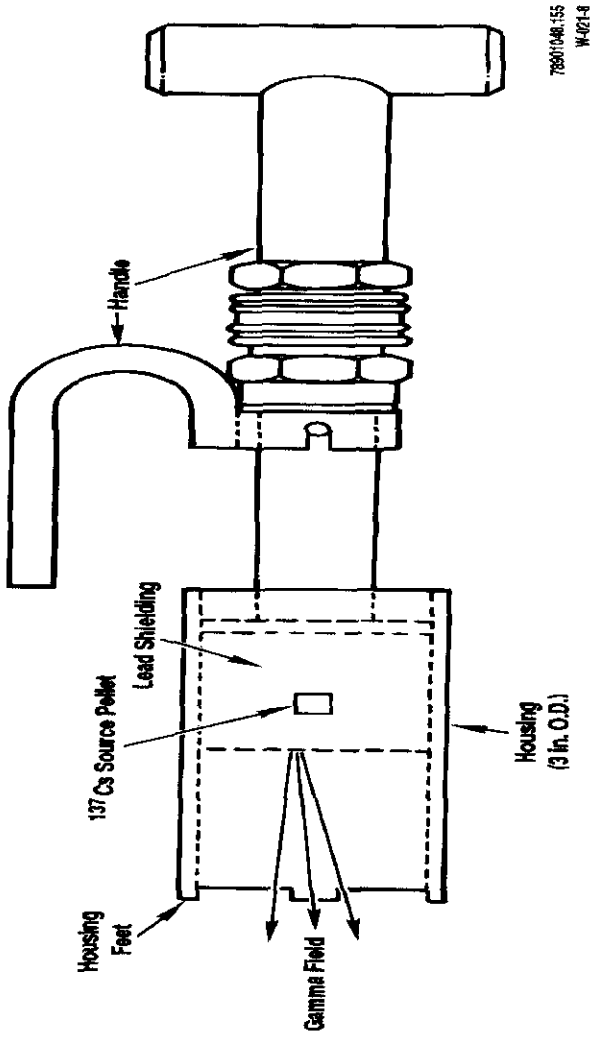


Figure 8-26. Criticality Alarm Source Holder.



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Figure 8-27. Criticality Alarm System - Building 234-5Z - First Floor
(4 sheets)

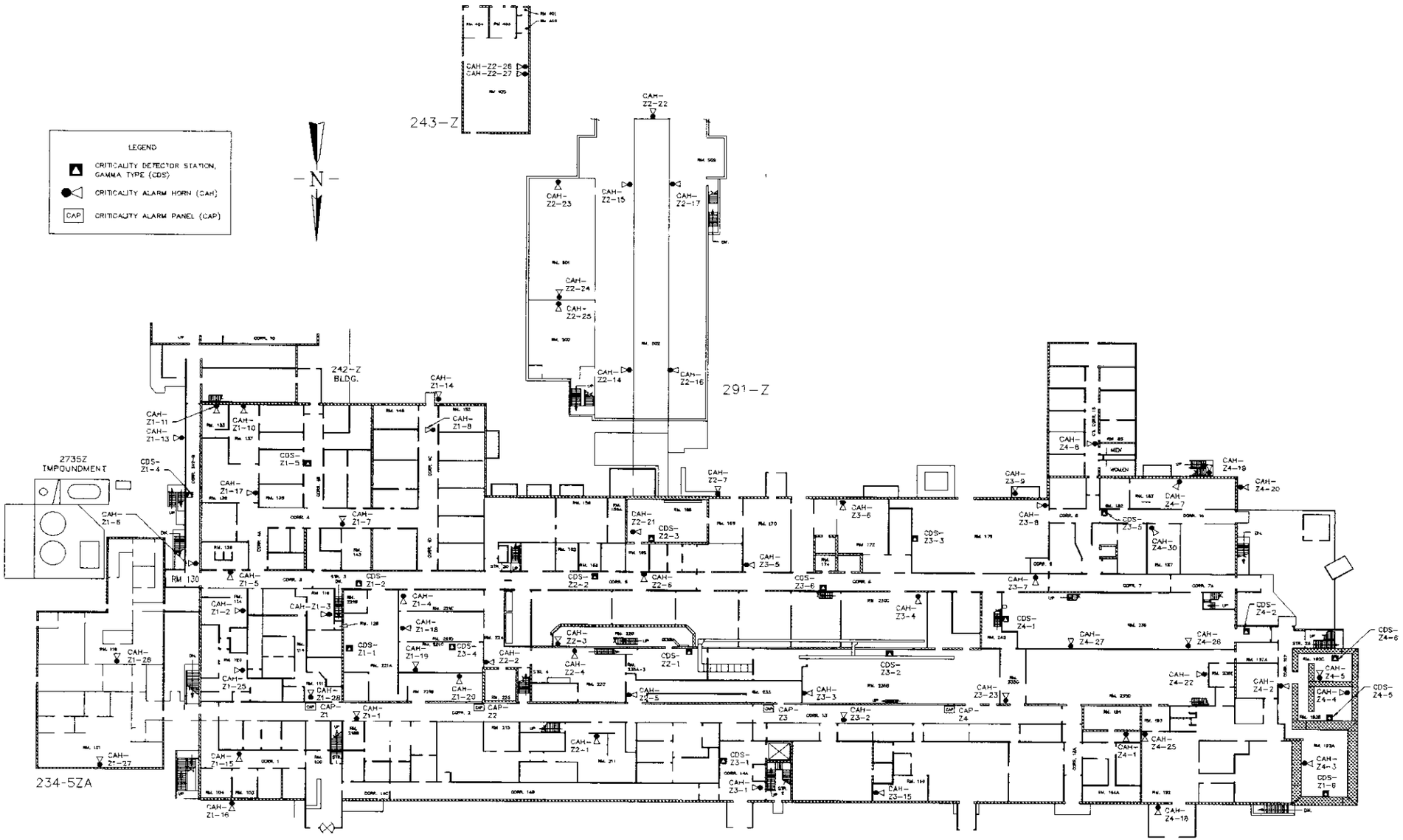
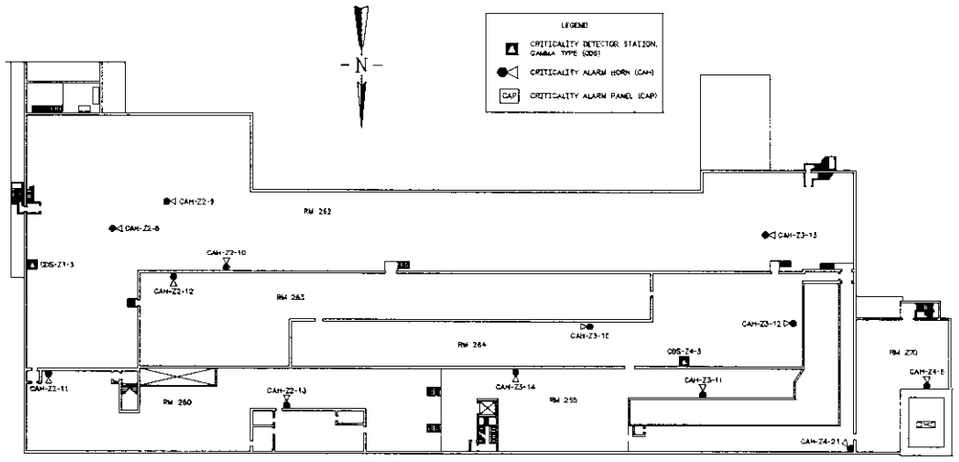
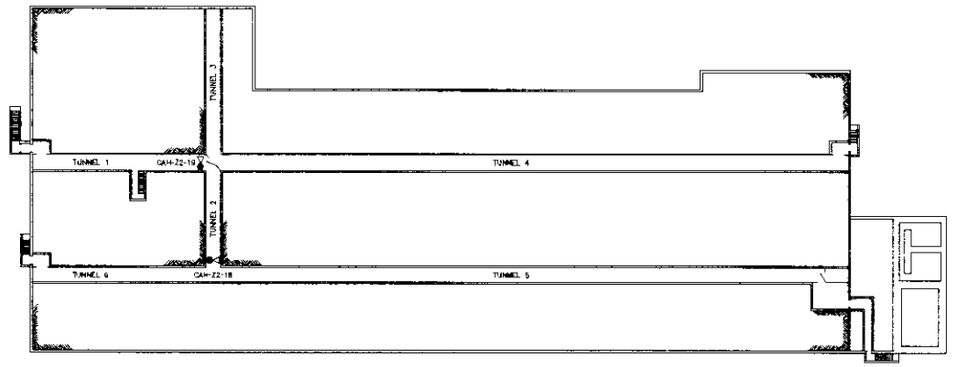


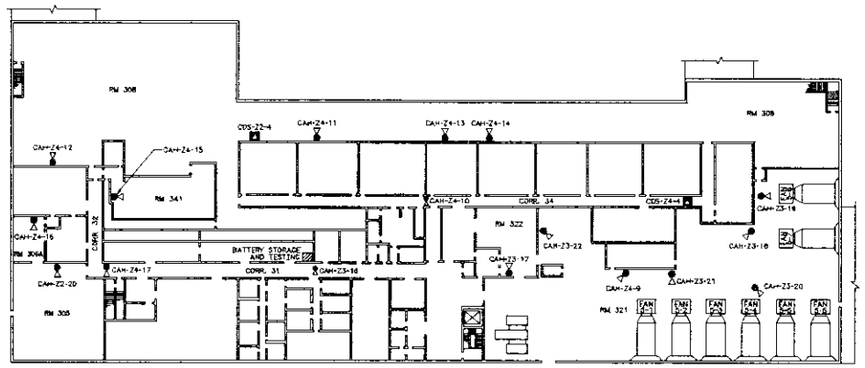
Figure 8-27. Criticality Alarm System - Building 234-5Z - Various Floors
(4 sheets)



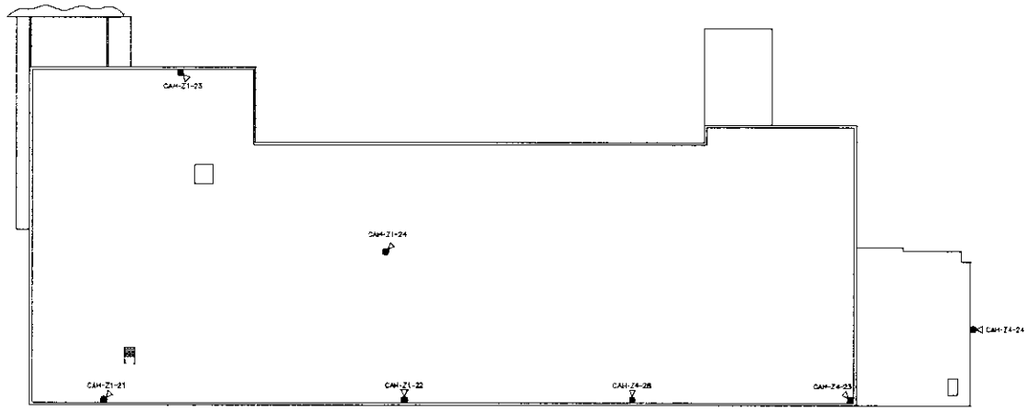
DUCT LEVEL



FOUNDATION AND TUNNEL



SECOND FLOOR



ROOF

Figure 8-27. Criticality Alarm System - Building 236-Z
(4 sheets)

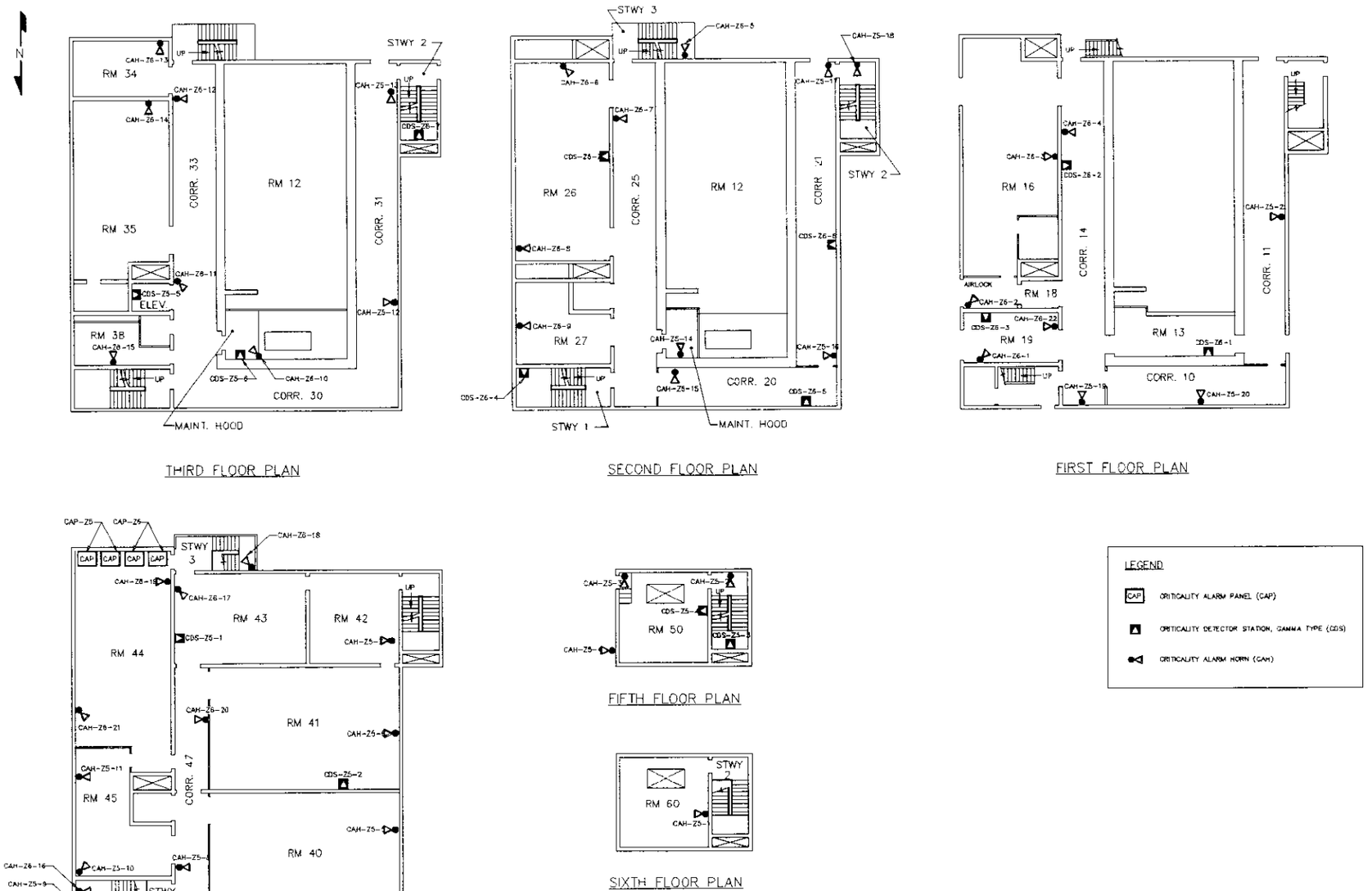


Figure 8-27. Criticality Alarm System - 2736-Z Complex
(4 sheets)

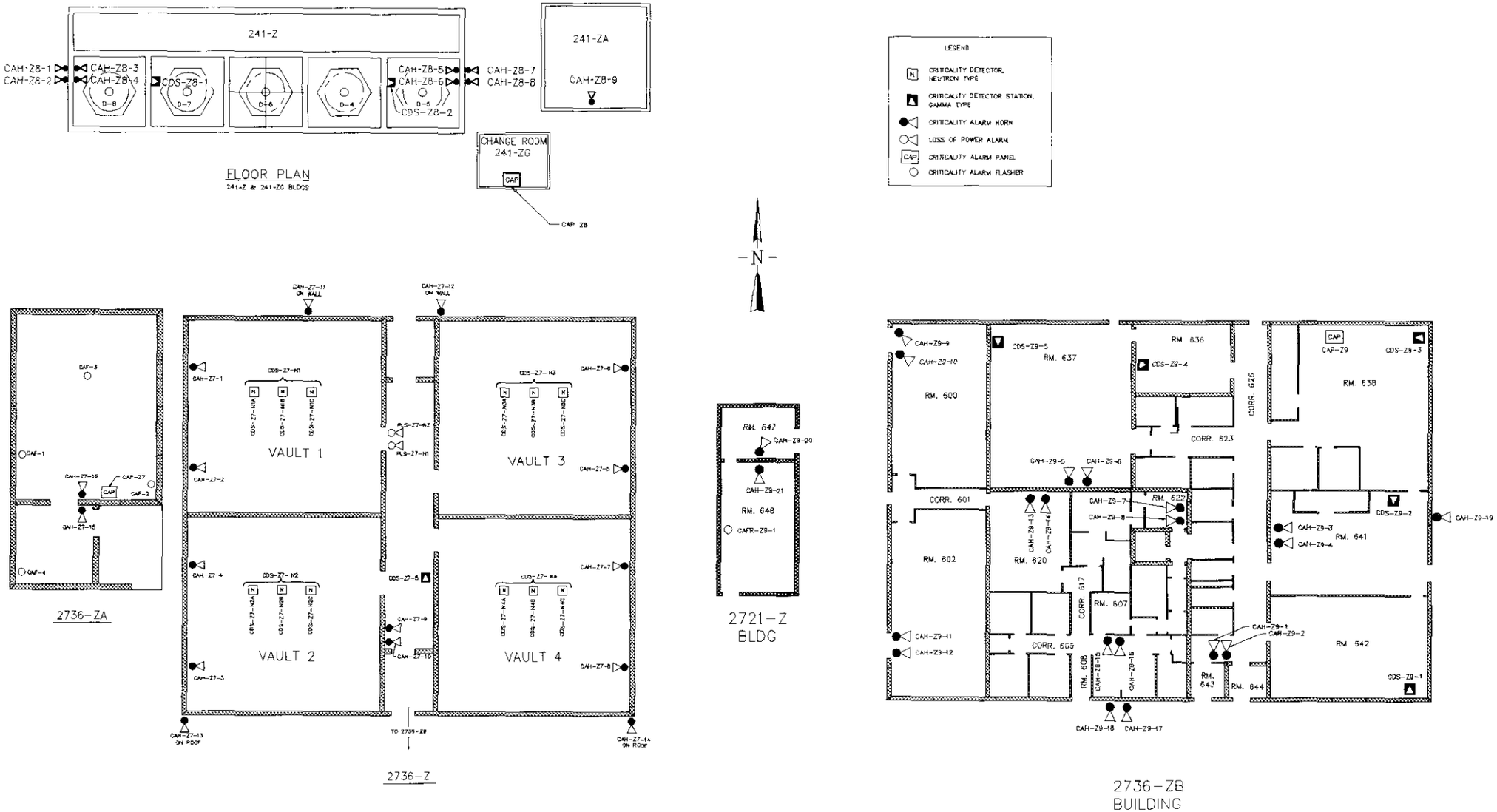


Figure 8-28. Continuous Air Monitor (Alpha).

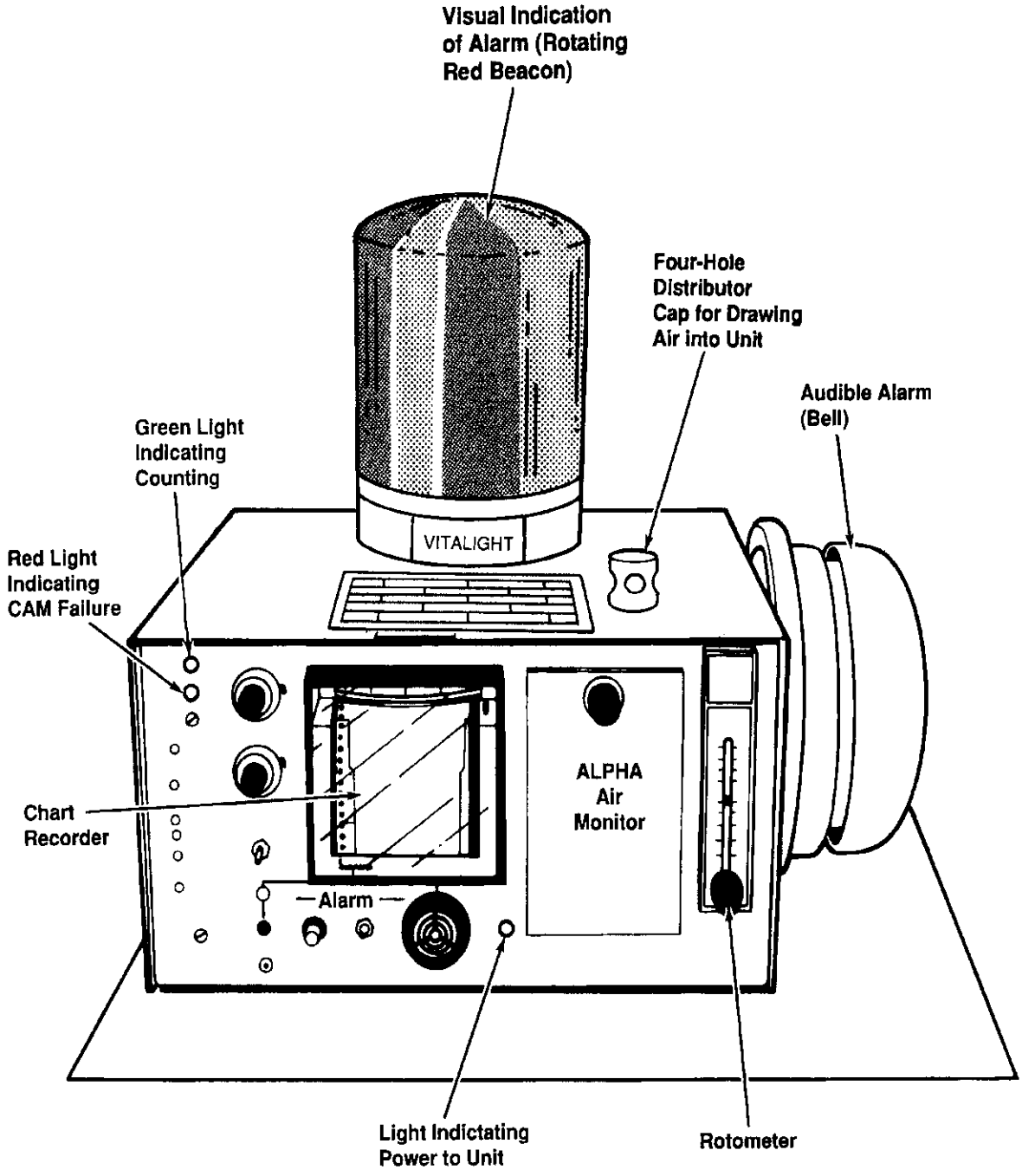


Figure 8-29. Sample Probe Pickup Line.
(Flanders Room Exhaust Filters are
Located in Building 2736-ZB.)

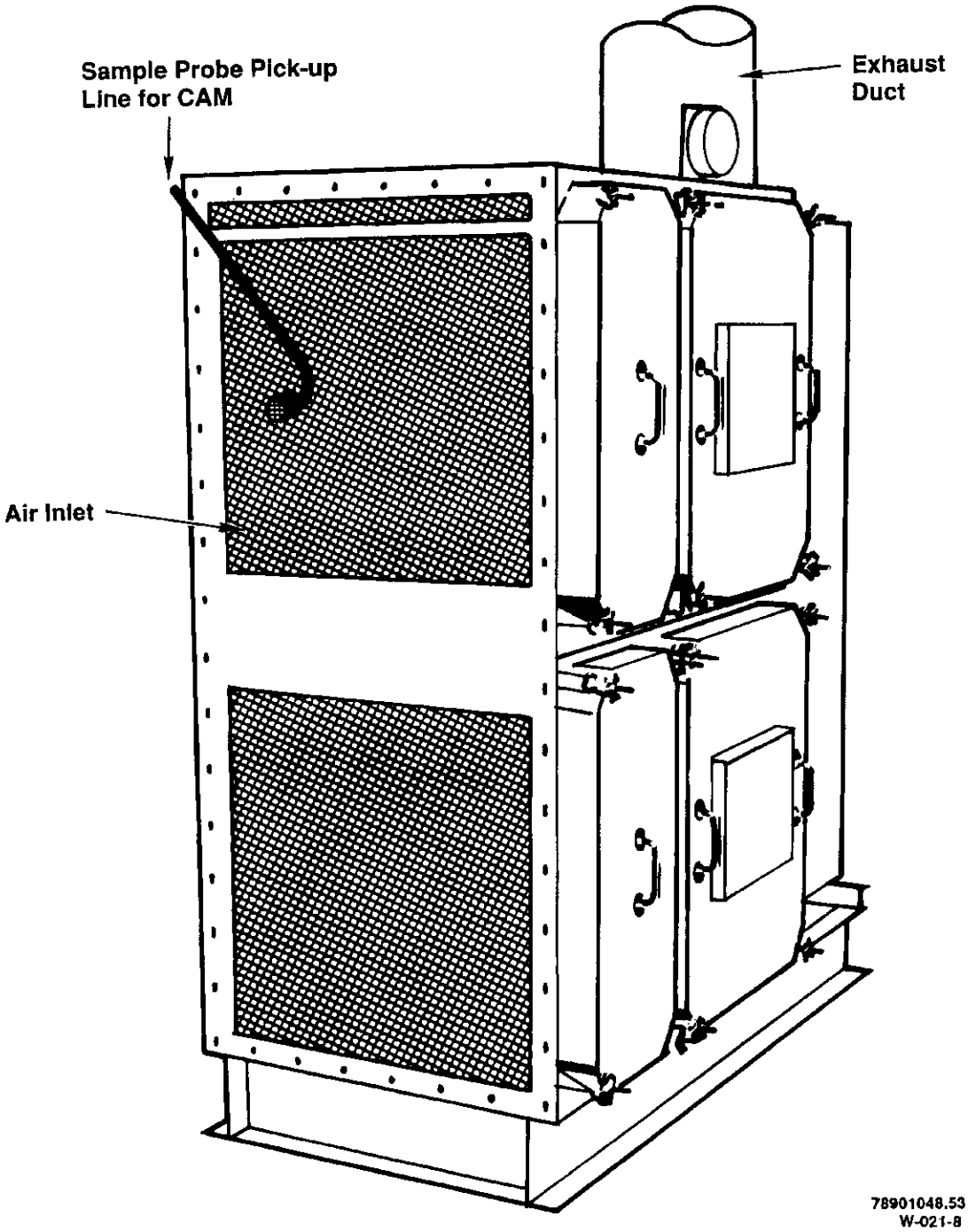


Figure 8-30. Not Used.

Figure 8-31. Not Used.

Figure 8-32. Not Used.

Figure 8-33. Not Used.

Figure 8-34. Not Used.

Figure 8-35. Not Used.

Figure 8-36. Not Used.

Figure 8-37. Not Used.

Figure 8-38. Not Used.

Figure 8-39. Not Used.

Figure 8-40. Not Used

Figure 8-41. Temporary Radiological/Exhaust System for Containment Control.

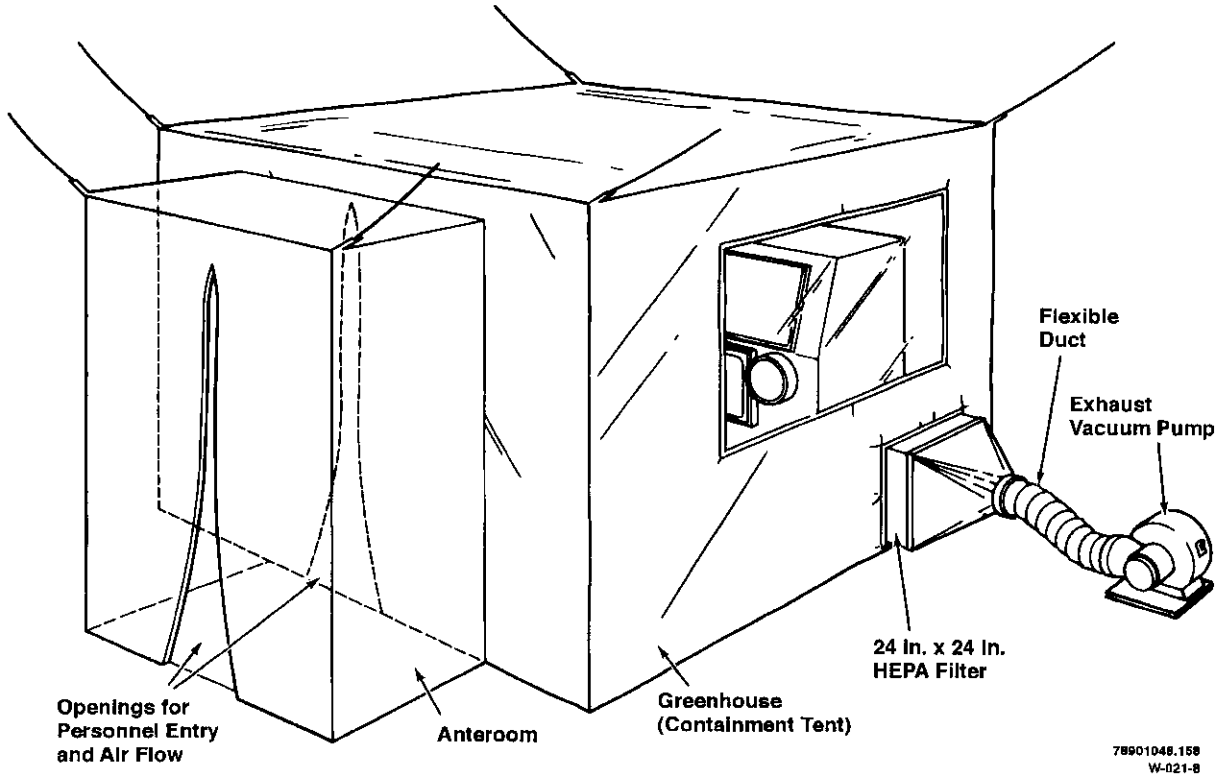
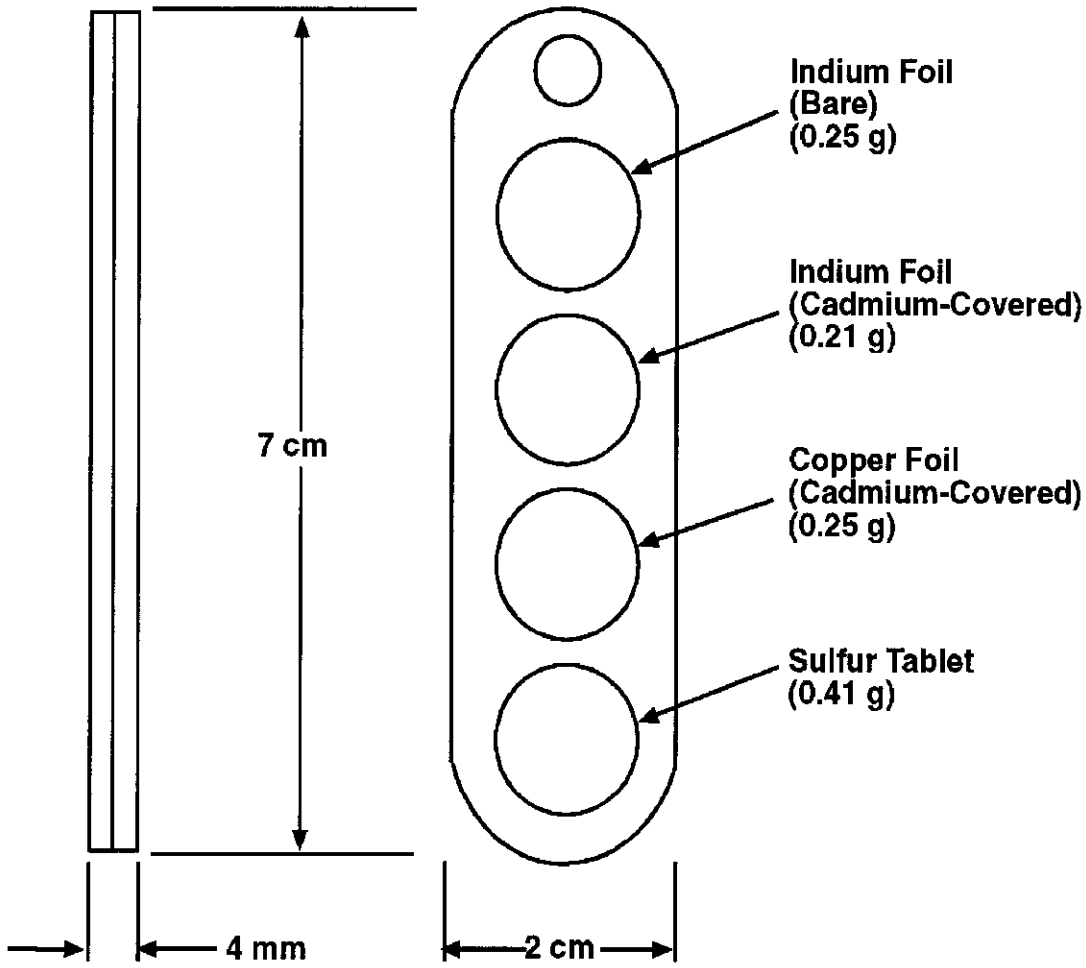


Figure 8-42. Personnel Neutron Accident Dosimeter and Components.

Dosimeter	Neutron Energy Range
Bare Indium Foil	0.025-0.5 eV
Cadmium-Covered Indium Foil	0.5-2.0 eV and 1-9 MeV
Cadmium-Covered Copper Foil	10^{-5} -1 MeV
Sulfur Tablet	2.9-9 MeV



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W-021-8 8/96

Figure 8-43. Nuclear Accident Dosimeter.

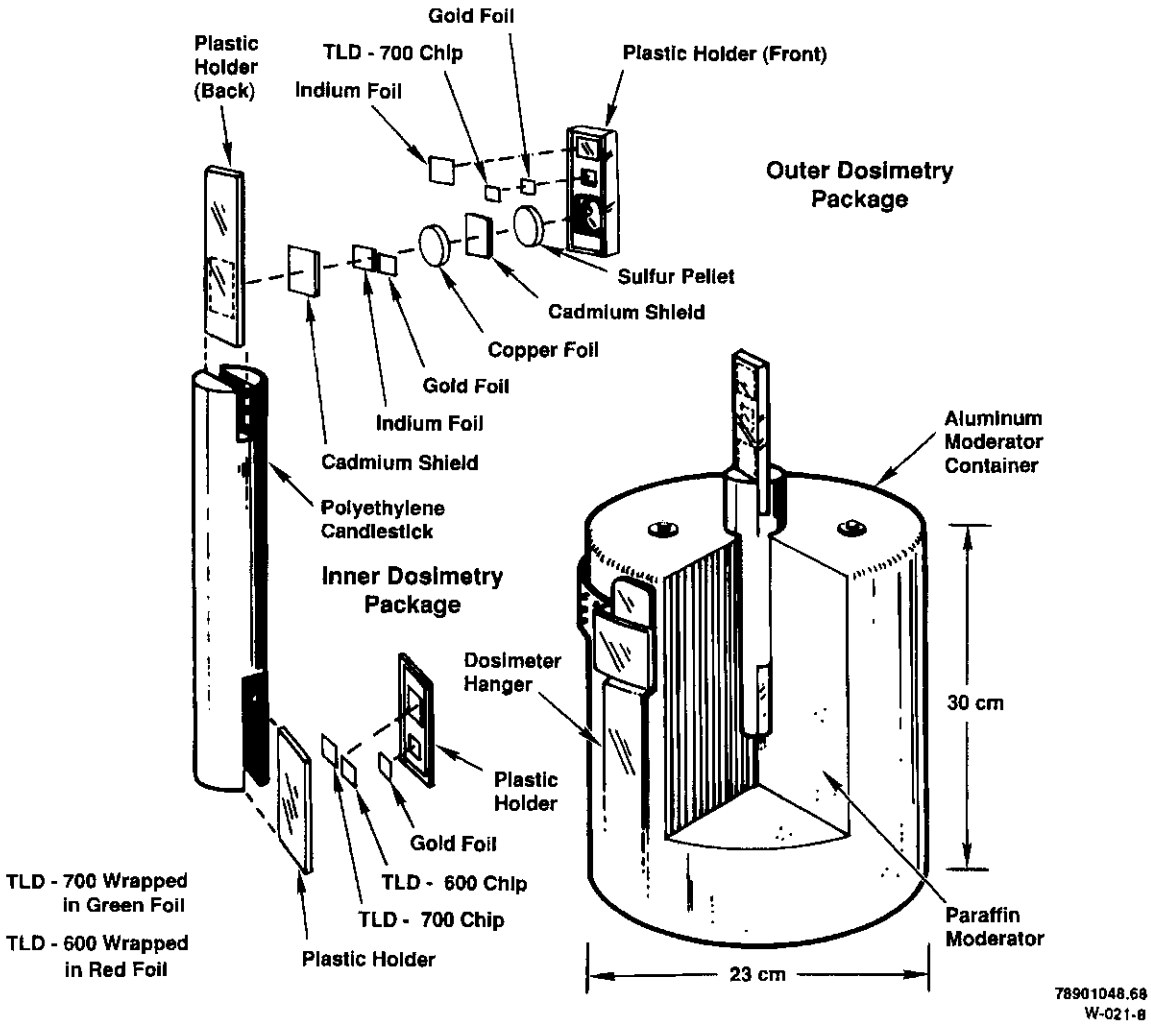
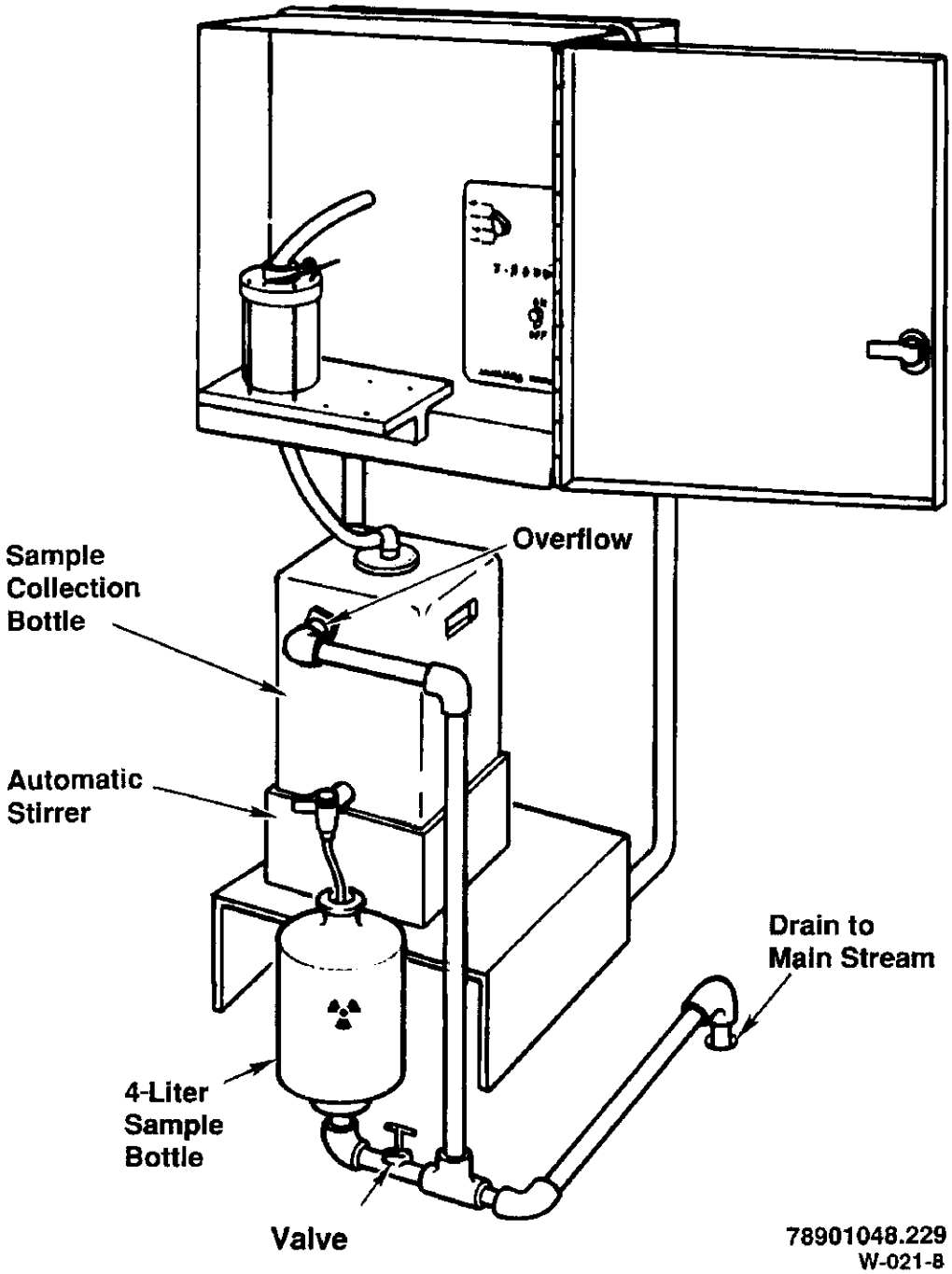


Figure 8-44. 225-WC Composite Sampler.



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APPENDIX 8A

COMPILATION OF NONDESTRUCTIVE ASSAY DATA ON E-4 DUCTING IN THE PLUTONIUM FINISHING PLANT

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B&W Hanford Co.
a McDermott company

To	R. D. Redekopp, Director PFP Operations	T5-15	
From	G. A. Westsik PFP Analytical Laboratory	T5-53	File No. Or Ref.: 15400-99-001
Subj	Residual Plutonium In Remediation Project		Date: January 07, 1999

In early 1996 the PFP Remediation Project Segment 2, a 57 foot long segment of glovebox exhaust ventilation ductwork located in rooms 263 and 264 of 234-5Z, was removed. Prior to removal the segment of 6" diameter ductwork was assayed in about 1977 and then again in 1996. During the removal process the individual cut out pieces were assayed. These measurements were all performed using NaI-based detection systems. The sections of ductwork were scraped and the material assayed using segmented gamma scanning (SGS) technology. The waste from these processes was placed in waste drums and assayed again using SGS technology. Below is a summary of the assay results from the various measurements.

1.	~1977 assay *in situ*	1800 g Pu
2.	January 1996 assay *in situ*	1354 g Pu
3.	Removed ductwork sections assayed prior to scraping	1878 g Pu
4.	Assay of material scraped from ductwork plus waste drums	2183 g Pu

The results from assays after removal confirm the initial assay data. They also give an indication of the stability of plutonium holdup over time. The material does not appear to have moved in the nearly twenty years between assays. Based on this information the current accountability value of 4.1 kg Pu is confirmed also.

Please contact me on 373-1947 if you have any questions.

Ift

Distribution

B&W Hanford Company
J. D. Dick
S. T. Hurlbut
P. M. O'Brien
D. L. Sorenson
T. L. Welsh

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Westinghouse Hanford Company | Appendix A | Internal Memo

From: PFP Analytical Laboratory 12243-88-128
Phone: 3-2628 T5-05
Date: May 11, 1988
Subject: COMPILATION OF NONDESTRUCTIVE ASSAY DATA ON E-4 DUCTING IN THE PLUTONIUM FINISHING PLANT

To: A. D. Danko T5-01

cc:

B. R. FitzPatrick	T5-05	E. J. Kosiancic	R2-15
J. C. Fulton	T5-14	R. M. Marusich	R3-02
M. Haas	T4-10	J. P. Sloughter	T6-16
R. A. Jones	T6-12	G. A. Westsik	T5-06
AES File/LB			

In support of Remote Mechanical C (RMC) Line Startup the Plutonium Finishing Plant (PFP) Analytical Laboratory has been requested to further evaluate, and summarize, the measured plutonium holdup in the E-4 ducting of the PFP. This compilation of nondestructive assay (NDA) and "radiation survey" data was made in cooperation with PFP Process Engineering, Process Chemistry & Engineering Laboratory and Analytical Chemistry Services Laboratory personnel.

Based on a process engineering estimate, the total length of E-4 ducting in the PFP is approximately 4,000 linear feet. During previous campaign and contractor turnover inventories, 960 linear feet of E-4 ducting was measured for plutonium holdup using standard portable NDA equipment. These NDA measurements, documented in Internal Memo Number 12243-88-081, revealed a measured plutonium holdup of 5 Kg with a range of 3.5 Kg to 7.1 Kg.

To satisfy concerns on the amount of plutonium holdup in unmeasured areas of the E-4 ducting, a "radiation survey", using a collimated CP meter, was made of the remaining 3,040 linear feet of E-4 ducting. This "radiation survey" was used to locate areas of E-4 ducting for additional NDA measurements. The results of these additional NDA measurements are documented in Internal Memos Number 12234-88-NMU-029 and Number 12221-88-088. This "radiation survey" revealed a plutonium holdup of 0.65 Kg over roughly 3,016 linear feet of E-4 ducting with an undetermined uncertainty. This same "radiation survey" revealed an additional 24 linear feet of ducting which contained a significantly higher plutonium holdup than the 3,016 linear feet. This portion of the E-4 ducting was also measured nondestructively using standard portable NDA equipment and revealed a measured plutonium holdup of 0.33 Kg with a range of 0.13 Kg to 0.49 Kg.

A. D. Danko
Page 2
May 11, 1988

The combined plutonium holdup in PFP E-4 ducting is estimated to be 6 Kg. Since the systematic error, or bias, for the combined assay data is not known, the total uncertainty cannot be evaluated.

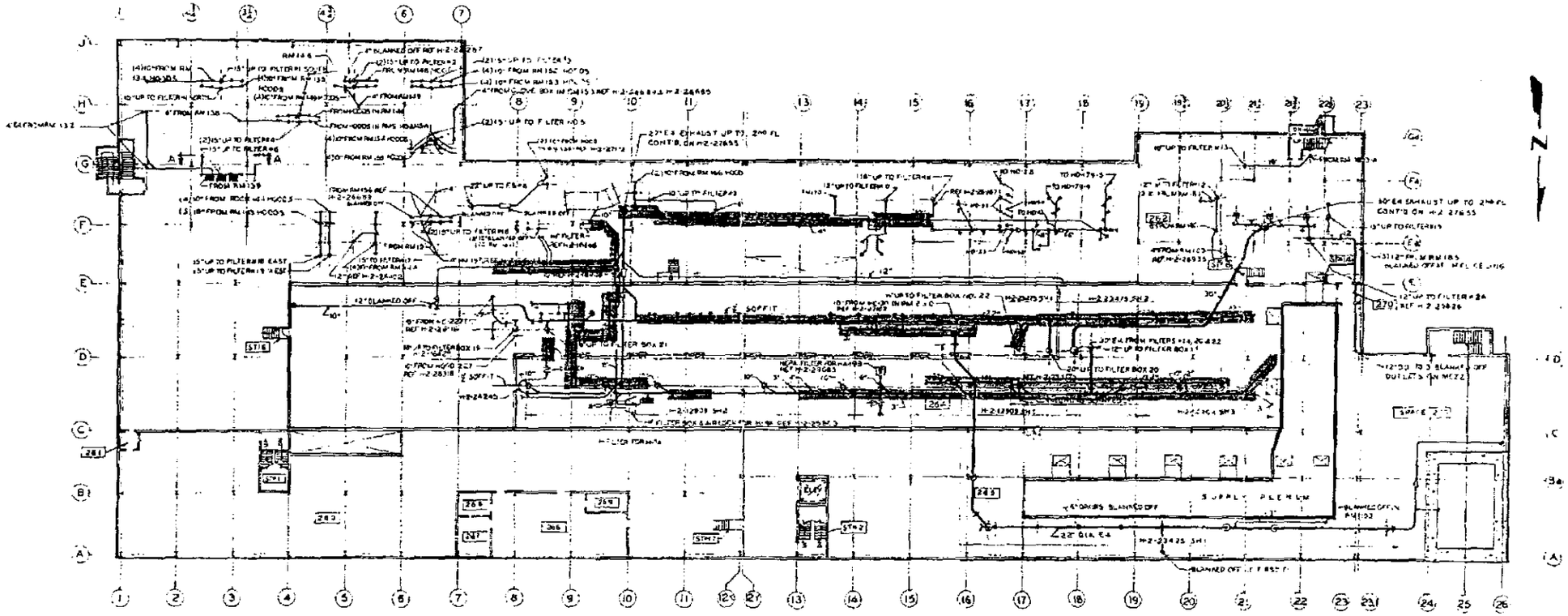
The location of this material holdup is graphically presented in Attachment I, by type of assay, and Attachment II, by material loading in grams plutonium per foot of ducting. Any questions on this subject can be addressed to me or Mr. R. A. Jones on 373-2886.

A. E. Schilling, Manager
PFP Analytical Laboratory

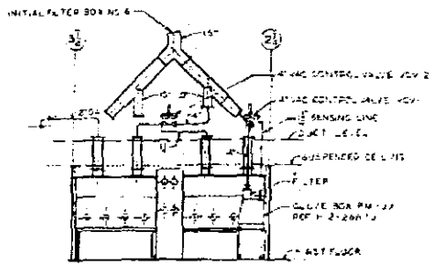
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Attachments

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Duct Level Plan
Showing E4 Exhaust System

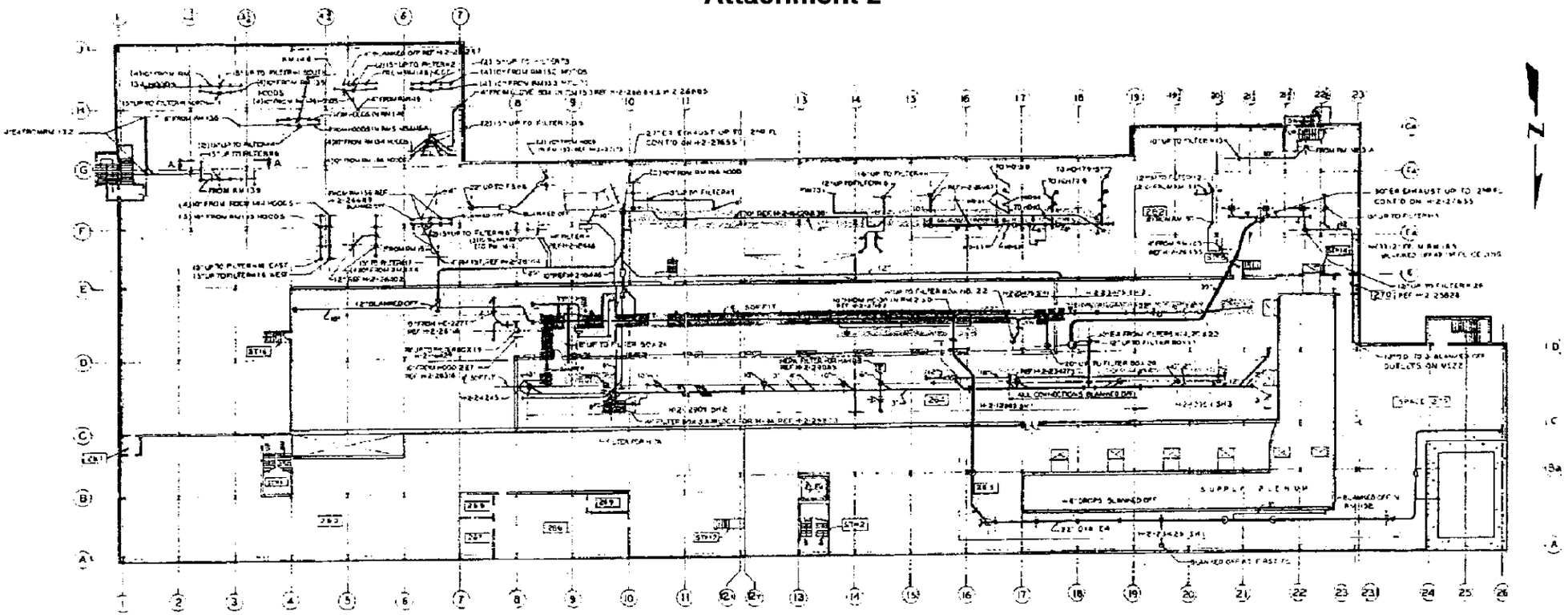


Section A-A
RM139 REF. H-2-26689

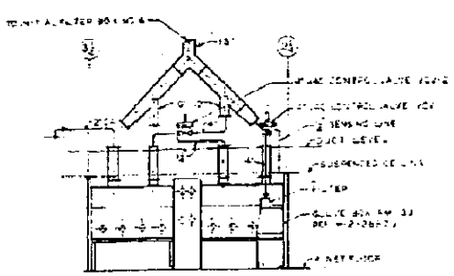
	90'	5kg (3.5kg to 7.1kg)
	24'	0.33kg (0.13kg to 0.49)
	3.040	0.65kg
	Total:	6kg (No Available Uncertainty)

28907017.1C
W-021-8

Attachment 2



Duct Level Plan
Showing C4 Exhaust System



Section A-A
RM 139 REF H-2-26689

	>50 but <100 gPu/ft
	>14 but <40 gPu/ft
	>2 but <14 gPu/ft
	>0.25 but <2 gPu/ft
	<0.25 gPu/ft

28907017.2C
W-021-8

APPENDIX 8B

CORROSION RATES FOR SOLUTIONS STORED AT PLUTONIUM FINISHING PLANT

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APPENDIX-B

Westinghouse
Hanford Company

Internal
Memo

From: PFP Process Control Engineering 15530-94-WSL-007
Phone: 373-2789 T5-55
Date: January 13, 1994
Subject: CORROSION RATES FOR SOLUTIONS STORED AT PLUTONIUM FINISHING PLANT

TO: E. C. Vogt T5-50

cc: M. W. Gibson T5-55
L. H. Rodgers T5-53
WSL File/LB

There is a large quantity of plutonium bearing solutions stored at the Plutonium Finishing Plant (roughly 4100 liters). Of this quantity, the majority is in a nitric acid matrix and is stored in stainless steel PR cans. A small subset of these solutions are stored in 10-L containers and are in a HCl matrix. These items (27 items) represent a serious potential for leaking. The U.S. Department of Energy, Richland Operations Office, (DOE-RL) has requested information on the expected corrosion rates of these containers.

The FL-10 container is a 10 liter polyethylene bottle (polybottle) that is roughly 4 feet high and 4 inches in diameter. The bottle is set inside a 6 inch schedule 40 stainless steel pipe. This, in turn, is placed inside a set of two 55 gallon drums that are stacked on each other and welded together. The polyethylene becomes embrittled over time due to radiolysis and acid attack. The 10-Ls have been in storage for roughly 20 years and the integrity of the polybottles are suspect. Neither the stainless steel pipe or the carbon steel outer drums are designed to with stand HCl corrosion.

The corrosion rates for 304L stainless steel in HCL solutions are sketchy . The "Metals Handbook Ninth Edition", Volume 13, Page 1162 states:

> The commonly used austenitic stainless steels, such as 304 and 316, are nonresistant to HCl at any concentration and temperature. At ambient temperatures and above, corrosion rates are high.

High corrosion rates are rates that are over 20 mpy (0.02 inches/yr). The rates could be much higher. At a rate of 20 mpy a schedule 40 stainless steel wall (0.28 inches) would last about 13 years. Chances are the rates are much higher.

Some of the solutions contain low concentrations of HF. In a corrosion study performed at the Idaho Chemical Processing Plant by H.S. Cole in 1974 indicate that at room temperature corrosion rates of 0.1 M HF in a nitric acid matrix has corrosion rates around 10 mpy. Due to the low HF concentrations the HCl rates bound the corrosion rates.

In the absence of rate data x-ray photography using an Iridium source for assessing the integrity of the polybottles is planned. This is the same technology that is currently used to x-ray welds. The x-rays will show a shadow of the edge of the stainless steel pipe, the polybottle and the liquid level. Any solution that may have leaked out of broken polybottle into the annular space inside the pipe will also be visible. If any leaking polybottles are identified, the outer drum will be opened, the stainless steel pipe will be visually inspected for signs of corrosion, and an acid absorbent will be placed in the bottom of the drum to prevent corrosion of the drum as a precautionary measure. These items will be the first items to be transloaded and stabilized once the necessary modifications to glovebox 227 have been completed as identified in the plant integrated schedule.

The PR cans contain plutonium bearing solutions in a nitric acid matrix. The 304L containers have excellent corrosion resistance to nitric acids.

The reference above states that:

> The basic corrosion data for the austenitic stainless steels is plotted (see page 1155). The diagram shows the effect of the temperature and HNO3 concentration on the corrosion of type 304 stainless steel (304L will be a little better). Increasing either or both the temperature of the acid concentration increases the corrosion rate. At room temperature or the acid concentration needs to reach 100% to reach a rate of 0.13 mm/yr. Most of the PR containers are schedule 80 pipe (wall thickness 0.432 inches). A few (the Mark IV type) are schedule 40 (wall thickness of 0.28 inches). Regardless, it would take over 50 years for the acid to corrode through the schedule wall if the acid were 100%.

In conclusion the HCl based solution represent a major concern that should be addressed in the near term. Pu nitrate solution does not represent a significant corrosion hazard and allows safe storage well beyond the expected completion of the Environmental Impact Statement.

W.S. Lewis, Cognizant Engineer
PFP Process Control Engineering

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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 9.0

ACCIDENT SAFETY ANALYSIS

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 9.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) consists of modifications to incorporate additional thermal stabilization operations in Gloveboxes HC-21C and HA-21I and new operations involving solution stabilization using the Magnesium Hydroxide Precipitation Process and plutonium material packaging operations using the Bagless Transfer System. Engineering Change Notice 632069 appended the thermal stabilization of non-product quality oxide feed material addendum (HNF 1999b) to the PFP FSAR allowing non-product quality, reactive plutonium-bearing material to be thermally stabilized in Glovebox HC-21C. All reactive plutonium-bearing material suitable for stabilization in Glovebox HC-21C, except PRF sludges, can also be thermally stabilized in Glovebox HA-21I. The Magnesium Hydroxide Precipitation Process addendum (Carson 2000) to the PFP FSAR has been incorporated in Revision 2. In addition, the calculation notes for the Bagless Transfer System (FH 2000) have been incorporated in Revision 2 of the FSAR. The total facility dose from a seismic analysis was previously discussed only in the Laboratory Prototype Calciner addendum. In this revision (Rev 2), the total facility dose from a seismic analysis is discussed in Section 9.2.4.12 and only the Laboratory Prototype Calciner portions are discussed in the addendum. A few editorial changes have also been incorporated in this revision of the FSAR.

It is noted that various sections of Chapter 9.0 present information concerning plutonium-bearing solution stabilization operations using the Production Vertical Denitration Calciner located in the RMC Line and the Laboratory Prototype Calciner in the Plutonium Process Support Laboratories. Operation of either the production calciner or the laboratory calciner for solution stabilization is not authorized at this time and the related portions of Chapter 9.0 will be updated, if necessary, prior to initiation of operations. Portions of the Hazard Evaluation in Appendix 9A for thermal stabilization operations in Gloveboxes HC-21A, HC-21C, HC-18BS, and HC-18M have been superseded by the hazard evaluations in Appendices 9F and 9G.

The new packaged boilers operated by Johnson Controls, Inc. which provide steam to the PFP were previously incorporated in the FSAR. This included switching the emergency exhaust fans from those which are steam-driven to those which are connected to the backup power system. However, the conversion from using steam-driven fans to backup power driven fans has not been fully implemented. The emergency exhaust fans are currently run by the new steam supply system installed under the Hanford energy conservation program. Electrically-driven emergency exhaust fans are planned to be connected to the diesel-generator standby power supply during Fiscal Year 2000. A supplemental ECN has been written for the FSAR to reflect the continued use of the steam-driven emergency exhaust fans currently in operation. The emergency exhaust fan functions are unchanged from that described in the FSAR regardless of the type and source of power.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each affected page.

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9.0 ACCIDENT SAFETY ANALYSIS

9.0.1 Introduction

Chapter 9.0 contains analyses of a number of potential accidental events that could have adverse radiological or chemical consequences. Abnormal events considered in Section 9.1 address scenarios that could result in radiological consequences to plant personnel but where plant confinement barriers are not significantly challenged and hence significant consequences outside the facility are not expected. The primary focus of the accidents addressed in Section 9.2 is on the consequences to offsite individuals and to workers onsite but in adjacent facilities. The analyses of events affecting onsite and offsite people combine probability and consequences to develop a risk level. The risk level is then compared to acceptability guidelines in order that Management can evaluate the safety status of the plant.

The chapter includes three sections in addition to the sections on abnormal operations and accidents. These are a description of the screening process through which the detailed analyses were chosen, a discussion of the methods used to calculate radiation dose, and a section presenting the risk guidelines.

9.0.1.1 Summary Conclusion. There were no events analyzed that had unacceptable consequences as defined by the guidelines presented in Section 9.4.

9.0.1.2 General Observations. During the process of developing Chapter 9.0 a number of general observations were made that may not be apparent when looking at individual events. These observations are presented below.

9.0.1.2.1 Site Impact on Offsite Safety. The site is described in detail in Chapter 3.0. However, it is appropriate to identify specific qualities of the site which reduce the impact of the Plutonium Finishing Plant (PFP) on the nearest offsite individuals. The PFP is on a 560-mi^2 government owned, U.S. Department of Energy (DOE) controlled site. The surrounding region has a low population density as demonstrated by 1990 data. The population density is 20 persons per square mile within a 20-mi radius and increases to 42 persons per square mile within a 50-mi radius. The density drops to 7 persons per square mile in the 22.5° sector identified in the worse case scenario. These features emphasize the isolation and low availability of population to exposure.

9.0.1.2.2 Site Impact on Onsite Safety. Processing plants in the Hanford 200 Areas were built with considerable separation from each other. Early site design criteria addressed the prospect of attack by Japanese carrier-based aircraft. Spacing and orientation of the buildings were intended to make them less vulnerable to attack and more easily defended. It is not clear how much consideration went into protection of adjoining onsite personnel from radiological harm, but the fact is that the protection is provided. The 234-5Z Building was built on the western side of the 200 West Area, as a result of considerations for safety, security, and convenience. Thus accidental releases of radioactive materials or chemicals

are considerably dispersed before they potentially impact the non-PFP or onsite person.

9.0.1.2.3 Plant Features Impacting Safety. Chapter 5.0 provides a detailed physical description of the plant. The plant contains approximately 220,000 ft^2 considering all levels. Ten percent of the space is active in plutonium processing. The major processing areas are surrounded by reinforced concrete walls. The remaining areas are used for laboratories, service areas, offices, utilities, ventilation, filter rooms, and small batch processes.

The main facility, 234-5Z, was designed based on criteria circa 1943 to 1949 and construction was completed in 1949. The 234-5Z Building has a structural steel framework with outer panels consisting of steel sheeting, insulation and aluminum sheeting. Eight-inch reinforced concrete internal walls separate major process and storage areas into compartments. These areas and the rest of the building are subdivided by metal or plaster on metal lath walls. The roof, which was upgraded in 1983, is a Factory Mutual Class 1 roof over a pre-existing metal deck. Considering the time period and the existing structure, the design likely leaned heavily on the primary operating contractor's experience with facilities used to process hazardous materials. Later buildings were also designed as isolated compartments. This separation of process lines and storage areas enhances the safety of the plant.

9.0.1.2.4 Process Operations Impacting Safety. Chapter 6.0 contains detailed descriptions of PFP process operations. These operations include the following:

- Special Nuclear Material (SNM) shipping/receiving
- SNM storage
- Remote Mechanical A (RMA) and Remote Mechanical C (RMC) Line operations, including reactive material stabilization and plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner (VDC)
- Laboratory support
- Facility cleanout activities
- Radioactive waste handling.

A narrative description of SNM receiving/sorting/storing and shipping is provided in Section 6.2 and 6.3. Reactive material undergoes thermal stabilization conducted in gloveboxes HC-21C and HA-21I. Plutonium-bearing solutions are stabilized using the Production VDC in glovebox HC-230C-2. Narrative descriptions and detailed information are contained in Section 6.4.1.

The PFP contains three laboratories: the Plutonium Process Support Laboratories (PPSL), the PFP Analytical Laboratory (PFPAL), and the Standards Laboratory. Information regarding these laboratories is provided in Section 6.5. Radioactive and mixed waste handling operations are addressed primarily in Chapter 7.0, and facility cleanout activities are addressed in Section 6.7.

Any future operations involving plutonium recovery and conversion operations will have appropriate safety documentation prepared. Note that, although these processes are inactive, the seismic accident analysis contained in Section 9.2.4 assumes that Plutonium Reclamation Facility (PRF) and RMC

line gloveboxes and process equipment contain maximum allowable plutonium inventories. This was done to (1) account for residual quantities of plutonium remaining in the process equipment and gloveboxes following the cessation of operations, (2) allow flexibility in the use of gloveboxes for in-process storage of plutonium, and (3) provide an upper bound estimate of potential radiological consequences of a seismic event.

Note also, that the validity of the analyses found in Sections 9.1 and 9.2 are predicated on the assumption that the equipment in the plant will be well maintained and that modifications to the facilities and equipment will be made under stringent controls.

All discoveries and changes (i.e., physical modifications, new construction, new procedures, procedure modifications, and tests and experiments) receive an unreviewed safety question (USQ) screening and, if required, a USQ evaluation. Screenings and evaluations are performed in accordance with Section 2.23, "Identification and Resolution of Unreviewed Safety Questions," of the PFP Administration Manual, FSP-PFP-5-8. Section 2.23 of the Administration Manual is used in conjunction with HNF-PRO-062, *Identifying and Resolving Unreviewed Safety Questions*. HNF-PRO-062 is the governing procedure for implementation of an unreviewed safety question process necessary to comply with DOE Order 5480.21, *Unreviewed Safety Questions*.

9.0.1.2.5 Receptor Location for Dose Consequences. The radiological dose consequences resulting from the postulated accident scenarios were calculated at the location of the maximally exposed onsite and offsite receptors as determined using the GXQ code [described in *GXQ Program Users Guide* (Hey 1993a)]. The receptor location was dependent upon the type of release applied to the accident scenario. For the accident scenarios at the PFP, four different types of releases were applied: 1) elevated release (release occurs from the 291-Z-1 stack), 2) ground level release (release occurs from openings in a building), 3) buoyant plume rise release (waste drum fire outside buildings), and 4) point source ground level release (waste drum rupture outside of buildings and collapse of the 232-Z Building in a seismic event). The location of the onsite and offsite receptor was determined to be as follows:

Type of Release	Onsite Receptor Location	Offsite Receptor Location
Elevated	242-S Facility	12.5 km west of PFP
Ground-level	272-WA Facility	12.5 km west of PFP
Buoyant plume rise	U-Plant	17.4 km north-northwest of PFP
Point-source ground-level	272-WA Facility	12.5 km west of PFP

9.0.1.2.6 Chapter Layout. This chapter consists of four more sections and eight appendices. Section 9.1 presents the analysis of events that do not breach containment or confinement. Section 9.2 presents the analysis of events that are generally thought to have a potential for breaching the protection systems. These include natural phenomena hazards, fires, and

explosions. Section 9.3 discusses the methods used to calculate radiation dose, and Section 9.4 presents the risk guidelines and evaluation. Appendix 9A documents the preliminary hazard analysis initially performed for the PFP. Appendix 9B provides a discussion of release fractions for plutonium powders dispersed from a seismically unqualified glovebox. Appendix 9C presents a model for estimating the number of grams of plutonium released from the PFP to the environment. Appendix 9D documents a hazards and operability (HazOp) analysis performed for the plutonium-bearing solution stabilization process. Appendix 9E presents the calculations related to rupture of a compressed gas cylinder. Appendix 9F presents the Preliminary Hazards Analysis performed for the thermal stabilization of "clean" plutonium oxide. Appendix 9G presents the Preliminary Hazards Analysis performed for the thermal stabilization of non-product quality oxide material. The plutonium-bearing solution and plutonium oxide stabilization processes were added to the PFP after the PHA in Appendix 9A was performed. Appendix 9H presents a hazards analysis evaluation of plutonium metal opening and stabilization.

Figure 9-1 provides a flowchart to the various sections of the Chapter. Note that Figure 9-1 has not been updated to reflect reactive plutonium-bearing material thermal stabilization operations or plutonium-bearing solution stabilization using the Laboratory Prototype Calciner.

9.0.2 Preliminary Analysis

9.0.2.1 Discussion. Plant malfunctions are analyzed in two categories, Abnormal Operations and Accidents. The two categories are defined as follows:

1. Abnormal Operations - In this category, events which could result from malfunctions of systems, operating conditions, or operator error are presented. In general, the magnitude of the events discussed in this section would not have a significant consequence beyond the exclusion area.

2. Accidents - This category contains analyses of situations where primary and/or secondary confinement may credibly be breached to the extent of releasing toxic/radioactive materials beyond the exclusion area or a quantity that could seriously endanger personnel within the exclusion and restricted area. Include consideration of industrial type accidents that would not result in a release of radioactivity but could endanger onsite personnel.

There is no clear-cut distinction between the two categories but in actuality there are two distinct types of events. The two can be distinguished by whether or not the building containment or confinement is breached. In general, those events chosen as accidents potentially occur with sufficient energy to both breach the structure and disperse hazardous materials. A number of events, such as a fire, that were originally selected as accidents were later shown via analysis to have low consequences or probability. Even so, the analyses were retained in the accident section from a sense of expectation. This is also true for natural phenomena events (earthquakes, flood, high winds) and for criticality. These are the types of events which are generally thought to have a potential for defeating the protection systems. Thus, they are included as accidents.

The first step in the identification of abnormal operations and accidents is to determine where combinations of energy and hazardous material exist in sufficient quantities to pose a hazard. The second step is to determine if credible mechanisms (e.g., equipment failures, human errors) exist for combining these two parameters to create unacceptable consequences. A Preliminary Hazard Analysis (PHA) was performed to accomplish these two tasks. The PHA helps identify events and also provides a qualitative estimate of risk.

Appendix 9A describes the rigorous hazards-analysis methodology used to identify and qualitatively assess hazards associated with the PFP, and presents the results in tabular format. The hazard analysis systematically:

1. Identifies building processes, systems and subsystems

2. Identifies activities and associated failures that could lead to potentially hazardous conditions

3. Identifies safety systems, preventive and mitigative controls, and administrative procedures that would prevent the failure event from occurring or reduce its consequences

4. Presents a qualitative hazard screening.

5. Identifies the location in Sections 9.1 and 9.2 where representative or bounding quantitative analyses can be found for each of the hazardous conditions.

The hazard analyses presented in Appendix 9A are grouped into the following major PFP buildings:

Appendix 9A.1--234-5Z Building

- 9A.1.1 RMA/RMC Line
- 9A.1.2 PFPAL
- 9A.1.3 PPSL
- 9A.1.4 Radiochemical standards laboratory
- 9A.1.5 Load-in/load-out (LI/LO)
- 9A.1.6 Storage vaults
- 9A.1.7 Miscellaneous areas

Appendix 9A.2--2736-Z Building; Support/Storage Complex

- 9A.2.1 2736-Z Building
- 9A.2.2 2736-ZA Building
- 9A.2.3 2736-ZB Building
- 9A.2.4 2736-ZC Building
- 9A.2.5 2736-ZD Building
- 9A.2.6 2721-Z Building

Appendix 9A.3--236-Z Building; PRF

Appendix 9A.4--241-Z Building; Waste Storage and Treatment Facility

Appendix 9A.5--232-Z Building; Waste Incinerator Facility

Appendix 9A.6--243-Z Building; Low-Level Waste Treatment Facility

Appendix 9A.7--291-Z Building; Exhaust Fan House

Appendix 9A.8--242-Z Building.

Floor plans and oblique aerial photographs of buildings in the PFP complex are presented in Figures 9-2 through 9-6 as an aid in following the systematic search for various possible events. These and other drawings, plus repeated visits to the plant, and consultations with cognizant/plant engineers were used in performing the hazards analysis.

The hazards analyses contained in Appendix 9A do not address severe natural phenomenon and external events. The severe natural phenomenon are known accident initiators and the phenomenon analyzed in Section 9.2 (e.g., earthquake and strong wind) were selected based on known site characteristics. The external event analyzed (e.g., aircraft crash) was selected based on a evaluation of nearby industrial, transportation, and military facilities (see Chapter 3.0, Section 3.2).

9.0.2.1A Preliminary Hazards Analysis of Plutonium-Bearing Solution Stabilization Using the Production VDC Process. The hazards analysis documented in Appendix 9A does not include the process for plutonium-bearing solution stabilization using the Production VDC. This process was added to the PFP after Appendix 9A was completed. Solution stabilization is accomplished using the Production VDC installed in glovebox HC-230C-2, added to the end of the RMC line in room 230C of the 234-5Z Building. In addition to the Production VDC, glovebox HC-230C-2 contains glass vessels for supplying feed and flush solution to the Production VDC, a NaOH scrubber to condense and treat offgases from the VDC, a phase separator tank, spent scrub solution receiver tanks, and various pipes, pumps and valves to transfer liquids and gases through the system. The Production VDC, scrubber, and phase separator tank are connected to the plant vacuum system. Plant compressed air is used to operate pumps and valves associated with the process. Bottled compressed air is used to atomize plutonium nitrate solution fed into the VDC and to blowback filters on the VDC to prevent clogging. The VDC receives plutonium nitrate solutions from PR cans and L-10 bottles. The plutonium nitrate solutions are loaded into tanks in glovebox HC-227S (via hood HC-227T) and then pumped to glovebox HC-230C-2 via an encased transfer line. A more detailed description of the equipment used to stabilize plutonium bearing solutions is contained in Chapter 5.0, Section 5.2.1.2. The solution stabilization process is further described in Chapter 6.0, Section 6.4.1.

A hazards and operability (HazOp) analysis was performed to identify the potential hazards associated with Production VDC operations in glovebox HC-230C-2. The HazOp analysis is documented in Appendix 9.D. As discussed in Appendix 9.D, the scope of the HazOp analysis includes the operations performed within glovebox HC-230C-2 and the systems interfacing with glovebox HC-230C-2. The potential effects of various external natural phenomena on Production VDC operations are also examined. Operations supporting solution stabilization using the Production VDC that are performed outside glovebox HC-

230C-2 (e.g., load-in of Pu nitrate solutions, LOI sampling, and canning) are considered to be adequately covered by the PHA contained in Appendix 9A.

The HazOp in Appendix 9D systematically identifies process deviations that can lead to hazardous conditions (initiating events or sequences) at logical nodes in the Production VDC solution stabilization process by following the flow of material through the stabilization equipment in glovebox HC-230C-2. The HazOp is documented in a tabular format in Table 9D-4. The HazOp qualitatively estimates the consequences and frequencies of each postulated hazardous condition and identifies the engineered and administrative features available to prevent or mitigate the hazardous condition. The rigorous methodology employed in developing the HazOp is discussed in detail in Appendix 9D.

The hazardous conditions identified in the HazOp in Appendix 9D are summarized and binned into logical categories based on the type of initiating event and mitigative barriers challenged in Appendix 9D, Table 9D-3. The hazards bins in Table 9D-3 are identified as abnormal occurrences or accidents based on the likelihood of their occurrence and their potential to breach primary confinement barriers. The abnormal occurrence bins from Table 9D-3 are addressed in detail in Section 9.1 along with the other abnormal occurrences identified prior to installation of the Production VDC process for plutonium-bearing solution stabilization. The accident bins from Table 9D-3 are addressed in detail in Section 9.2 with the other accidents identified prior to installation of the Production VDC process for plutonium-bearing solution stabilization.

9.0.2.1B Preliminary Hazards Analysis of Thermal Stabilization of Plutonium Oxide Process. A Preliminary Hazards Analysis (PHA) was performed that covered the operations performed within the RMC line glove boxes for the thermal stabilization of plutonium oxide (both "clean" and non-product quality) and other non-product quality feed materials, from seal-in of containers of feed material into Glovebox HC-21A to bag-out of the thermally stabilized product oxide from Glovebox HC-18M.

The PHAs in Appendices 9F and 9G systematically identify the potential hazardous conditions associated with the thermal stabilization of reactive plutonium-bearing materials within the RMC line and is broken down into logical sets of operations performed at specific locations. The PHA related to thermal stabilization of "clean" plutonium oxide is documented in a tabular format in Table 9F.2. The PHA related to thermal stabilization of non-product quality feed material is documented in a tabular format in Table 9G.2. The PHAs qualitatively estimate the consequences and frequencies of each postulated hazardous condition and identifies the engineered and administrative features available to prevent or mitigate the hazardous condition. The methodology employed in developing the PHA related to thermal stabilization of "clean" plutonium oxide is discussed in detail in Appendix 9F. The methodology employed in developing the PHA related to thermal stabilization of non-product quality feed material is discussed in detail in Appendix 9G.

The hazardous conditions identified in the PHA in Appendix 9F are summarized and binned into logical categories based on the type of initiating event and mitigative barriers challenged in Appendix 9F, Tables 9F.3 - 9F.20.

Grouping according to event consequence is shown in Tables 9F.21 - 9F.23. The event bins are discussed in Appendix 9F, Section 9F.4.1, including the assignment of Accident Designation categories. The event bins are given Accident Designation categories based on the likelihood of their occurrence and their potential to breach primary confinement barriers. The hazardous conditions identified in the PHA in Appendix 9G are summarized and binned into logical categories based on the type of initiating event and mitigative barriers challenged in Appendix 9G, Tables 9G.3 - 9G.20. The event bins are discussed in Appendix 9G, Section 9G.4.1, including the assignment of Accident Designation categories. The event bins are given Accident Designation categories based on the likelihood of their occurrence and their potential to breach primary confinement barriers. The abnormal occurrence Accident Category event bins are addressed in detail in Section 9.1.11 related to both PHAs discussed above. The Accident Category "Accident" event bins are addressed in Section 9.2.10 related to both PHAs discussed above.

9.0.2.1C Preliminary Hazards Analysis of the Laboratory Prototype Calciner. In addition to plutonium-bearing solution stabilization using the Production VDC, the Laboratory Prototype Calciner in Room 188 of the PPSL is used for solution stabilization operations. The hazards analysis for the Laboratory Prototype Calciner as well as descriptions of the process and equipment are provided in the Laboratory Prototype Calciner addendum to this FSAR.

9.0.2.1D. Thermal Stabilization of Metal. A Hazards Evaluation (HE) was done for the opening of containers of Pu metal, conversion of the metal and corrosion products to plutonium oxide product, and sampling, testing and packaging the product. Hazards evaluation is the analysis of the significance of hazardous situations associated with an activity or process. The HE used the qualitative techniques of Hazard and Operability (HazOp) analysis and What-If analysis to identify those elements of handling and thermal stabilization processing that could lead to accidents. The hazards evaluation is documented in Appendix 9H.

The results of the hazards evaluation determined that the consequences are worker related, i.e., there were no consequences to the onsite individual or the public. The primary causes identified include: 1) superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened cans; and 2) accumulation and subsequent reaction of more than 200 grams of the most reactive corrosion products (hydrides) producing sufficient energy to pressurize a glovebox during can opening (Glovebox 636) or processing (Gloveboxes HC-21A, HC-21C and HC-18M) and breach containment.

No new accident analyses were performed to address these issues. The PFP declared a USQ, which evaluated the concern. The results of the USQ and subsequent process controls are discussed further in Section 9.1.9.

9.0.2.1E. Preliminary Hazards Analysis of Chemical Hazards. Due to the explosion of Tank A109 in the PRF multiple chemical hazards assessments were performed at the PFP. The assessments evaluated damage to the PRF, current chemical operations, and chemical storage and handling areas within the facility, including the laboratories. The analyses are summarized in HNF-6492, *Summary of Chemical Hazards Assessments and Chemical Management*

Programs at the Plutonium Finishing Plant, (Ullah 2000). The results of the analyses determined the following represent the greatest hazards at the PFP:

1. Potential for incompatible chemical mixing
2. "Hold-up" or legacy chemicals
3. Chemical storage and storage container integrity
4. Chemical aging effects
5. Process piping or vessel integrity

It was determined that these areas have the potential to injure facility workers due to fires, explosions, or contact, or expose facility workers, on-site individuals, and the public to airborne chemical releases. Each of these issues have been addressed by the PFP in chemical management programs or completed and planned remedial actions. The following PFP actions and programs were identified in Ullah 2000, as requirements to ensure chemical hazardous or hazardous conditions within the PFP are understood and managed appropriately, thus reducing the potential for adverse impacts to Hanford Site personnel and the public (see Section 10.4.5 for programs descriptions):

- PFP Chemical Management Program (implementation of HNF-PRO-2258)
- PFP Hazardous Material Management Plan (FSP-PFP-5-8, Volume 1, Section 7.1)
- PFP Chemical Hygiene Program (ZAP-000-010)
- Facility or vessel or piping specific operating and surveillance procedures (series ZO)
- For those systems identified as remedial actions the existing PFP controls to manage those systems (e.g., RMC Chem Prep Tanks, Duct Level piping) must be maintained. These systems have been inspected, process data has been reviewed, and, where necessary, residual chemicals have been sampled.

9.0.2.2 Screening Process, Plutonium Releases. The radiological Risk Acceptance Guidelines given in Table 9-49 are not very useful during a screening process because plutonium inventories and release fractions are given in grams. Thus, it is not clear, without further calculation, how much material must be released in order to arrive at the dose figures. During the PHA the dose limits were converted to gram-release-equivalents (Tables 9-51 and 9-52) to give the analyst a more easily-used mental tool for estimating whether or not an event should be forwarded to Sections 9.1 or 9.2. An additional mental calibration tool was provided by translating the stack alarm set point to a gram release by assuming a 1-h duration of release (Section 9.4.4).

From Table 9-52, the most sensitive or lowest amount of release derived from risk criteria is that for a ground-level, offsite organ dose with Class W material where

$$\text{Release} = 0.005 \text{ g}$$

Derivation of this number and other combinations of probability, and type of release, are presented in Section 9.4.3.

A useful benchmark for evaluation is to assume a 1-h release of plutonium at the stack alarm level of 2×10^{-12} Ci/m^3 and a flow rate of 270,000 ft^3/min. Such a release corresponds to 5.7×10^{-7} g/h. A comparison of this alarm limit value with the least allowable stack release of 0.015 g during an accident, at probability 1.0 (Table 9-52), shows a factor of 2.6×10^4 difference.

9.0.2.3 Functions Excluded from Analysis. Analysis of an operating facility cannot be completed in one version of a document. Certain functions of the facility are out of operation at any given time and must undergo procedural or design modifications that are not defined. In order to publish a document a time comes at which the scope must be frozen. The functions listed in Table 9-2 were excluded. As other functions are brought online they will be included as future revisions.

In addition, the activities associated with terminal cleanout operations (TCO) are not addressed in the accident analysis. TCO must be evaluated to determine that they are covered by the facility authorization basis. If the activities directly or indirectly affect the facility authorization basis, then the activity must be reviewed in accordance with the Unreviewed Safety Question (USQ) process specified by DOE Order 5480.21, *Unreviewed Safety Questions*. Changes to the authorization basis will be incorporated into the PFP FSAR during the annual update.

9.1 ABNORMAL OPERATIONS

Section 9.0.2.1 defined abnormal operations and how they differ from accidents. While the upper bound of what constitutes an abnormal operation is fairly well defined, the lower bound has no definition.

Most events identified by the hazards analysis process are those caused by or resulting from deviation from normal or expected operation. Once an abnormal event has been identified, a decision must be made as to whether the event requires additional formal evaluation or will simply remain in the PHA. For this safety analysis the decision as to whether or not an abnormal event was selected for further evaluation was based on probability of occurrence and subjective engineering judgement of possible impact on plant personnel. Events identified as "abnormal" were not selected for further evaluation if two or more independent errors or failures were required to cause the event. Note however, that some abnormal events were forwarded for evaluation in spite of the two-failures rule. The bounding scenarios for the release of plutonium compounds into the buildings require more than two failures, but the scenarios were selected for further evaluation to present bounding cases.

9.1A ABNORMAL OPERATIONS FOR THE PLUTONIUM-BEARING SOLUTION STABILIZATION PROCESS USING THE PRODUCTION VERTICAL DENITRATION CALCINER

Abnormal operations for the plutonium-bearing solution stabilization process using the Production VDC in glovebox HC-230C-2 are defined as those relatively high likelihood process upset conditions with the potential to result in elevated radiological or toxicological releases to the glovebox confinement or plant vacuum systems. The glovebox confinement system is considered to be composed of the glovebox structure and the E-4 ventilation system. Two general types of abnormal operations were identified from the HazOp contained in Appendix 9D: releases of radiological material from solution stabilization equipment to the glovebox HC-230C-2 atmosphere (Bin ID B from Table 9D-3); and releases of process liquids, NO_x, or nitric acid vapor to the plant vacuum system (Bin ID I from Table 9D-3). Both types of events have the potential to increase facility worker doses (either direct shine dose during normal operations or personnel contamination potential during maintenance activities) but do not pose an immediate inhalation hazard to facility workers since airborne particulates and toxic gases remain confined to the E-4 ventilation and plant vacuum systems. Accident scenarios that can result in significant releases of radiological material outside the glovebox or Zone 4 confinement system, which could pose inhalation hazards to facility workers or to individuals outside the PFP exclusion zone, are addressed in Section 9.2.

In addition to performing the HazOp analysis to identify new or unique hazards associated with the plutonium-bearing solution stabilization process, the abnormal operations in Sections 9.1.1 through 9.1.9 were revisited to identify potential impacts from Production VDC operations. Additional analyses or changes to the existing analyses would be required if: 1) a process upset condition within the Production VDC solution stabilization process was identified that was of a similar type to the existing abnormal operation but with postulated consequences that were higher than in the existing analysis, or 2) if the radiological inventory associated with the

Production VDC solution stabilization process required that the release source term in an existing plant abnormal operation analysis be increased significantly. The evaluation of potential impacts posed by the Production VDC process for plutonium-bearing solution stabilization on the original abnormal operations contained in Sections 9.1.1 through 9.1.9 is summarized in Table 9-54. The evaluation examined the effects of potential upset conditions within glovebox HC-230C-2 and potential upset conditions in other areas of PFP associated with the Production VDC solution stabilization process. No significant changes to the original abnormal operation analyses were found to be warranted. In all cases the original analyses were found to be adequately representative of postulated upset conditions in the Production VDC solution stabilization process or to be not relevant to upsets in the solution stabilization process.

Sections 9.1.1 through 9.1.9 contain the abnormal operations developed for the PFP before the Production VDC process for plutonium-bearing solution stabilization was put in place. The two abnormal operations for the Production VDC process for plutonium-bearing solution stabilization, identified from the HazOp analysis, are addressed separately in Section 9.1.10.

9.1B ABNORMAL OPERATIONS FOR THE THERMAL STABILIZATION OF PLUTONIUM OXIDE PROCESS

Abnormal operation categories (bins) identified for the thermal stabilization of "clean" plutonium oxide are summarized in Appendix 9F, Table 9F.22. The abnormal operation categories were screened from the PHA and are discussed in Appendix 9F, Section 9F.4.3.2. Abnormal operation categories (bins) are identified for the thermal stabilization of non-product quality feed material as those operation categories represented by hazards with either an "S0" or an "S1" consequence rank in Appendix 9G, Table 9G.2 The abnormal operation categories were screened from the PHA and are discussed in Appendix 9G, Section 9G.4.1. The abnormal operations categories represent types of events associated with the thermal stabilization operations in Glove Boxes HC-21A, HC-2, HC-21C, HA-21I, HC-18BS, and HC-18M that have a relatively high likelihood of process upset conditions with the potential to result in elevated radiological or toxicological releases to the room atmosphere, glovebox interior, or temporary waste storage area. Ten categories of abnormal operations for the plutonium oxide thermal stabilization process were identified in the PHAs documented in Appendices 9F and 9G. These event categories are: contaminated wound, dispersal of plutonium oxide powder inside a glove box, dispersal of minor amounts of plutonium oxide powder outside a glove box during bagout operations, dropped container outside glovebox, flammable gas deflagration in glovebox, flammable gas deflagration in a waste drum, loss of glovebox confinement due to mechanical breach, loss of glovebox confinement due to ventilation failure, rupture of container in storage vault, and pyrophoric reaction in furnace. Each of the abnormal operations categories from Table 9F.22 and Table 9G.2 are discussed in Section 9.1.11. Each abnormal operations category is compared and evaluated against the original analyses contained in Sections 9.1.1 through 9.1.10.

In addition to performing the PHA analysis to identify new or unique hazards associated with the thermal stabilization of plutonium oxide process,

the abnormal operations in sections 9.1.1 through 9.1.10 were revisited to identify potential impacts from the process. Additional analyses or changes to the existing analyses would be required if: 1) a process upset condition within the thermal stabilization process was identified that was of a similar type to the existing abnormal operation but with postulated consequences that were higher than in the existing analysis, or 2) if the radiological inventory associated with the thermal stabilization process required that the release source term in an existing plant abnormal operation analysis be increased significantly. No significant changes to the original abnormal operation analyses were found to be warranted. In all cases the original analyses were found to be adequately representative of postulated upset conditions in the thermal stabilization process or to not be relevant to upsets in the thermal stabilization process.

9.1C ABNORMAL OPERATIONS FOR THE LABORATORY PROTOTYPE CALCINER

Abnormal operations identified and evaluated for operation of the Laboratory Prototype Calciner are discussed in the Laboratory Prototype Calciner addendum to this FSAR. It is noted that operation of the laboratory calciner is not currently authorized.

9.1D ABNORMAL OPERATIONS FOR THE MAGNESIUM HYDROXIDE PRECIPITATION PROCESS

Abnormal operations identified and evaluated for operation of the Magnesium Hydroxide Precipitation Process are discussed in the related addendum (Carson 2000) to this FSAR.

9.1E ABNORMAL OPERATIONS FOR THE BAGLESS TRANSFER SYSTEM (BTS)

Abnormal operations identified and evaluated for operation of the BTS are discussed in the calculation notes (FH 2000) for the BTS.

9.1F SYNOPSIS OF ABNORMAL OPERATIONS

Table 9-3 presents a synopsis of each of the abnormal operations considered in the following subsections.

9.1.1 Radioisotope-Bearing Liquid Spills

Three different types of containers, each having a volume of 10 L, are used to store $Pu(NO_3)_4$ solution. The three containers are designated: L-10, 10-L, and the FL-10. These containers are all stored within the 234-5Z Building. There are no plans for moving these containers to other buildings of the PFP complex. The containers are transported within the building by hand trucks. Even if plans should change and the containers were moved to the 2736-Z Building for storage, the probability of a spill is considered incredible. The L-10 and FL-10 containers are built to withstand the forces involved in a public highway accident without loss of containment. In such accidents, the outer container may lose integrity but show no evidence

of inner containment vessel leakage. (The actual innermost vessel is a plastic bottle but, given the embrittlement caused by radiation, it is assumed that even in a low energy accident such as tipover the bottle would leak.) The containment vessel consists of type 304-L stainless steel, 5-in.-dia, schedule-40 pipe, 53.5 in. long, with type 304-L stainless steel 300-lb slip-on flange. A blind flange is fastened to this with 8 3/4-in. steel bolts. The blind flange is gasketed to the vessel and equipped with a protected vent valve (Genoni 1984, p. 29). Thus, loss of liquid to the environment from a simple tip-over accident during hand transport is assumed to be incredible. In contrast, the 10-L container is equipped with a clamp-on closure for the containment vessel. Even though they do not meet U.S. Department of Transportation requirements and are not approved for cross-country highway use they are not expected to leak from both the inner and outer containers as a result of a simple tipover event.

9.1.1.1 Postulated Cause of the Event.

9.1.1.1.1 Starting Conditions and Assumptions. Plutonium-containing liquid spills have occurred during past PFP operations and may be expected to occur in the future due to common human errors. Factors such as psychological stress, the quality of training and supervision, differences in attention to human factors details, design and maintenance are all variables which affect the probability that a spill will occur. In the past, spills have been caused by the misrouting of glovebox connections, accidental discharge of sprinkler systems in contaminated areas, failed seals, leaking valves, overfilling of vessels, check valves failing in the open position and allowing unanticipated backflows, operators turning the wrong valve, management error, and corrosion of a protective barrier.

The composition of a potential liquid spill can run from slightly contaminated waste water to liquids containing significant amounts of radionuclides. A liquid spill can produce contaminated aerosols, which are then dispersed as a function of the available air currents. Aerosols are classified as either condensation or dispersion, depending on the mechanism of their deposition. Liquid spills can produce both condensation-type aerosols from offgasing or gas-phase reactions and dispersion-type aerosols from liquid shear during a spill.

Virtually any liquid handled at the PFP has some probability of being spilled. These spills can occur anywhere within the facility that the liquids are handled. However, PFP design, equipment, systems, training, management, and operations, reduce the likelihood of large spills with concentrated material. The likelihood for inconsequential spills is greater. The greatest likelihood of a spill occurs during routine handling of small plutonium-bearing laboratory samples. If the samples are spilled, the consequences would be minimal and are, in fact, anticipated events.

9.1.1.1.2 Engineered Safety Features and Protective Systems. All radionuclide-bearing liquids handled in the PFP are confined within systems such that a single failure will not result in the release to the environment. In most cases, several failures would be required to result in an environmental release. Contaminated liquids are normally handled within enclosed gloveboxes or hoods that have preferential airflow away from operational personnel. Liquids are not brought out into a room until they

have been enclosed in several protective layers which include containers, canisters, and sealed plastic bags.

Laboratory sample-size radionuclide-bearing liquids may be handled in open-faced fume hoods, which are standard laboratory equipment, and exhausted via the ventilation system serving the particular room. Airflow is maintained into the hoods at aerosol capture velocity and there are capture ledges to prevent spilled liquids from running out. The high efficiency particulate air (HEPA) filters are not normally installed at the point of fume hood exhaust. The rooms containing fume hoods are provided with continuous air monitors (CAMs) and air samplers. Shielding is not normally provided. For high dose rate samples, extension tools or smaller sample sizes are used to reduce exposure. Each workstation is normally provided with a trouble alarm.

In the event a spill occurs, the first line of personnel defense is operator training, which teaches the correct responses to a spill. In addition, the processing rooms are equipped with CAMs that alert personnel to the presence of respirable airborne contaminants. Either due to actions of trained operators and/or the warning by CAMs, response to upsets has historically resulted in evacuation of the immediate area before operators have inhaled significant amounts of any airborne contaminants. The CAMs are an aid to warn personnel of airborne contamination; however, the first and best detection/warning is the operator on the scene.

The construction of the facility and systems, training, operation, maintenance, and management are designed to include appropriate redundancy and diversity of safety features to minimize the possibility of concurrent common-mode failures. The PFP confinement systems include the confinement barriers and the associated ventilation systems. Multiple barriers and redundancy in systems are provided in the unlikely event that any barrier or component of a particular confinement system fails.

The PFP has at least three redundant confinement systems that protect against an inadvertent release of radionuclides.

- **Primary Confinement System**--Consists of the process enclosures and their associated ventilation system, which maintain a negative pressure drop from the room into the process enclosures or gloveboxes. The primary system can also be considered to be the process vessels within the enclosures or the cans and containers that products are handled and stored in.

- **Secondary Confinement System**--Consists of the barriers that enclose the areas (rooms) that house the primary confinement system and the system that ventilates those areas. Those areas may be referred to as operating areas or operating area compartments.

- **Tertiary Confinement System**--Consists of the building structure and its ventilation system.

Ventilation systems within each of the confinement systems maintain a controlled, continuous airflow pattern from the environment into the confinement building, then from uncontaminated areas of the building (zone 1) to potentially contaminated areas (zone 3), and then to normally contaminated

areas (zone 4). Thus, the airflow is toward areas of higher radioactive or hazardous material contamination. Note that ventilation zone designations are reversed in the 2736-Z Complex; Zone 1 is the most contaminated, Zone 4 is uncontaminated. The three confinement systems are balanced so as to ensure that the individual system air pressures in zones 3 and 4 are normally negative with respect to the outside atmosphere to prevent movement of airborne material out of the building.

The confinement systems are instrumented and monitored to display/record system status and to alert operations and response personnel in the event of upset conditions or loss-of-confinement capability. The ventilation systems are instrumented so that an alarm will sound in the power control room following loss of negative pressure from one confinement system into the next, except from zone 3 to zone 4. The CAMs are provided to detect airborne radioactive material resulting from a liquid spill into zone 3.

9.1.1.2 Detection of Event. A liquid spill may be detected by a variety of established passive or active methods.

9.1.1.2.1 Methods or Means of Detection. An operator or other individual may simply observe a spill; a Radiological Control Technician (RCT) performing a surveillance could find evidence of a spill; CAMs may detect the radioactive aerosols produced from a spill; personnel in the course of self-monitoring may detect evidence of a spill; or, as a last recourse, surveys done at building or protected-area exits may detect spill spread contamination.

Air monitoring and warning systems are installed in work areas where dispersible radioactive materials are handled in order to detect airborne contamination. Air sampling heads are located to provide a representative sample of potential airborne radioactive materials being breathed. Depending on the volatility or energization of the potentially spilled radionuclides, air monitors may or may not be able to discover a spill. The CAMs are set to detect and alarm at prescribed airborne radioactivity levels, but, if the components of a spill do not become airborne in sufficient concentration then detection may not occur by this method.

Spills are also detected by RCTs performing routine area or equipment surveillances or preinspection of a radiation work area.

9.1.1.2.2 Response Time Assessment. Since the most likely component of a liquid spill in the PFP is potentially airborne radionuclides, the immediate evacuation of the spill area is required. Respiratory protection must be used if room access is necessary. However, unless the extent of the spill is large or the liquid falls from a significant height, automatic detection may not be affected due to the small amount of material that becomes airborne. In that case there may be significant lag time between the event and detection. First detection may come about through self-monitoring of shoecovers at exits by personnel who walk through a contaminated area. Detection of spills in remote areas may take some time until found by a RCT making a periodic check of the area. An experienced operator or laboratory technician is often aware of a spill as soon as it occurs, because they recognize their own error. Process or laboratory personnel can, with the aid of RCTs, assess the extent of the spill. Often this can be accomplished from the door to an adjoining room or

corridor. Personnel safety is assured through a combination of airflow and respiratory protection devices.

9.1.1.3 Analysis of Effects and Consequences. For the purpose of this analysis it was assumed that the entire contents of a 10-L polyethylene or steel bottle containing plutonium nitrate solution spilled from a height of 3 m within the facility and onto the floor outside a glovebox. This is considered to be very conservative since 10-L polyethylene bottles at one time were hoisted up and out of the container to be emptied. This required that the bottles be lifted ≈1.5 m in hood HC-227T, but this method of unloading has been discontinued. The product receiver (PR) cans are still lifted up and out of their containers to be unloaded; however, they are considerably stronger than the polyethylene 10-L bottles; PR cans are constructed of steel. It was also assumed that all other protective systems were operating normally before the spill.

Spill energy is an important factor in determining the magnitude of release. Spill height determines the amount of gravitational energy available to break up and rebound particles on impact. Height also influences the amount of time source material is exposed to shear forces during the fall. These forces work to break off particles from a falling stream. Some plutonium may be resuspended from a spill surface but this amount is estimated to be insignificant to the spilling process and is time dependent.

As the result of a spill from a height of 3 m, it is estimated that 0.002% by weight of the plutonium nitrate solution as droplets will become airborne (NRC 1981). For a 10-L bottle of plutonium nitrate solution with a 1.64 g/cm^3 density, a total of 0.33 g of plutonium nitrate solution (0.16 g of plutonium) may become airborne. This amount can vary depending on the presence of air currents, the relative humidity, and the temperature; however, these factors are considered small contributors to total airborne mass. A single stage of HEPA filtration reduces the quantity of plutonium released to approximately 1×10^{-4} g. This is significantly below the quantity of plutonium necessary to be released to exceed the allowable dose for an event with probability 1.0 (Table 9-51).

9.1.1.4 Corrective Actions. If a liquid spill occurs outside a glovebox, the corrective actions necessary can be summarized into evacuation, exclusion, investigation, confinement, cleanup, and restoration/inspection. The first step would be to establish and post the area as an Airborne Radioactivity Area following the evacuation of personnel. Reporting the event through required channels would ensure that additional help would be made available. Evacuation would then restrict or exclude access to all but those individuals authorized to monitor and clean up the spill. The next step would be to determine the nature and extent of the spill and to prevent it from moving or being moved from its known location using established procedures designed to ensure that any contamination is fixed in-place. Cleanup begins only after trained operators have donned prescribed protective equipment. Care is taken that recovery efforts do not expand the event beyond its present confines or cause contamination of operators. It might be necessary to erect a greenhouse at the entry to the adjacent room or corridor to confine the spread of contaminants while cleanup proceeds. Cleanup would involve removing and stabilizing the spilled material until the results are satisfactory to Radiological Control and management personnel. Once the area has been

restored to the prespill condition, any further inspections and administrative functions necessary would be applied to release the area to a normal operational status.

9.1.2 Radioisotope-Bearing Pressurized Liquid Container

Containers of plutonium-bearing solutions, all of which have some small potential to become pressurized, are stored in the PFP in a variety of locations, quantities, and concentrations. Due to physical and procedural controls, potential for significant discharge of a pressurized container into an occupied area is low. Discharge within a glovebox would be contained. The discharge of a pressurized container of plutonium-bearing liquid outside of a process enclosure was reviewed and the consequences were found to be marginal within the PFP. Plutonium nitrate liquid is stored in 10-L containers, which represents the largest total quantity and most concentrated solution that is routinely handled outside a process enclosure in proximity to the plant staff. Laboratory sample-size containers and dilute quantities from cleanup operations are also routinely handled outside of process enclosures and are more numerous; however, they involve smaller quantities of materials. This section discusses both types of pressurized liquid containers.

A variety of liquid containers handled within the PFP have the potential to become pressurized to the point that, when opened, part of the contents could be rapidly discharged. The manner in which the pressurization of the containers could occur, and the resultant relieving of the pressure buildup in general, is of concern. The Fire Hazard Analysis (McKinnis 1998) identified a potential hydrogen deflagration resulting from a pressurized release from a Product Receiver (PR) drum. The hydrogen flammability concerns for all containers are briefly discussed in this section and are detailed for PR drums in Section 9.1.2A.

9.1.2.1 Postulated Cause of the Event. Liquid containers can either be passively or actively (i.e., due to application of an outside agent) pressurized. Passive causes can be attributed to the chemical decomposition of the contained liquids, nuclear degradation of the container material, chemical corrosion of the container material, or radiolytic gas buildup. Active pressurization agents could be attributed to the application of heat; mishandling, resulting in physical crushing; or a chemical reaction within the vessel.

9.1.2.1.1 Starting Conditions and Assumptions. It is assumed for this analysis that liquid containers are handled in a normal manner. The primary containers are located within secondary vessels or containers designed for that usage. They are handled with devices provided for that usage. In addition, it is assumed that experience recorded in event reports and their corrective actions exists and personnel training includes this information. The PR cans and L-10 containers (overpacks) are opened in open-faced hoods with the operators wearing supplied-air respirators in the event of an inadvertent release that could be inhaled. All venting and lid removals are performed in these hoods.

Pressurization of a liquid container does not constitute a problem until it causes the failure of its primary container or causes an event when an

attempt is made to transfer the liquid. The result of primary container failure would, in most cases, be mitigated by the secondary container or overpack. Should the primary container fail during transfer of the primary container to a hood or glovebox, the result could be personnel injury and contamination spread. To a lesser degree, there could be spread of contamination during the venting steps of a piped liquid transfer.

The major portions of plutonium solutions are typically kept in either FL-10 or L-10 shipping containers and PR cans and 10-L storage containers. Liquid solutions containing plutonium nitrate require unloading for processing. Plutonium solutions are currently stored in the PFP and delivered to the room 227 load-in/load-out (LI/LO) hood as needed. Due to a prohibition against shipping radioactive solutions offsite, it is anticipated that the PFP will not receive any additional offsite plutonium solutions. Shipping containers for liquids have a special provision for venting internal pressure, while storage containers have vents built in or installed that allow continual venting of the interior. Normally, a shipping container will be in a vented condition while being stored, and the vent will be closed or removed by an operator before transport to the 234-5Z Building to minimize the possibility of a leak during shipment.

In addition to the large containers of liquid products that are routinely handled outside gloveboxes, small bottles of samples for analysis are routinely handled that also have the potential to become pressurized. The PFPAL receives sample bottles of liquids from PFP operations, the PPSL, and other Hanford Site and offsite customers. Sampling or nondestructive assay NDA is made of materials entering or leaving various points in the process. Measurements of material are used in process control, criticality control, and in the control and accountability of plutonium as part of the overall safeguards program.

9.1.2.1.2 Sequence of Events. There are essentially two points in the processing of liquid containers where the overpressurization of the container can become an abnormal event. The first occurs when, upon opening an overpack, the operator observes that the primary container has failed due to overpressurization. The contents must now be emptied from the overpack into a new container and the ruptured container must be removed and discarded. The overpack must be decontaminated before reuse, or simply discarded.

The second case arises when the pressure has not been relieved from the liquid container either through plugging of the vent valve or the improper application of the venting procedure before opening the pressure vessel (PV). Most liquid containers and overpacks have vents constructed into them to prevent an overpressure condition. The L-10 and 10-L bottles are closed with a vented cap and placed into an overpack that has a vent valve constructed into the lid. Before opening the overpack, a discharge line is connected to the vent valve and the valve is opened to allow any excess pressure to be safely discharged. In a past event, venting of the overpack was overlooked with the result that excess gas volume was discharged and the gas ignited. The resulting deflagration singed the operator's eyebrows and lashes.

During storage PR cans are closed with a vented stopper held in place with an attachment clamp, and the outer PR container is equipped with vent clips or a filtered vented lid. During shipping the vent clips are removed

from the outer drum and the ring tightened to a specified value with a torque wrench. After receipt of a full PR container/can, the outer container is vented and vent clips applied within a specified period of time. Due to the low gas buildup rate, lack of venting the container itself would represent a minimal hazard. A potentially significant hazard would exist if the vented polyethylene stopper in the PR can were to become plugged; the gas buildup rate is significant within the smaller volume of the can and the eventual discharge of the pressure could distribute a fraction of the PR can contents. However, since the PR can is normally enclosed in the PR container, discharge into its bigger volume would not be a serious problem. It is only if the outer PR container is open during unloading that a pressure discharge would pose a significant hazard. The venting device resembles an inverted hat set into the neck of the PR can, with a vent hole in the crown and the hat filled with glass wool. The brim of the "hat" acts as a gasket which, along with a softer gasket, is held in place by a bolted-down steel lid. Pressure could blow out the gasket or collapse the "hat" upward and break it. With the PR can upright for loadout not much solution would come out. Workers handling the PR cans are garbed to handle releases. Failure to vent the outer container could lead to H_2 enrichment and pressurization of the outer container, which is described in Section 9.1.2A.

As required, liquid containers are transported by a hand operated dolly to room 227. A 10-L bottle/overpack or PR can/container is placed in the lower section of the LI/LO hood, 227-T. The containers are surveyed for contamination and radiation levels before opening. The outer container or jacket is then electrically grounded to prevent sparking that could ignite any enclosed hydrogen, and the lid removed. The open top of the FL-10 or L-10 shipping container, PR cans, and 10-L storage containers would then be enclosed into the PR hood and a greenhouse placed around the container. The interior of the container is surveyed and decontaminated as necessary. The inner container is then grounded. If the container is an FL-10 or L-10, the vent valve outlet is connected to the building's 26-in. vacuum system, the vent is opened, and the container is vented. The container lid would then be unbolted using nonsparking tools and the lid removed. If the venting procedure was less than adequate, the rapid discharge of collected gases and possibly some liquids would occur. A load-out head is then used to vacuum-transfer the solution to a glass tank in glovebox 227-S.

If a PR can vent port was to become plugged, pressure could build up in the can and, upon loosening the PR can lid, a rapid discharge of gases and some liquids could occur. Hydrogen flammability issues are described in Section 9.1.2A. The lid of a 10-L bottle is similar in configuration to the lid of a PR can and is subject to vent blockage in the same fashion as a PR can lid. In all cases the discharge of gas with contained liquid due to excessive pressure would occur from the periphery of the lid or cap, and probably be directed in a flat spray from one side of the container. This would spread contamination within the hood but would not expose the operators, since during unloading the operators are required to wear respiratory protection, acid suits, and heavy Viton[1] gloves.

[1]Viton is a trademark of E.I. DuPont de Nemours and Company, Wilmington, Delaware.

Experience indicates that a small number of the polyethylene bottles can be expected to leak within the overpack. The leak usually occurs along a seam. If the bottle vent is plugged, the pressure of radiolytic gas may force liquid out of the bottle, causing a level lower in the bottle than that in the surrounding PV. In this situation the contaminated bottle would rise out of the vessel as the lid is removed. In either case, the liquid is vacuum-transferred out of the bottle and the PV if necessary. If the bottle is contained in a 10-L storage container, the bottle and vessel are rinsed with acid, sprayed with fixant, the lid is clamped in place on the overpack, and the entire storage container is disposed of as waste. If the bottle is contained in a shipping container, the bottle is normally bagged and disposed of, and the container decontaminated for reuse.

Small bottles of laboratory samples can become pressurized due to the chemical decomposition or radiolysis of the contained materials. The samples are taken to ascertain the characteristics of the product or recoverable materials stream at various points in the process. One of the characteristics is the ability to cause offgasing, which will build up pressure in a closed container. The offgasing process is time dependent and, if the sampling or NDA is performed quickly, there is little hazard. However, over a period of time overpressurization of the sample bottle can result. Bottles that must be kept for some time are either vented on a scheduled basis or are equipped with a vented cap.

There have been several examples of pressurized PFPAL sample containers failing. Some years ago a glass bottle exploded in a closed cupboard, leaving glass shards stuck into surrounding objects. In another instance the contents of a 30-mL plastic bottle of plutonium-product solution were found spread over a considerable area of laboratory floor, after the bottle pressure was relieved through a small hole blown out of the bottom of the bottle, where the plastic entered the mold during manufacture. The bottle rose out of its container and, as it was propelled to the back of the hood, the liquid squirted out into the room. These events did not lead to release to the environment or result in exposure to plant personnel due to the training, controls, and barriers at the PFP.

9.1.2.1.3 Operator Actions. Operator actions other than normal handling routines, need not be required at the time of the occurrence. Incorrect actions of others set up the situation, as when a PR container that had the vent clips removed for shipping had not had the clips replaced in the required time specified by procedure. Effort is made to learn from past events to preclude the reoccurrence and any similar events and continued declines in event occurrence rates indicate success. There is little likelihood that any operator actions would increase the consequences, other than the gross violation of procedures (e.g., opening a pressurized container in an occupied area). Although in the past, procedural steps have been missed and hold points sometimes bypassed, the probability of that occurring to a bottle that had a venting failure or blockage of a vent is not likely.

9.1.2.1.4 Engineered and Administrative Safety Features and Protective Systems. The uncontrolled spread of airborne contamination outside of the facility is prevented by a combination of physical barriers and the building ventilation system. The probability of contamination release to the environs is minimized by maintaining progressively decreasing pressures from

noncontaminated, or "cold" zones, to the highly contaminated gloveboxes, and by pulling the exhaust air from these areas through HEPA filters. Integrity of the filters is ensured by the specified periodic aerosol penetrant challenge tests (Section 5.4.1.2.2) and are monitored continuously for signs of failure by the stack-sampling program.

To eliminate pressurization, containers must be properly vented while in storage and sample bottles must be emptied or vented. If it is determined that the containers are not vented or sample bottles have not been emptied, immediate corrective action must be taken to protect personnel.

9.1.2.2 Detection of Event.

9.1.2.2.1 Methods or Means of Detection. Detection of a liquid container that has not been properly vented is most likely to occur through direct observation by the operator or technician. For bulk process solutions this is likely to happen when the operator removes the L-10-type PV lid or the PR can lid. This will result in the rapid discharge of the excess pressure into the greenhouse around the FL-10 or L-10 containers. The PR cans would discharge the excess pressure into the 227-T hood, having been raised out of the container before lid removal. The enclosure constructed around the bottom of the container would contain any discharged contaminants and prevent operator exposure, unless the greenhouse was defective. In that event, CAMs and other protective measures would detect the loss of confinement, warning the operator and management of the event.

Small plastic bottles are likely to be swollen. The most hazardous are the glass bottles, which show no visible signs of pressurization, but could explode while in a worker's gloved hand.

9.1.2.3 Analysis of Effects and Consequences. For the purpose of this analysis it was assumed that 5 L of the contents of a 10-L polyethylene bottle containing plutonium nitrate solution were ejected and dropped from a height of 3 m, within the facility and onto the floor outside a glovebox. This highly improbable scenario was chosen from the various sequences in Section 9.1.2.1.2 as a bounding case. This is considered to be a highly conservative estimate, since the top of the tallest container assembly is less than 2 m and, for the most part, only gaseous products would be released from the top of the container, since the most likely source of pressure relief would occur during improper container opening. Unlike a pressurized leak from a line under pump pressure, the pressure here would decrease with time. It was also assumed that all other protective systems were operating normally before the pressure relief. Pressure and height are the most important factors in determining the magnitude of the release. The liquid must fall onto the floor outside the hood and the spill height determines the amount of gravitational energy available to break up and rebound particles on impact. Height also influences the amount of time source material is exposed to shear forces during the fall. These forces work to break off particles from a falling stream. Some plutonium may be resuspended from a spill surface, but that amount is estimated to be insignificant compared to suspension from the spilling process, and is time dependent.

As the result of a spill from a height of 3 m, it is estimated that 0.002% by weight of the plutonium nitrate solution as droplets will become

airborne (NRC 1981). For a 5-L spill from a 10-L bottle of plutonium nitrate solution with a 1.64-g/cm^3 density, a total of 0.16 g of plutonium nitrate solution (0.08 g of plutonium) may become airborne. This total number can vary depending on the presence of air currents, the relative humidity, and temperature; however, these factors are considered small contributors to total airborne mass. A single stage of HEPA filtration reduces the quantity of plutonium released to approximately 1 x 10^{-4} g. This is less than the quantity of plutonium necessary to be released to exceed the allowable dose for an anticipated event (see Table 9-51).

Contaminated liquids are normally handled within enclosed gloveboxes or hoods that have preferential airflow away from operational personnel, and they are not brought out into a room until they have been enclosed in a number of different layers of protective containers and canisters. An exception to this is laboratory sample-size amounts and laboratory waste bottles; however, in contrast to a postulated 5-L release, the amount is insignificant. Either due to actions of trained operators and/or the warning by CAMs, response to upsets has historically resulted in area evacuations before operators have ingested significant amounts of any airborne contaminants. The CAMs are an aide to warn personnel of airborne contamination, but the first and best detection/warning is the operator on the scene.

9.1.2.4 Corrective Actions. The PFP has trained plant personnel, administrative procedures, and equipment available to recover from any potential spill. Regardless, emphasis is placed on prevention of spills, which is based on information of past spills and postulated spills. However, if the sudden release of an overpressurized liquid container occurs, such as to spray liquid out of the load-out hood or a sample bottle breaks outside a glovebox, the necessary corrective actions can be summarized as evacuation, exclusion, confinement, cleanup, and restoration/inspection. The first step would be to establish the area as an Airborne Radioactivity Area after the alarms have sounded and the personnel were evacuated. This would restrict or exclude access to all but those authorized individuals needed to monitor and clean up the spray. The next step would be to determine the nature and extent of the spill and prevent the liquid from moving or being moved from its known location. Cleanup would involve removing and stabilizing the spilled material until the results are satisfactory to monitoring and management personnel. Once the area had been restored to the pre-event condition, any further inspections and administrative functions necessary would be applied to release the area to normal operational status.

9.1.2A Hydrogen Flammability Conditions of Product Receiver Drums

Containers of plutonium-bearing solutions all have the potential to pressurize. Some of the radiolytic gas generated is hydrogen, which is flammable at concentrations above 4%. This section examines the hydrogen flammability potential in PR drums (overpacks) and in Room 236, which stores a maximum of 378 PR drums, at the PFP. The Fire Hazard Analysis (McKinnis 1998) indicates that there is no hydrogen flammability concern (with a large safety margin of more than 5 orders of magnitude) in Room 236 under normal ventilation conditions (6800 ft^3/min).

9.1.2A.1 Postulated Cause of the Event. Radiolysis takes place in all radioisotope-bearing pressurized liquid containers and generates gases. Hydrogen is one of the radiolytic gases generated. The radiolytic gas generation rates depend upon the types of radiation particles, their integrated energies, the chemical composition of the solutions, and the chemical composition of the containers. It has been shown in HNF-2061, *Plutonium Finishing Plant Project: Gas Generation from Plastics during Vault Storage via Radiolysis Reactions* (HNF 1999c), that alpha radiation from plutonium dominates the production of radiolytic gases from hydrogenous substrates. The main substrate with hydrogen in the bottles stored in the PR drums is plutonium nitrate ($PuHNO_3$), and the radiolytic gases are hydrogen, oxygen, nitrogen, and nitric oxide, with hydrogen making up about 62% (mole number percentage) of the generated gas (Cooper 2000, *Gas Generation in Product Receiver Can Drums*).

With hydrogen being generated in the bottles stored in the PR drums, flammability conditions can be reached as soon as 3000 hours (Cooper 2000, Figure 2) for a worst-case drum, and in 20,000 hours (< 2.5 years)for an average drum, if the PR drums are leak tight (i.e., with only hydrogen diffusion through gasket occuring) and are not vented. Furthermore, hydrogen flammability conditions can be reached in a worst-case PR drum with a small vent, but not in an average PR drum (Cooper 2000). With flammable conditions expected in the PR drums (assuming that the interior bottles leak under pressure) with no vent or a plugged vent, and in a worst-case drum with a small vent, opening the PR drums could ignite the hydrogen and cause a hydrogen deflagration.

In regards to flammability conditions in the storage room (Room 236), the Fire Hazard Analysis (McKinnis 1998) conservatively used a maximum hydrogen generation rate of 0.82 L/week per drum (based on the higher, more conservative, radiolytic G-value of water instead of plutonium-nitric acid solutions), for a total generation rate of 44.3 L/day for 378 drums in Room 236. More realistic calculations result in a maximum hydrogen generation rate of about 0.63 L/week (Cooper 2000) per worst-case PR drum, for a total generation rate of 33.9 L/day for Room 236, assuming each of 378 drums is the worst-case drum. With a room ventilation rate of 193 m^3/min ($2.78 \times 10^{+8}$ L/day), the maximum hydrogen generation rate of 44.3 L/day is only 0.000016% of the total ventilation rate. Hence, flammability conditions (hydrogen concentration of 4%) cannot be reached in the storage room if the ventilation system is functioning since the conservative maximum hydrogen concentration is only 0.000016%. Even if the ventilation system is not functioning, the analysis in 15F00-00-42 (Cooper 2000) indicates that flammability conditions are not expected in Room 236 based on just barometric pressure changes and resulting leakage and dilution.

Hence, the only concern with hydrogen flammability conditions is inside a PR drum, which is leak tight and not vented or plugged, or the worst-case PR drum with small vent (Cooper 2000).

9.1.2A.1.1 Starting Conditions and Assumptions. The small bottles in the PR drums are assumed to leak under pressure or vent into the PR drums by design. The accidental PR drum is assumed to have no vent or a plugged vent, or the drum is a worst-case drum (in regards to hydrogen generation rate) with a small vent.

9.1.2A.1.2 Sequence of Events. In order for a hydrogen deflagration to occur when a PR drum is opened, improper application of the venting procedure must have been followed on a problem drum (not vented or worst-case vented drum).

9.1.2A.1.3 Operator Actions. Based on the results of the analysis there will be the potential for hydrogen gas at or above the LFL within unvented (e.g., no vent clip) or non-venting drums (e.g. plugged vent orifice). This is based on the analysis of a worst case configuration (i.e., low molarity and high plutonium concentration and activity). The solutions contained in a product receiver poly-bottle or other vessel were generated during processing and can be segregated by batch.

The first required action, operations will identify and segregate PR drums by batch and identify the worst case drum (i.e., low molarity and high plutonium concentration and activity) based on the existing solution sample analysis results. An analysis will be made to determine if there is potential for the gas in the drum to exceed 25% of the LFL for hydrogen (or 1% hydrogen). If the modeling or analytical results determine that the gas within the drum is less than 25% of the LFL, the drum can be opened without punching.

If the modeling or analytical results determine that the gas within the drum is equal to or greater than 25% of the LFL (equal to or greater than 1% hydrogen) the worst case drum will be punched and sampled. If the modeling or analytical results are validated, then all drums within the batch must be punched. If the modeling results cannot be validated, that is, the sample results do not agree with the modeling results, a representative sample of the batch must be punched and sampled. If any gas sample indicates that the gas within the drum exceeds 25% of the LFL all drums in the batch must punched. If all sample results indicate that the gas within the drum is less than 25% of the LFL, the drum can be opened without punching.

9.1.2A.1.4 Engineered and Administrative Safety Features and Protective Systems. Before opening or moving, the PR drums are grounded (grounding clips, drum webs and transportation carts) to prevent sparks, and only non-sparking tools are used to open the PR drum. There is also a remote drum opener for drums without vents (BWHC 1999b). In the storage room, the ventilation system prevents flammability conditions by a large margin, and passive ventilation due to barometric pressure changes and leakage would be sufficient to prevent flammability conditions.

9.1.2A.2 Detection of Event. Detection of a PR drum that has no vent clip is by direct observation by the operator. However, detection of a drum with a plugged passive vent is not directly observed; hence, all drums are treated as if they have flammable conditions.

9.1.2A.3 Analysis of Effects and Consequences. The main consequence of a hydrogen deflagration is injury to the operator. The gas volume is relatively small, such that the deflagration will be very localized.

9.1.2A.4 Corrective Actions. The PFP has trained plant personnel, administrative procedures, and equipment available to prevent a hydrogen deflagration upon opening a PR drum with flammable conditions inside. The

emphasis is placed on prevention by following normal venting procedures and using proper equipment.

9.1.3 Radioisotope-Bearing Powder Spills

Plutonium-bearing powders are generated and stored in the PFP in a variety of locations, quantities, and concentrations. The handling of containers of plutonium-bearing powders both within and outside of the process enclosures was reviewed for the potential to cause an abnormal condition or spill in the PFP and a subsequent release into an occupied area. It is more likely that a container of powder could be spilled within a glovebox or process cell, but any material released would be completely confined. A plutonium-bearing powder container is less likely to be spilled, due to overpacks and a plastic bag, but if released in transit or while in a storage vault, the spill could cause an exposure to personnel. The PuO_2 powder is placed in metal slip-lid cans capable of holding a mass of 2.5 kg. The slip-lid is taped and then removed from a glovebox in a heat-sealed 8-mil-thick bag. Tests have shown that slip-lid cans can withstand drops of 3 meters without loss of contents (Reichmuth 1988). The slip-lid can and bag are then mechanically sealed into two successively larger food-pack cans. Smaller quantities, principally laboratory sample-size containers and cans of scrap from cleanup operations, are also stored but represent an insignificant risk of release compared to the 2.5-kg cans.

Plutonium oxide is assumed for this discussion rather than plutonium tetrafluoride for three reasons. Plutonium fluoride powders are handled less often in slip-lid cans. Plutonium fluoride powders contain a lower fraction of respirable powder than plutonium oxide. Plutonium fluoride is not produced at the PFP anymore. However, it may still be stored in the PFP.

9.1.3.1 Postulated Cause of the Event.

9.1.3.1.1 Starting Conditions and Assumptions. Powder spills and subsequent airborne contamination (aerosols) have occurred in the past due to improper handling, inadequate training, less-than-adequate design of containers, etc. Aerosols are classified as condensation and dispersion aerosols. Powder (or dust) spills produce dispersion-type aerosols from the resuspension of the powder by air currents or vibration.

The composition of a potential powder spill can vary from laboratory sample-size containers containing barely detectable quantities of radionuclides, to an oxide form of plutonium. Virtually any powder that will be handled within the facility has some remote probability of being spilled. However, PFP design, equipment, systems, training, management, operations, and review make the relative likelihood for spills inversely proportional to the hazard presented. For instance, production quantities of PuO_2 are containerized in metal slip-lid cans and the joint taped. Before any material or laboratory samples are transported within the PFP, the container is sealed out of a glovebox using plastic bags, which maintains contamination control of the can from the room.

In order for a spill to occur, the overbag on the bagged and sealed slip-lid can would have to rupture and the slip-lid can would have to open up

and spill its contents. The penetration of an overbag could result from an exposure to any sharp object, but the accidental opening of a slip-lid is unlikely. Drop tests were performed on slip-lid cans containing a variety of materials, and in 25 drop tests from heights up to 14 ft, not one can failed to maintain integrity (Reichmuth 1988). Integrity was maintained despite the fact that the tape seal normally placed over the can/lid joint was purposely left off during the drop tests.

The outer surface of cans is routinely contaminated, however. Therefore, cans must be kept in overbags to prevent the spread of smearable contamination. Overbags also offer additional protection from a potential accidental spill.

The release of plutonium from a spill during seal-out is comparable to the scenario of the oxides spill in *Z Plant Plutonium Handling Operations Safety Analysis Report*, RHO-CD-1224, Rev. 1, Vogt (1983). Plutonium metal buttons, slag and crucible (S&C) fragments, and scrap materials are sealed out occasionally if repackaging is necessary. Buttons and S&C fragments are mechanically sealed in food pack cans in contrast to the taped slip-lid cans described as the single can (Vogt 1983, Section 9.2.1). Dry powders from the vacuum cleaner are sealed out in slip-lid cans with taped lids. Wet or damp scrap is loaded out in wide-mouthed, screw-capped plastic jars (polyjars). Thus, the probability of a single drop resulting in a complete spill is much less than 1.0 due to the nature of the seal-out procedure and equipment used. The probability of such an accident is quite low, as evidenced by the absence of such an incident reported in the accident history (Roemer 1987).

The can and portion of bag being sealed are placed on a special table, which is either portable with adjustable height or is attached to the glovebox. The two layers of bag are heat-sealed and then the end section, in which the can is located, is cut off and the exposed edges reinforced with tape. In addition, the lid on the slip-lid can is normally taped in place as required by procedure. Thus, to have the contents of a can spill out into the room a series of errors, rather than a single error, must occur. There would have to be no tape on the can lid or the can would have to fall in a manner not yet observed or conceived to cause the taped lid to pop off.

9.1.3.1.2 Engineered Safety Features and Protective Systems. All radionuclide-bearing powders handled in the PFP are confined at all times within safety systems such that, at a minimum, a single failure will not result in the release to the environment. In most cases several failures would have to occur. The construction of the facility and systems, training, operation, maintenance, and management are designed to include appropriate redundancy and diversity of safety features to minimize the possibility of concurrent common-mode failures of redundant items.

The PFP confinement systems are composed of the confinement barriers and the associated ventilation systems. Multiple barriers and redundancy in systems is provided in the unlikely event of the failure of any barrier or component of a particular confinement system.

Plutonium-bearing powders are transported between buildings of the PFP and from hand trucks in the three basic types of containers. Powders are stored and transported within and between buildings in steel cans of the type

used in the food industry. All units are at least double contained in metal food pack cans, with the cans mechanically sealed as in the food industry. These cans are then placed in another device for handling. Individual cans are sometimes placed in a 50-lb slip-lid can known as a "lard-can" that is either carried by hand or in a specially designed wagon, depending on the radiation dose rate. When more than two units are transported, they are placed in a fixed-array wagon that is covered by a cage to hold the cans in place should the wagon tip over.

Roadway transport between the PFP and other facilities is done by trucks that are loaded at a dock. The possibility exists for an ≈4-ft drop during loading or unloading. However, the cans of plutonium powder are within U.S. Department of Transportation (DOT)-approved cross-country shipping containers. These containers, usually DOT-6M, are built to withstand the much higher forces of a public highway accident.

There is no credible way to get a release of plutonium-bearing powder into the environment from dropping or overturning a DOT-approved transport device at a loading dock.

9.1.3.2 Detection of Event. A powder spill may be detected by a variety of either passive or active established methods.

9.1.3.2.1 Methods or Means of Detection. The most likely method of detection would be by operational personnel in the immediate area of a spill. A RCT performing a routine surveillance could also find evidence of a spill, personnel in the course of self-monitoring may detect evidence of a spill, or CAMs located within the facility would detect aerosols released from a powder spill.

Air monitoring and warning systems are installed in work areas where radioactive material is handled in order to detect airborne contamination. The air monitors are highly sensitive and, in some cases, will detect evidence of contamination not otherwise detectable by an unaided human. If plutonium is released into the PFP atmosphere, then alarms will be actuated when the CAM alarm setpoint is reached. Upon actuation, facility workers are trained to promptly evacuate the affected air space. These actions in combination serve to reduce the potential plutonium inhalation dose received by the affected facility workers, thereby mitigating some potential facility worker hazards at PFP.

The PFP ventilation systems are sized to exchange room air volume six times every hour so there is adequate air passage from all areas of any room past the air monitors. Air sampling heads are located to provide a representative sample of potential airborne radioactive materials being breathed. Depending on the volatility or energization of the potentially spilled radionuclides, air monitors may or may not be able to discover a spill. The CAMs are set to detect and alarm at prescribed airborne radioactivity levels; if the components of a spill do not become airborne or quickly drop to the floor then detection is not possible by this method.

Throughout the facility provisions have been made for personnel monitoring devices.

Spills are also detected by RCTs performing routine area or equipment surveillances or pre-inspection of a radiation work area.

9.1.3.2.2 Response Time Assessment. Since the most likely component of a powder spill in the PFP is potentially airborne radionuclides, the immediate evacuation of the spill area is required. Respiratory protection for re-entry is also required. With the aid of RCT personnel, an assessment of the spill and its composition can be made by authorized personnel and mitigative action taken. Upon detection, assessment, mitigation, and decontamination, the isolated/confined area can then be prepared for investigation of the cause of a spill and for maintenance and repair purposes.

9.1.3.3 Analysis of Effects and Consequences. For the purpose of this analysis it was assumed that the entire contents of a 2.5-kg slip-lid can containing PuO_2 spilled from a height of 3 m onto the floor outside a glovebox. The 2.5-kg mass and slip-lid can are conservative choices since 2.5-kg masses are normally mechanically sealed into three successively larger containers and most plutonium powder handling is done in 400-g amounts. It was also assumed that all other systems were operating normally before the spill. As stated in Section 9.1.1, spill energy is an important factor in determining the magnitude of airborne releases. Spill height determines the amount of gravitational energy available to break up, shear, and rebound particles on impact. Height also influences the amount of time source material is exposed to shear forces during the fall. These forces work to break off particles from a falling stream. Some plutonium may be resuspended from a deposit pile due to air currents, but this is estimated to be insignificant compared to the spilling process and is also time dependent.

As the result of a free-fall spill from a height of 3 m, it is estimated that 0.12% by weight of the PuO_2 will become airborne (NRC 1981) or, for a 2.5-kg slip-lid can, 0.0030 kg (3.0 g) will become airborne immediately. This number is an upper-bound case from spill tests of free-falling powders, a condition not likely to occur in the PFP. The locations with the highest probabilities for powder spills within the PFP are the glovebox seal-out stations, which are 1 m off of the floor. From the same free fall spill tests identified previously, the observed maximum average weight percent airborne for a 1-m free fall spill was stated as 0.034%. The 0.12% represents a maximum observation from a series of tests where spill height, spill weight, and chemical composition were varied for a free-falling powder. Additionally, the amount of material airborne will vary depending on the size of the powder particles, presence of air currents, the relative humidity, and duration of release.

All PuO_2 powder is handled within enclosed gloveboxes. In case of a breach of confinement these gloveboxes have preferential airflow from operational personnel to the glovebox to reduce potential personnel exposure. The PuO_2 powder is only brought out of a glovebox once the powder has been enclosed in several overpacks and in an outer can. In the unlikely event of a spill occurring, the processing rooms are equipped with CAMs that would alert operators to the presence of respirable airborne contaminants even if the actual spill was not observed. Additionally, operators are required to wear respiratory protection (masks) rated at 99% efficiency during glovebox seal-outs. Seal-outs are anticipated to be the locations for the highest probability of contamination and powder spills.

The most extensive treatment given offgases in the 234-5Z Building is the particulate removal from the ventilation system exhaust. This includes exhaust from contaminated hoods, gloveboxes, process vessels (E-4 exhaust system), and potentially contaminated rooms around the gloveboxes (E-3 exhaust system). The Zone 3 rooms discharge into the E-3 system. The E-3 system air is filtered through a single stage of roughing filter at the exhaust point from the room and then through a single stage of HEPA filtration. The HEPA filter has an efficiency of greater than 99.95% (transmission fraction of 1 - 0.9995 = 0.0005). Given the 3.0 g of plutonium powder potentially spilled in this section and the HEPA filter rating, only 3.0 g x 0.0005 = 0.0015 g plutonium would reach the PFP stack. This is below the 0.02 g acceptance criteria for a stack release of Class Y material (Table 9-51) given a probability of 1.0.

9.1.3.4 Corrective Actions. The PFP has trained plant personnel, administrative procedures, and equipment available to recover from any potential spill. Regardless, emphasis is placed on prevention of spills, which is based on information of past spills and postulated spills. If a powder spill were to occur outside a glovebox, the necessary corrective actions can be summarized into evacuation, exclusion, stabilization, confinement, cleanup, and restoration/inspection. The first step would be to establish the area as an Airborne Radioactivity Area after the alarms had sounded and the personnel were evacuated. This would restrict or exclude access to all but those individuals needed to monitor and clean up the spill. The next step would be to stabilize the spill to prevent it from moving or being moved from its known location. Then it would be necessary to erect a greenhouse with a ventilation system to confine the spread of contaminants while cleanup proceeds. Cleanup would include removing and stabilizing the spilled material until the results are satisfactory to monitoring and management personnel. Once the area has been restored to the pre-spill condition, any further inspections and administrative functions necessary would be applied to release the area to normal operational status.

9.1.4 Radioisotope-Bearing Pressurized Powder Container

Potentially pressurized powder containers may include those containers containing PuO_2 powder, PuF_4 powder, plutonium metal buttons, and recoverable materials (containing reportable amounts of plutonium metal or compounds). Plutonium-bearing powders are generated and stored in the PFP in a variety of locations, quantities, and concentrations. The handling of containers of plutonium-bearing powders, both within and outside of the process enclosures, was reviewed for the potential to cause an abnormal condition or release in the PFP and a subsequent release into an occupied area due to a potential pressurized release.

Plutonium-bearing materials stored in closed containers can pressurize those containers due to the effects of radiolysis, chemical reactions, or internal thermal energy. Plutonium-bearing material forms that may be stored or handled include plutonium metal, dry powders (e.g., PuO_2), and plutonium-bearing recoverable material items.

Plutonium-bearing materials principally are seen as oxides or fluorides but may be combined with organic compounds. The probability of container

failure and the magnitude of any resultant contamination spread is increased by container pressurization. Personnel exposures may be incurred if pressurized containers rupture during handling or rupture occurs outside of confinement and is not detected in a timely manner.

Plutonium-bearing recoverable materials are divided into three categories: (1) unstabilized recoverable material [i.e., recoverable material that is known to be capable of gas generation sufficient to pressurize a container to 34 lbf/in^2 (gauge) during storage]; (2) stable/shippable recoverable material (i.e., material that has well-defined characteristics and is safe for shipment); and (3) potentially unstable recoverable material (i.e., material for which insufficient information is on hand to readily categorize).

Recoverable materials come from processing activities and are obtained from glovebox sweepings meant to control the loss of plutonium-bearing materials and to keep operator exposures As Low As Reasonably Achievable (ALARA). The types of plutonium-bearing recoverable material that may be stored or handled include, but are not limited to, PuF_4 sweepings, PuF_4 for recycle, incinerator ash, polystyrene cubes, Pu-U mixtures, S&C fragments, unirradiated fuel rods, plutonium-beryllium sources, and unique plutonium-bearing solutions.

9.1.4.1 Postulated Cause of the Event.

9.1.4.1.1 Starting Conditions and Assumptions. The PuO_2 powder is contained in metal slip-lid cans capable of holding a mass of 2.5 kg. Smaller quantities, principally laboratory sample-size containers and cans of recoverable materials from cleanup operations, are also stored but represent an insignificant risk of release compared to the 2.5-kg cans. Plutonium powders are stored in a series of successively larger cans, which provide the assurance of a can-within-a-can protection against both inward and outward leakage. The innermost container is typically a 2.5 kg capacity steel can with a lid commonly known as a slip-lid can. The second container, or overpack, is a standard food industry size container commonly used to pack tomatoes, and the outer 7-in. can is the kind commonly used for fruit juices. The successively larger cans provide head space to accommodate expansion; the void space between cans is not filled with any solid materials.

Plutonium metal ingots or "buttons" are stored and overpacked in steel cans of the type used in the food industry. The inner can is the type of small can commonly used to pack tuna fish while, the overpack or "tomato" can size is large enough to accommodate any compound formed from the reaction of the metal with any oxygen or nitrogen contained in the overpack, or with oxygen or nitrogen that might leak through a defective can seam. However, plutonium metal buttons have been known to oxidize in a manner in which the resulting oxide powder did not act as a fluid as it expanded. Rather than rise and expand laterally with approximately equal pressures, the lateral force predominated to rupture the side of the containing can. The use of overpack cans provides additional environmental protection, reducing the probability of an in-leakage of gas, thereby reducing the probability of a rupture due to expansion. Improved canning methods since the mid-1970's have reduced compound formation significantly.

Can pressurization also occurs as a result of radiolysis of hydrogenous material or chemical reaction products. Recoverable materials suspected of containing such materials are heated to temperatures on the order of 600 °C and then tested against Loss-On-Ignition (LOI) criteria. The LOI test is conducted by heating a sample amount of product for a specified amount of time and then measuring the weight loss. No attempt is made to determine the chemical species present. It is assumed that the gaseous products are composed of principally CO, CO_2, air, small amounts of hydrogen/oxygen radicals, and an insignificant amount of water. An LOI of less than 1 wt% is used as one criterion in evaluation of scrap destined for vault storage. The entire history of the material is considered because, as is shown in *Gas Generation in Stored Packed Plutonium*, ARH-CO-433 (Crawley 1975), as little as 0.1 wt% of water in 1,000-g plutonium powder would form ≈2.1 L of gas. Gas production of 2.1 L at atmospheric pressure in a closed 1-L container will produce pressures in excess of 30 lbf/in^2 (absolute).

After LOI samples have been taken, the material is placed in a sealed container before possibly being exposed to a high-moisture environment. As indicated in *Hygroscopicity of Plutonium Dioxide*, RFP-1056 (Stakebake and Dringman 1968), PuO_2 can adsorb water up to 9 mg/g PuO_2 at a temperature of 27 °C. The water seems to be involved in a chemisorption process that is essentially nonreversible at temperatures less than 100 to 200 °C. Loss of moisture control can therefore not be compensated for by simply placing the powder in a dry atmosphere for a comparable period of time.

Current plutonium-handling operations in the storage vaults and storage gloveboxes at the PFP are directed toward shipping and receiving stable/shippable materials, and maintaining the inventory of reactive and potentially unstable recoverable material items in a safe configuration until they can be stabilized. Stable material is that material for which sufficient information is available to ensure that shipment or retrievable storage of the item may occur without incurring undue hazard.

Unstabilized recoverable material is stored in specified gloveboxes in the 234-5Z Building. Items received from off plant that violate the LOI criterion (per acceptance testing), or bulging containers, are categorized as unstabilized recoverable material.

The recoverable material is placed in vented 0.5-L polypropylene or polyethylene jars (polyjars) or in slip-lid cans, which serve as primary containers. The containers are then placed in gloveboxes. The quantity of recoverable material in each container and position in the gloveboxes are controlled by fixed pedestal positions and administrative controls to provide critically safe arrays.

In the past, due to the common usage of unvented 55-gal drums for transuranic (TRU) and non-TRU waste disposal, it was necessary to recover from situations where the drum became a hazard (i.e., pressurized or contaminated). While rare, pressurized drums are generally identified by bulging of the top and bottom. However, not all internally pressurized drums are visibly bulged. There have been several reports, in publication by the DOE Office of Nuclear Safety, of drums burping (i.e., the lids popped off, apparently due to chemical reaction of the contents). These incidents have occurred at various facilities throughout the DOE complex. The internal pressure is caused by

chemical reactions taking place inside the drum, giving off various gases as a byproduct. One example is the nitration of cellulose in acid-soaked rags. Procedures require washing and neutralization of acid-soaked rags. If not so treated, a degree of nitration may result. Various reactions are possible in these drums, due to the varied nature and condition of their contents. Reactions may also take place that evolve hydrogen gas. Since 1978, procedures have specified fitting all drums with vent clips before sealing them, to allow gradual venting of any internal pressure, and with catalyst packets, to eliminate any hydrogen that may evolve during storage. Drums so equipped are assumed not to be pressurized and are opened without the precautions used for bulged drums and drums without vent clips.

9.1.4.1.2 Sequence of Events. Plutonium metal buttons may be transferred to a dry air glovebox for inspection and repackaging. When finished, each button is mechanically sealed into cans. Cans are purged with argon and sealed, and the quality of the seal is inspected to prevent even a minute hole in a can from leading to oxidation of the plutonium metal. The can is then labeled for seal-out. The can is worked to the end of a polyethylene sleeve and placed on a special table where an electronically heated bar seals a section, which is then removed. After securing the sealed edges with tape and the appropriate survey for contamination, the bagged tuna fish can is sealed into a larger can and finally into a 7-in.-dia. food pack can of the type typically used for fruit juices. This can is then surveyed, tamper-indicating seal/labels are applied, the can is weighed and sent to Building 2736-ZB for NDA, and then to storage in Building 2736-Z. If a leakage path is overlooked by the above procedures, oxidization could occur and cause can failure.

Failure to evaluate and control moisture in packaged plutonium metal can lead to container pressurization and possible container rupture. In past instances, container failure resulted from the direct pressure of PuO_2 formation. As the plutonium metal with a density of approximately 19.6 g/cm^3 oxidized to a powder of density approximately 3 g/cm^3, the pressure developed slowly. The release of pressure was not very dramatic. Pressure released following gas generation causes more of a problem. In one instance a can was found off of its pedestal and the contents spread on the floor after it apparently relieved its internal pressure. In another instance a seal ruptured as personnel were picking up the container, causing considerable personnel contamination.

Three mechanisms would likely be responsible for spread of material throughout the affected room. In an instance where a slow growth of oxide took place, the powder would tend to slowly work its way out of the can and fall at a slow rate to the objects and floor below. The airborne release would come about during the fall and by resuspension after it fell. In those instances where gas pressure was responsible, the primary suspension would come about from the violent ejection of powder. Resuspension of the ejected material is a function of the escape gas velocity and would probably take place in proportion to the air velocity.

9.1.4.1.3 Engineered Safety Features and Protective Systems. Plutonium-bearing recoverable material known to be capable of gas generation that could cause pressurization in a sealed container during storage is stored in a vented configuration, which maintains contamination control. The use of

nested cans to contain plutonium provides multiple barrier confinement. In addition, the cans are stored in facilities with at least one stage of HEPA filtration.

In the event that a drum was closed without a vent clip, as required by procedure, and the drum became pressurized, it would be opened under controlled conditions. The drums would be remotely opened using a drum punch assembly. Protective shielding would mitigate the effects of a rapid discharge of gases. Venting of any internal pressure would be done into the E-4 exhaust system. The interior would then be flooded with argon to displace and dilute any residual explosive gases.

For drums not exhibiting bulging, the puncturing device would be fixed just above the drum lid to act as a restraining device, and the lid vented manually. Manual venting would be accomplished by loosening the drum ring and prying up the lid to break the seal and vent the interior.

9.1.4.2 Detection of Event.

9.1.4.2.1 Methods or Means of Detection. Containers are inspected periodically for pressurization as indicated by bulging of the container. Containers are inspected for corrosion, dents, penetrations, and faulty seams or seals before being placed into storage in Building 2736-Z. In addition, electronically operated detectors in the storage positions can sense bulged cans. Any container pressurization revealed by these methods results in the container being taken to a glovebox and repackaged. Following an actual release in storage, the event would most likely be detected by the room CAMs and later by personnel inspection.

Chapter 8.0 of this FSAR details radiation detection. A brief summary follows.

Ambient air sampling and monitoring systems are placed in strategic locations to detect and evaluate potential airborne contamination at work locations. Air sampling equipment is used in occupied areas where, under normal operating conditions, a person is likely to receive an annual intake of 2% or more of the specified Annual Limit of Intake (ALI) values (40 Derived Air Concentration (DAC) hours). Locations of fixed head samplers (FHS) and CAMs are determined, documented, and periodically reviewed using the guidance of *Criteria for Westinghouse Hanford Company Work Place Air Sampling Program*, WHC-SD-GN-TA-30001, Rev. 0 (Ruben 1994), which was the guidance document for air sampling at WHC facilities. Air sampling and monitoring equipment and techniques used can be divided into four general categories: (1) breathing zone or room air samples, (2) CAM devices, (3) stack effluent samplers and monitoring systems, and (4) portable air samplers. Breathing zone or room air samplers are used to establish average breathing zone air concentrations or to quantify chronic low-level airborne exposures. The CAMs are used in areas where dispersible radioactive material is handled and/or the potential for airborne radioactive release is high.

The CAMs provide an annunciation of a changing workplace environment. Continuous air monitoring equipment is in occupied areas where a person without respiratory protection is likely to be exposed to a concentration of radioactivity in air exceeding 1 DAC or where there is a need to alert

potentially exposed workers to unexpected increases in the airborne radioactivity levels. Continuous air monitors are capable of measuring 1 DAC when averaged over 8 hours (8 DAC-hours) under laboratory conditions. Facility exhaust stacks are monitored by CAMs to provide rapid indication of a detectable release of airborne radioactivity. Portable air samplers are used for special or supplemental air sampling (grab sampling) when a CAM indicates an increase in radioactivity, for special evaluations of radiological conditions, or for specific tasks.

In addition to providing detection of the event, CAMs and their associated alarm function mitigate some potential facility worker hazards at PFP. Upon actuation, facility workers are trained to promptly evacuate the affected air space. These actions in combination serve to reduce the potential plutonium inhalation dose received by the affected facility workers. The public and onsite workers are not significantly affected by these potential releases inside PFP because the exhaust air flow is filtered by the applicable exhaust ventilation system prior to release outside of PFP.

9.1.4.2.2 Response Time Assessment. The discharge of gases from a pressurized powder container in the PFP could contain airborne radionuclides. Therefore, if a discharge occurs, the immediate evacuation of the area is required and can be affected in several seconds upon alarm notification. Unless the extent of the spill is large, automatic detection may not occur due to the small amount of material that becomes airborne. In that case there may be a significant lag time between the event and detection. Small quantities of radionuclides may be detected by self-surveying of personnel who come in contact with the material. In general, the smaller the quantity of uncontained radionuclides, the longer the response time will be due to detection lag. A significant release of a radionuclide can be expected to be detected immediately by a variety of means. Primary reliance is on using only trained personnel, and in prompt evacuation of the work area if a problem occurs.

9.1.4.3 Analysis of Effects and Consequences. The handling of containers of plutonium-bearing powders that become pressurized both within and outside of the process enclosures was reviewed for the potential to cause an abnormal condition or release in the PFP and a subsequent release into an occupied area. It is most probable that a container of powder would be discharged within a glovebox or storage vault, and any material released would be completely contained with the enclosure and the associated ventilation/confinement system. A pressurized plutonium-bearing powder container would be more likely to cause a release than handling an unpressurized container, but, due to the low incidence of pressurization, the risk to personnel is expected to be similar.

The effects of a can rupture can be modeled from data on pressurized releases (Sutter 1983), from free fall powder spill experiments (Sutter et al. 1981) and from various sources of resuspension data. The pressurized container information must be used with care when applied to the case of multi-packed containers. The free fall powder spill experiments involved spills of 100-g to 1,000-g quantities of UO_2 powder that caused interaction between particles and produced localized air currents as the material fell. The slow dribble of material to a floor might not produce as much disruptive energy per particle. Resuspension by the slow-moving air in a storage cubicle

is less than that reported in the literature. Upper-bound figures are not likely to be more than a few grams. While this would be sufficient to cause a significant in-plant event, it would not seriously challenge even a single stage of HEPA filtration.

The concentrations of airborne radioactive material expected during off-normal occurrences were based on historical data from 1986 through 1988 that was collected from 90 out-of-tolerance reports (see Chapter 8.0). This information shows that the concentrations of airborne radioactive material that exceeded the operational plant limit of 2×10^{-12} μCi/mL (^{239}Pu) has averaged 9.2×10^{-12} μCi/mL. Only two incidents occurred where concentrations were in the 10^{-10} range. The worst case reported was 2.52×10^{-10} μCi/mL.

Typical processing rooms are ventilated at rates of 300 ft^3/min to 1,000 ft^3/min and the stack discharges at ≈225,000 ft^3/min. Thus, even without any filters the release concentrations would be factors of 300/225,000 to 1,000/225,000 lower. The E-3 filter would lower this by another factor of 2,000 and the various other air clearing forces by some undeterminable amount. Thus, a release into a room at a level of 2.5×10^{-10} μCi/mL would result in an increase at the stack of between 5.6×10^{-16} μCi/mL and 1.7×10^{-16} μCi/mL both of which are well below the minimum detection level of 5×10^{-15} μCi/mL (Chapter 8.0, Section 8.6.1.1.1). This is in contrast to normal stack emissions in the range of 4×10^{-14} μCi/ml and an alarm limit of 2×10^{-12} μCi/mL. Such a room contamination would be undetectable at the stack, and if it was detectable, it would be orders of magnitude below a significant amount (Section 9.0.2.2).

Personnel involved with plant or process operations that may result in airborne radioactivity are routinely required, by procedure, to wear respiratory protection during these operations. The effectiveness of this requirement is demonstrated by the low incidence of recorded body burdens of personnel.

9.1.4.4 Corrective Actions. In the event that radioactive material that does not meet the LOI specifications is identified to be in pedestal, cubicle, or cabinet storage, management is alerted and the material is removed from storage within one working day and dispositioned per an approved work plan.

As a result of past container pressurization experiences, numerous corrective actions were taken to prevent recurrence. The range of lessons learned from container overpressurizations and the corrective actions that resolved the situation are summarized in Vogt (1983, Table 4).

9.1.5 Stack Release Resulting from Filter Changes

The secondary HEPA filters are the last barrier between contamination and the stack; if this barrier is in some way circumvented, then a release to the atmosphere is possible. Great care and judgment must be used in the changing out of these filters to avoid release of plutonium to the stack.

HEPA filters have proven to be the most effective, reliable, and economical device for removing low concentrations of sub-micron particles at extremely high collection efficiency. A HEPA filter is a throwaway,

extended-media dry-type filter with a rigid casing enclosing the full depth of the pleats. HEPA filters exhibit a minimum efficiency of 99.97% when tested with an aerosol of essentially monodispersed 0.3 micrometer particles. The type used in the 236-Z Building are cubes, 2 ft on a side. A plate with a nipple in the center is used for the front and back faces of the cube, the remaining sides are made of plywood. Those used in the filter rooms in the 234-5Z Building are only 11 3/4 in. deep and have open faces instead of the plate with a nipple. Other filters in the building are cylindrical with a metal housing. All cylindrical filters are in locations where there are other filters downstream, so that any material that might get loose would be caught on the downstream filter. The cylindrical filters will not be considered further.

9.1.5A Dropped Filter, Filter Room 309 or 310

The filter rooms within the 234-5Z Building use all plywood-cased HEPA filters that are either nailed or screwed together. The filter pack consists of a continuous sheet of glass fiber mat, pleated back and forth over itself so that it has a large surface area, is self-supporting, and is permanently bonded to the integral frame. The banks of filters in these rooms constitute the secondary or final stage of filtration before air is discharged from the 200-ft-tall stack.

9.1.5A.1 Postulated Cause of the Event. It is postulated that during a routine filter change in room 310 in the 234-5Z Building, a HEPA filter is dropped ≈8 ft onto a concrete floor. This results in the release of contaminated dust into the filter room. Because the louvered outlet dampers for these rooms do not close completely, the plutonium laden dust would be drawn to the exhaust plenum and directly to the stack, setting off the stack CAM.

9.1.5A.1.1 Starting Conditions and Assumptions. A filter change is in progress in either E-4 filter room 309 or 310. The louvered dampers have been closed to isolate the room from the stack plenum, but they leak and no plastic is placed over them as required by procedure (to prevent flow up the stack). To estimate the amount of plutonium present on the E-4 HEPA filters, reference is made to recent NDAs performed following a HEPA filter change-out of room 310 *Measurement Results of HEPA Filters* (Fazzari 1994). The measured plutonium loading of over 100 individual filters ranged from a low of 5.0×10^{-4} g to a high of 3.7×10^{-3} g, with a mean of 1.2×10^{-3} g. For this analysis, the measured high value of 3.7×10^{-3} g is used in conjunction with a safety factor of 2, which yields an inventory at risk of 7.4×10^{-3} g. The safety factor of 2 is applied to account for potential increases in future filter loadings and is judged to be appropriately conservative given that (a) the measured high value is used, and (b) the NDA results are for filters that were in place for 14 years, with major PFP processes operating during 7 years (e.g., the RMC Line and its support operations). In contrast, current plant operations are conducted on a much smaller scale (e.g., operation of glovebox HC-21C versus operation of the entire RMC Line) such that filter loadings are expected to be lower. Note that Fazzari (1994) and a safety factor of 2 are also used to assess the consequences associated with seismic-induced failures in the filter rooms (see Section 9.2.4.6.3.1.X.a).

9.1.5A.1.2 Sequence of Events. The normal complement for entry into the filter room includes two millwrights for removing and installing filters, two operators to assist in packaging and removal of filters from the filter room, two more operators outside of the filter room for final packaging of the filters, two RCTs for contamination surveys outside of the filter room, and vent and balance personnel for adjusting the airflow of the room. While the top filter on the south corner of the east bank is being removed, the millwright drops it to the floor. The filter lands on a corner of the frame, violating the integrity of the case, but the filter retains its original shape and dimension. The filter media is retained. Some contaminated dust from the filter is released. The airborne dust is exhausted from the room into the plenum and released from the 291-Z stack. Although the flowrate through leaking dampers would be low, respirable particles stay in the air for some minutes. As is shown in Section 9.2.4.7, a 4-μm particle falls at a rate of 0.32 ft/min and smaller particles at a slower rate. On notification of the stack alarm, the job would be terminated.

9.1.5A.1.3 Action Taken. In this scenario the personnel involved with the filter change do not recognize the problem associated with dropping the filter, and continue with the changeout. When the stack CAM exceeds its set point, it activates an alarm panel in MICON control room 714. The power operator immediately notifies the Shift Manager/Building Emergency Director in Room 104. Upon determining that it is a stack alarm for the 291-Z stack, a RCT is sent to pull a sample, count it, and determine if it is necessary to send the sample for laboratory analysis. (If the initial count by the RCT is high, then the CAM alarm is considered to be real until official results are received from the laboratory.) Operations Managers are notified, and the filter change is shut down.

9.1.5A.2 Detection of Events.

9.1.5A.2.1 Methods or Means of Detection. The first detection of the problem would most likely come from the changeout crew itself. However, because they would not know if they had created a stack release or how large it might have been, the assumption is that the work continues.

The airflow out of the building is monitored by a CAM that will annunciate an alarm when pre-established set points are exceeded. The stack CAM is also connected to the annunciator board in room 714 (MICON™ power control room) within the 234-5ZA Building. The room 714 board is monitored by power and operations personnel.

9.1.5A.2.2 Response Time Assessment. The time it takes from first notification of a stack alarm to initial assessment of release levels is assumed to be ≈1/2 h. Within this time frame the filter change is terminated and necessary notifications are made.

9.1.5A.2.3 Engineered Safety Features and Protective Systems. The dampers controlling the airflow into and out of the filter rooms do not provide a positive closure, allowing a minimum amount of airflow to exist, unless plastic sheeting is placed over dampers. This condition is allowed as it provides a negative atmosphere to the room while work is being performed within. Directly outside of the filter rooms on the outlet plenum is an

inline air sampler that is used to confirm any release and determine the level of particles released from the filter room.

There are no inline CAMs downstream of the filter rooms other than the stack CAM itself.

The filters are the final barrier between contamination and the 291-Z-1 stack. Based on the stack release shown in the previous section, it seems probable that the release would not exceed the guidelines for significant release even for an event with a probability equal to 1.0.

9.1.5A.3 Analysis of Effects and Consequences. A number of studies lead to a conservative estimate that 1% of the inventory on a dropped HEPA filter would be released as respirable particles. This figure is used in a study of the Westinghouse Cheswick Site, in which a strong wind was postulated to dislodge plywood cased HEPA filters from their housings. In the initial drop, 1% of the filter inventory was estimated to be released (Mishima et al. 1979a, p. 46). A number of the studies cited in *Waste Encapsulation and Storage Facility, K-3 Filter Drop-Inventory Release Fraction*, WHC-SD-WM-TI-171 (Wodrich 1984) indicate that the 1% figure is appropriately conservative. Thus

$$0.01 \text{ respirable powder released} \times 0.0074 \text{ g per filter} = 7.4 \times 10^{-5} \text{ g respirable powder released}$$

As is shown in Table 9-51, this amount of plutonium is below the release limit for a stack release event having an annual probability of one. It would be well above the amount needed to trip the stack alarm as is shown in Section 9.4.4.

9.1.5A.4 Corrective Actions. Corrective actions would be limited to cleanup of the filter room as the event would be over in seconds and there is no way to stop the airflow after the fact.

9.1.5B Filter Room 26, 236-Z Building

The 236-Z Building ventilation is exhausted through four banks of filters. Three of the banks are used to exhaust E-3 air and the other one is used to exhaust the E-4 air. There are HEPA filters in each bank. The E-4 exhaust can be switched over to one of the E-3 banks when the E-4 bank filters are changed out.

The filters used in the 236-Z filter room are 24-in. by 24-in. by 24-in. nipple-connected filters with a plywood casing. The casing completely encloses the filter except for two metal nipple connectors, one on each end of the filter.

The filters are held in place with metal hangers, with the nipple connectors facing one up and the other down. When the filters are removed,

the connectors are immediately covered with a cardboard or Lucite™[1] cover to prevent any contamination from being released from the filter media. Due to the ability to cap the nipples, there is little chance for noticeable stack release.

Radionuclides present in the PRF canyon and gloveboxes were deposited in the form of residues and sludges associated with wet processes and are not easily resuspended. In addition, PRF is an inactive facility, thus, significant amounts of contamination are not being disturbed and released to the ventilation system.

It is reasonable to assume that the release from 236-Z to the 291-Z-1 stack would be considerably less than the 7.4×10^{-5} g respirable released from a dropped filter in filter rooms 309 or 310.

9.1.6 Overpressure of Remote Mechanical C Line Pressure Vessel

Since plutonium metal is no longer produced at PFP, Section 9.1.6 is not required. The RMC Line pressure vessel is no longer used at the PFP. If future use of the vessel is required, Section 9.1.6 will be analyzed and incorporated.

9.1.7 Ventilation System Upsets

In no case was a ventilation upset in itself found to be the cause of a loss of plutonium control, but was shown to be a significant contributor to spread of contamination if it was already loose or to an external release if confinement was breached. The analysis examines a variety of upset conditions on a building-by-building basis which is reflected in the organization of this section. The sections associated with each building are designated by letters in the paragraph numbering system. The most plausible upset conditions found were for inadvertent pressurizations due to supply system malfunctions. The supply system for the 234-5Z, 242-Z, and 236-Z Buildings are served by a common source. Upsets in these buildings could come about through failures of one or more of the five Zone 3 subsystems.

Flowing air is the primary vector for the spread of radioactive materials within a building following events that cause their release from containment. An air pressure upset becomes significant because airflows that have been established for protection may become reversed. Events regarding airflow reversals are detailed in Sections 9.1.7, 9.1.8, and 9.2.4.

9.1.7A Excessive Building Pressurization--234-5Z

This analysis examines the mechanism for pressurizing the rooms in the 234-5Z Building housing sources of radioactive materials. If the pressure level is greater than the surrounding atmospheric pressure, any loose

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[1]Lucite is a trademark of E. I. Du Pont de Nemours and Company, Wilmington, Delaware.

radioactive materials will tend to be forced out of the building to the environment.

9.1.7A.1 Postulated Cause of the Event.

9.1.7A.1.1 Starting Conditions and Assumptions. Eight electric motor-driven supply fans and seven electric motor-driven exhaust fans provide the bulk of the ventilation for the 234-5Z Building. The ventilation provides contamination control as well as normal ventilation functions.

The supply fans furnish outside air to a supply plenum in Building 234-5Z. The fans are divided into two groups on the second floor of the 234-5Z Building. Three of the fans use continuously variable dampers for modulating the airflow and operate together under a single control system to maintain fine control of the plenum pressure (+2 in. w.g. with respect to an atmospheric reference point). The five remaining fans operate with full-open or full-closed dampers to provide large step sources of pressurized air. Each fan is on a separate on/off switch. None of the fans are on emergency power.

The exhaust fans are located both in the 291-Z Building and the 234-5Z Building. These fans remove air from the various rooms within the 234-5Z Building and discharge it to the outside. The exhaust fans are divided into two groups. Group one, in the 291-Z Building, discharges highly filtered air that ventilates the production part of the building. Group two, housed in the 234-5Z Building, discharges air that ventilates that part of the building used for office personnel (Zone 1).

Group one consists of seven exhaust fans. The controls and functioning are similar to the supply fans with two of the fans having modulating dampers while three of the remaining fans use full-open or full-closed dampers. The last two fans use manually adjustable dampers. Two of the group 1 electric motor-driven fans are on backup power. Group two consists of two main exhaust fans and other lesser exhaust fans dumping to atmosphere.

The ventilation air establishes four levels of pressure for rooms within Building 234-5Z to maintain contamination control. The rooms and areas housing radioactive materials are maintained at the lowest pressure, below the surrounding atmospheric pressure. The levels are labeled as in Table 9-4.

The ventilation is controlled by 5 dampers in the various airstreams. Continuously variable dampers controlled by closed loop pneumatic (instrument air pressure-driven) systems are used in the discharge of the supply plenums, on three of the supply fans, and on two of the exhaust fans in the 291-Z Building.

Office areas, designated as Zone 1 for being free of radioactive materials, are maintained at the highest pressure, above the surrounding atmospheric pressure. There are rigid barriers between Zone 1 and the other zones. Personnel must use an airlock to pass between the areas. Zone 3A is at a slightly higher pressure than Zone 3 but is still negative with respect to atmospheric pressure. Zone 3B is in the old inspection area (rooms 192 through 197). Zone 3B is at a negative pressure higher than either Zone 3* (serviced by damper B alone), 3 (serviced by damper C alone), and 3A.

Normal operation would find the system operating with all zones at pressures as shown in Table 9-4. Flowrates into the various areas are discussed in Chapter 5.0.

In all instances the amount of additional flow was found to be insufficient to load the filter to the overpressure resistance rating as stated in *Hanford Specifications for Fire- and Moisture-Resistant Nuclear Grade HEPA Filters*, HPS-157-M, Rev. 1, paragraph 6.2.5 (Price 1991).

An impact on the E-4 system (Zone 4) was not evaluated. Gloveboxes draw air from the rooms or from the building dry air system. Hoods draw air from the rooms. By drawing air from the rooms the gloveboxes and hoods follow the movement in the room pressure level and maintain the same DP with the room. Those gloveboxes ventilated with the dry air system are equipped with a large gas diaphragm-operated valve (DOV) designed to shut off the supply of dry air if the glovebox starts to pressurize with respect to the room. This would have no effect if the room overpressurizes; the glovebox would be at a negative pressure with respect to the room. However, if the room drops in pressure (see Section 9.1.7F), the valve would close--shutting off the source of dry air and allowing the glovebox to remain negative with respect to the room.

9.1.7A.1.2 Sequence of Events. A hypothesized scenario is that the building might be partially pressurized by the opening of one of the supply dampers attached to the supply plenum controlling the discharge of the air from the supply plenum to the various zones. It was hypothesized that an inadvertent opening would occur through the loss of control air caused by someone inadvertently opening (or closing) a valve on the pneumatic control lines. There are numerous small valves associated with the system both in back of the panelboard in the control room and at the dampers.

The postulated single event would be the opening of the single valve at any of the dampers. The control pressure would be lost and the damper would fail open, as this is its normal failure mode. The airflow to the system controlled by the individual supply damper would increase (to some level) and then stabilize. The drop in pressure in the supply plenum would be compensated for by the remainder of the supply system. There are normally five fans, each rated at 76,100 ft^3/min at 5 in. w.g., in service to pressurize the supply plenum. On the discharge side, the filter plenum pressure would likely rise a small amount. The sensor in the filter plenum would adjust the modulating damper to the one exhaust fan using such a damper, and the filter plenum pressure would return to its preset level.

The failure of damper A is not discussed. Zone 1, supplied through damper A, is maintained at a positive pressure with respect to atmosphere and all the other zones. A failure of the damper would drive the zone additionally positive, which would have no effect on contamination control. The amount of additional pressurization would be small.

9.1.7A.1.2.1 The Failure of Damper C. The S-3 ventilation supply, controlled by damper C, was the first situation examined. The production area is ventilated with this system and the failure could occur without tripping any alarms. The S-3 system supplies ventilation for those rooms in the building that contain most of the gloveboxes and hoods (Zone 3).

A failure of damper C (the damper opens) would have the following effects on a normally operating system.

- The filter plenum and exhaust plenum pressurize. The dampers have not had an opportunity to adjust. All pressures, except the supply plenum, rise.

- The pressure sensor in the supply plenum senses a drop in supply plenum pressure. It then signals the automatic controller for the supply plenum supply system to adjust the damper on the modulated supply fans to open. This increases flow to the supply plenum until supply plenum pressure is reestablished.

- The timer on the Zone 1 to Zone 3 pressure reversal alarm starts. If the reversed condition has not corrected itself within 5 s, an alarm sounds and the system shuts off the electrically driven supply and exhaust fans.

- The sensor in room 235-C signals the automatic controller for the supply plenum discharge system to adjust both damper B and C, since they are tied to a common control line, to decrease flow to both Zone 3* (serviced by damper B alone) and Zone 3 to reestablish zone pressure. However, this postulation has stated that damper C has failed and cannot respond. Damper B remains operative and does respond to the point where room 235 is returned to the preset pressure (room 235 receives ventilation air from both damper B and damper C controlled systems).

- Those Zone 3* rooms that are supplied solely from damper B will experience a drop in pressure.

- The sensor in the filter plenum signals the automatic controller for the exhaust system to adjust the damper on the modulated exhaust fans to increase flow from the filter plenum to reestablish filter plenum pressure.

- In the previous step, if the modulating damper on exhaust fans 3 or 4 adjusts to full-open, an alarm will sound.

Zone 3* serviced by damper B alone, Zone 3 serviced dually by duct work from dampers B and C, and Zone 3A serviced by duct work from damper D can all be pressurized with the same failure mechanism. These will be addressed later.

Scoping calculations for the damper C failure scenario show that an opening of damper C would briefly change the ventilation pressure for those rooms throughout Zone 3 receiving air solely from the S-3 ventilation supply. Pressure would increase from the normal range of -0.14 to -0.17 in. w.g. to 0.9 in. w.g. The exhaust damper adjusting and the supply plenum adjusting have no effect. Room 235 and certain others with a dual supply from both the damper B and damper C controlled ventilation supplies will return to near the preset pressure.

Those Zone 3 rooms serviced solely from damper B will experience a drop in pressure. Room 235 houses the pressure sensor for a feedback loop to correct the control of both damper B (Zone 3*) and damper C (Zone 3) and receives air from both supply ducts. In this scenario damper C has failed and is thus inoperative, but damper B remains active and will be responsive to the control loop throttling supply air to correct room 235 back to the original preset pressure. This throttling of damper B could drive air from the dually supplied rooms back into the damper B system to supply those rooms served solely by damper B. Predicting the resultant pressure level in these rooms is nearly impossible as all pneumatic resistances from the supply plenums to the rooms change. A scoping calculation predicts that the room will depressurize to as much as -2.5 in. w.g. The fact that other sources will feed into rooms 210, 211, and 212 to raise the pressure in the rooms is not considered. Zone 1 supplies air to the "clean side" of rooms 210, 211, and 212.

Failure of damper C would not trip the low pressure alarm for the supply plenum. The instantaneous loss of pressure would be ≈0.11 in. w.g. The system requires a loss of 1 1/2 in. w.g. before tripping. Lacking an alarm the system would reestablish the supply plenum pressure to a 2 in. w.g. without further incident.

A failure of damper C would likely fail to trip the pressure level reversal alarm between Zone 1 and Zone 3. A reversal between building ventilation Zone 1 and Zone 3 will occur but would likely clear within the 5 s count delay for sounding the alarm. A worse case is to assume that damper B would compensate to bring the pressure in room 235-C back to the preset pressure level. If the compensation occurs within the 5 s alarm time delay, the automatic shutdown system will not complete its cycle and the ventilation will continue operation. The system would not be sensing a pressure reversal between Zones 1 and 3 because none would exist at the respective sensing points.

Damper C opening would likely fail to trip the position alarms on the exhaust modulating dampers D-95 and D-97. The magnitude of the total building flow change due to the upset is too small.

Damper C opening would also likely fail to trip the pressure level alarm in the main exhaust plenum.

The failure of damper C would result in a pressure reversal between the operating (viewing) galleries (rooms 229 and 233) and the process areas (rooms 228 and 235-A) (Figure 9-3). A similar reversal would exist between process rooms 235 and 232. Note that room 235-A-1 may, at times, be maintained as an Airborne Radioactivity Area, while room 232 is normally maintained as a Surface Contamination Area.

In conclusion, damper C opening would pressurize rooms 146, 148, and 308; however, any release due to this pressurization is considered of low probability since so many events must occur simultaneously. Although these rooms house a variety of containers, including gloveboxes, open-faced hoods, filterboxes, or the equipment that provides the 26-in. Hg vacuum system a substantial quantity of suspendable contamination from them must be present in the room free of the containers. As discussed in Sections 9.1.1

through 9.1.4, free materials, even if completely released, would not exceed the Risk Acceptance Guidelines.

A pressurization of Zone 3 (damper C supply) cannot transfer radioactive materials from Zone 3 to Zone 1. That part of Zone 3 that is supplied from damper C lacks a direct interface with Zone 1. The other zones will buffer any influence from this zone into Zone 1.

9.1.7A.1.2.2 The Failure of Damper B. The control rooms for the RMA and RMC Lines, the radiation zone side of rooms 210, 211, 212, and the 225 (vault) are the only areas serviced solely by the damper B controlled S-3 system. Other rooms have a mix of S-3 air from both the damper B and damper C duct work, as listed in Table 9-5. As with the damper C failure, a failure could occur without tripping any alarms. A failure of damper B (the damper opens) would have the same effects as those of damper C, except the roles of dampers B and C are reversed.

Scoping calculations for the damper B failure scenario show that an opening of damper B would change the ventilation pressure, for those rooms throughout Zone 3 receiving air solely from the duct work serviced by damper B ventilation supply, from the normal range of -0.14 to -0.17 in. w.g. to 1.0 in. w.g. Again, room 235 and certain others with a dual supply from the S-3 (both dampers) ventilation supply will return to near the preset pressure.

In this scenario, damper B has failed open and is thus inoperative, but damper C remains active and will be responsive to the control system. The control loop will throttle supply air to correct room 235 back to the original preset pressure. This throttling or shutting down of damper C will drive those rooms supplied by only the S-3 (damper C) system to a -0.9 in. w.g. pressure. Those rooms serviced dually by the S-3 (both dampers) supply air systems will behave similarly to room 235 and will return to close at the preset negative pressure. The actual pressure will depend upon the original mix of S-3 supply from both dampers.

Damper B's failure would not trip the pressure level alarm for the supply plenum. The instantaneous loss of pressure in the supply plenum would be less than 0.07 in. w.g.

A failure of damper B would likely fail to maintain a trip of the pressure level reversal alarm between Zone 1 and Zone 3. A reversal between building ventilation Zone 1 and Zone 3 would occur and trip the timer on the alarm. However, the upset condition between the sensors in corridor 14 (Zone 1) and room 235 (Zone 3) will clear; the timer would reset within the 5-s count delay for sounding the alarm, and the alarm would not sound.

Damper B opening would likely fail to trip the position alarms on the exhaust modulating dampers D-95 and D-97. The magnitude of the total building flow change due to the upset would be too small to trip the pressure level alarm in the main exhaust plenum.

A pressurization of Zone 3* (damper B supply) cannot transfer reasonable quantities of radioactive materials from Zone 3 to Zone 1. Room 211 is supplied from damper B and lies wholly within Zone 1. A pressurization

would sweep Zone 3 air into Zone 1. This should not result in spread of contamination to Zone 1 since the room is free of contamination. The other interface of Zone 3 with Zone 1 exists between room 233 and corridors 2 and 13. Door 305 connects room 233 and corridor 2. Door 306 connects room 233 and corridor 13. Room 233 is the control room for the RMA Line. There are no radioactive materials stored in this room.

9.1.7A.1.2.3 The Simultaneous Failure of Damper B and Damper C. There are numerous valves on the control lines to these dampers, and it could be postulated that the control air is inadvertently shut off to both dampers. The possibility of damage has been recognized.

The S-3 ventilation supply, controlled by dampers B and C, presents a condition that would be immediately recognized in the control room due to the alarms that sound. The nature of the areas serviced with these systems has been noted previously.

A failure of dampers B and C (the dampers open) together would have the following cascade of effects (in a rough order of occurrence).

- The filter plenum and exhaust plenum pressurize to a point where the exhaust fans cannot handle the increased flow. The dampers have not had an opportunity to adjust. All pressures, except the supply plenum, rise.

- The pressure sensor in the supply plenum senses a drop in supply plenum pressure. It then signals the automatic controller for the supply plenum supply system to adjust the damper on the modulated supply fans to open. This increases flow to the supply plenum until supply plenum pressure is reestablished.

- The timer on the Zone 1 to Zone 3 pressure reversal alarm starts. After 5 s, it sounds an alarm.

- The sensor in the filter plenum signals the automatic controller for the exhaust system to adjust the damper on the modulated exhaust fans to increase flow from the filter plenum to reestablish filter plenum pressure.

- If, in the previous step, the modulating damper on exhaust fan 3 or 4 adjusts to full-open the alarm will sound.

- A minor effect would be the driving of Zones 3A and 3B to above atmospheric pressure as in the first listed response above. The sensors in room 270 for Zone 3B and corridor 5 for Zone 3A would signal the control system for both zones to return the zones to the preset pressure. Their pressure excursion above atmospheric would be brief.

Scoping calculations for this dual damper failure scenario show that all the rooms serviced by either the S-3 from damper C or a mix of each ventilation system will change from the normal range of -0.14 to -0.17 in. w.g. to a positive 0.9 in. w.g. Thus, failure of dampers B and C would not trip the pressure level alarm for the supply plenum. The instantaneous loss

of pressure would be less than 0.2 in. w.g. The system requires a loss of 1 1/2 in. w.g. prior to tripping. Lacking an alarm, the system would reestablish the supply plenum pressure to a 2 in. w.g. without further incident.

A failure of these dampers will trip the pressure level reversal alarm between the Zone 1 and Zone 3.

A failure of these dampers will trip the position alarms on the exhaust modulating dampers D-95 and D-97.

A failure of these dampers will fail to trip the pressure level alarm in the main exhaust plenum.

In conclusion, a failure of these dampers will have the same effect to the outside environment as a failure of the individual dampers. This would mean a problem will exist with potential releases to the atmosphere from corridor 4C (door 122), room 169 (door 123), room 171 (door 125), and room 179 (door 126) as with the failure of damper C. As with the failure of damper B, the radiation zone side of the RMA and RMC Line area will be pressurized, dumping air into Zone 1.

A pressurization of Zone 3 (damper B and damper C supply) could transfer radioactive materials from Zone 3 to Zone 1. That part of Zone 3 supplied by both dampers B and C interfaces with Zone 1 at room 221-B (door 280), at room 233 (doors 305 and 306), at room 235-B (door 308), at room 264 (door 363), at corridor 34 (door 440), at room 308 (door 405), and at room 235-D (door 651). These doors all are latched security doors. The doors are either sealed with tape or are close fitting. There are no materials stored in room 221-B and only drums stored in room 235-D. Room 235-B does have materials contained in gloveboxes housed within the room. A simultaneous pressurization and existence of materials outside (an accident situation) would stress the interface barriers. The barrier would then have to experience a breach.

9.1.7A.1.2.4 The Failure of Damper D. A fail open occurrence of the S-3A ventilation supply, controlled by damper D, will pressurize almost the entire south wall of the 234-5Z Building and will pressurize the 242-Z Building. The S-3A system supplies ventilation for the remainder of the rooms in the building that contain gloveboxes and hoods (see Table 9-6).

A failure of damper D (the damper opens) would have the following cascade of effects (in a rough order of occurrence).

- The filter plenum and exhaust plenum pressurize to a point where the exhaust fans can handle the increased flow. The dampers have not had an opportunity to adjust. All pressures, except the supply plenum, rise.

- The pressure sensor in the supply plenum senses a drop in supply plenum pressure. It then signals the automatic controller for the supply plenum supply system to adjust the damper on the modulated supply fans to open. This increases flow to the supply plenum until supply plenum pressure is reestablished.

- The sensor in the filter plenum signals the automatic controller for the exhaust system to adjust the dampers on the modulated exhaust fans to increase flow from the filter plenum to reestablish filter plenum pressure.

- If, in the previous step, the modulating damper on exhaust fan 3 or 4 adjusts to full-open, the alarm will sound.

Scoping calculations for the damper D failure scenario show that an opening of damper D would change the ventilation pressure for those rooms throughout Zone 3 receiving air solely from the S-3A ventilation supply from the normal range of -0.11 to -0.14 in. w.g. to 0.8 in. w.g.

There are two other rooms that are also driven positive. These are supplied from both S-3 and S-3A ventilation supply systems through dampers and so should be at a higher positive pressure, somewhere between the S-3 pressure and the supply plenum pressure, than those rooms supplied by the S-3 system solely.

Failure of damper D would not trip the pressure level alarm for the supply plenum. The instantaneous loss of pressure would be less than 0.13 in. w.g. The system requires a loss of 1 1/2 in. w.g. before tripping. Lacking an alarm, the system would reestablish the supply plenum pressure to a 2 in. w.g. without further incident.

A failure of damper D would likely fail to trip the pressure level reversal alarm between Zone 1 and Zone 3 as it is a separate system.

Damper D opening would likely fail to trip the position alarms on the exhaust modulating dampers D-95 and D-97.

Damper D opening would likely fail to trip the pressure level alarm in the main exhaust plenum.

In conclusion, damper D opening could cause a problem with releases to the atmosphere from rooms 131, 146 (from corridor 4B), 152, 153, 155, 169, and 170. These rooms have an outside wall of standard PFP construction and house a variety of confinement structures consisting of gloveboxes and open-faced hoods. There has to be contamination in the room free of the confinement structures. The gloveboxes and hoods, which set their own pressure based on the room pressure, would have to be breached sufficiently so that control through maintenance of a DP would not be adequate. And, finally, the building has to be breached along the outside walls of these rooms. Recent mathematical studies and actual testing (Giller 1989b, pp. 8 and A-23) demonstrate that the walls have structural capacity beyond that imposed by the pressure exerted by these upset conditions.

A pressurization of Zone 3A (damper D supply) could transfer radioactive materials from Zone 3 to Zone 1. Room 308 interfaces with Zone 1 at the airlock bounded by doors 404 and 405, at the abandoned office area comprised of rooms 341 through 350, at the airlock bounded by doors 440 and 439, at

door 452 into the Maintenance Shop area (room 325), and at the airlock bounded by doors 425 and 426. Room 308 houses filterboxes and the motive system for the building 26-in.-Hg vacuum system. This system services contaminated gloveboxes and process vessels. If a simultaneous release of the contamination within a filterbox or the 26-in. Hg vacuum system were to occur with a pressurization, stress would be placed on the barriers between the two zones.

9.1.7A.1.2.5 The Failure of Damper E. The failure of damper E was not evaluated in detail as there are no unsealed sources of radioactive materials. In addition, the rooms would not be pressurized as the damper fails closed, unlike all the other major dampers emanating from the supply plenum that fail open. Damper E could conceivably cause a decompression of that part of the building, but is frequently outfitted with blocks to limit travel. This would preclude the possibility of shutting off all air to the rooms serviced by this damper.

In conclusion, the upsets shown above would likely be short lived because of the effect on the people working within the facility. Very strong drafts would be felt upon the opening of interconnecting doors. There would be the physical effect of ear popping and possibly earaches. Unlatched doors may spring open.

9.1.7A.1.3 Operator Actions for Situations 9.1.7A.1.2.1 Through 9.1.7A.1.2.5 Upon being alerted to these upset conditions, the Power Operations personnel verify that a problem exists per operational procedures. Upon verification, they would follow their procedures to deactivate the supply fans and the Zone 1 exhaust fans.

9.1.7A.2 Detection of Event (234-5Z Building Pressurization).

9.1.7A.2.1 Methods or Means of Detection. Means of detection consist of a pressure level alarm for the supply plenum, a pressure level reversal alarm between Zone 1 and Zone 3, position alarms on the exhaust modulating dampers D-95 and D-97, and a pressure level alarm in the main exhaust plenum. The supply plenum alarm will sound if the supply plenum pressure is not within the bounds of 0.5 and 2.4 in. w.g. The Zone 1 and Zone 3 reversal alarm will sound if the pressure in the Zone 3 system sensor (room 235) is higher than that in the Zone 1 system sensor (corridor 14). The position alarms on the exhaust modulating dampers D-95 and D-97 will sound when either damper travels to a full-open position. These dampers service the exhaust fans EM-3 and EM-4. The pressure level alarm will sound if the pressure level in the main exhaust plenum rises above -3.5 in. w.g. This exhaust plenum pressure level alarm system appears to be more directed toward a failure of the exhaust fans than a pressurization of the building.

These means of detection incorporate protective systems that respond with alarms. The alarm for the supply plenum acts alone except for a required operator response. The reversal alarm between Zone 1 and Zone 3 does include a subsequent automatic shutdown protective system. When position alarms on the exhaust modulating dampers D-95 and D-97 indicate a problem, an operator response is required to bring the system under control in three minutes, or operations are halted. The pressure level alarm in the main exhaust plenum includes a subsequent automatic shutdown protective system.

The protective system between Zone 1 and Zone 3 will shut down the EM-11 and EM-12 fans that exhaust the Zone 1 air if the upset exceeds 5 s. The 5-s period was designed into the system to avoid shutdown due to transitory events. Shutdown of these fans pressurizes Zone 1 to re-reverse pressure levels between Zone 1 and Zone 3 and maintains contamination control. The EM-11 and EM-12 fans will remain shut down due to action of the seal-in contact relay MA. Closure of the reversal alarm switch DPS-1A-25A will cause, after a 5-s delay, an opening of contacts K-3 (1) and K-3 (2) in the EM-11 and EM-12 exhaust fan circuits deenergizing the fans. However, this will only occur if control switches are in the "auto" position, which is the normal operating position.

The protective system, acting in conjunction with the pressure level alarm in the main exhaust plenum, can shut down the supply fans and the exhaust fans EM-11 and EM-12.

9.1.7A.2.2 Response Time Assessment. The response time would vary with the type of event. If only a single damper (such as damper C) failed, it has been postulated above that no alarms would sound. The power operators may notice that their printing recorders and gauges have jumped or that the bank of Magnehelics[1] are indicating less than zero (needles pinned).

A period of 2 min can be expected to pass before the people in the affected zones call the power operators. An additional 3-min period is allowed for the power operators to correct the condition before deactivating the electric power for the supply fans. On shutting down the supply fans to the building, all but the emergency exhaust fans are interlocked to shutdown. Although this clears the condition, it is only a backup. Upon shutdown of the building ventilation supply system, personnel in all the Zone 3 areas will quickly be evacuated. Generally, evacuation is complete in 5 min, although personnel who must perform shutdown duties don full face respirators and leave later.

9.1.7A.2.3 Engineered Safety Features and Protective Systems. The PFP ventilation system depends upon deactivating the electric-driven supply fans and shutting down all but the emergency electric-motor driven exhaust fan(s) to stabilize the building ventilation to maintain contamination control. This system does not have the capacity to provide the number of changes per hour for proper ventilation.

The above feature is generally manually tripped. A failure to sustain a preset level of vacuum in the exhaust plenum can also cause the trip.

9.1.7A.3 Analysis of Effects and Consequences.

9.1.7A.3.1 Methods, Assumptions, and Conditions. Calculation of room pressures resulting from failure of supply plenum discharge dampers assumes the following conditions:

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[1]Magnehelic is a trademark of Dwyer Instruments, Inc., Michigan City, Indiana.

- The supply and exhaust fans with fixed dampers are operating at rated conditions: 76,100 ft^3/min at 5 in. w.g. for the supply fans, and 72,500 ft^3/min at 11 in. w.g. for the exhaust fans.

- To simplify the calculation, the Bernoulli flow equation was linearized. This approach yields somewhat smaller values of head drop than those resulting from the use of the straight Bernoulli flow equation. The friction factor used for the calculation for the damper open will compensate for this reduction.

- The friction factor used for the duct work leading from the supply plenum to the rooms when the damper is full-open is deduced by treating the duct outlet from the supply plenum as an orifice of the same area as the duct outlet. This number is probably lower than the actual but is satisfactory because the linearization of the Bernoulli equation compensates for this lower approximation of the friction factor.

- All doors are closed and remain closed. There is no crossflow from zone to zone.

- The fans operate along their rated fan curves.

- The flowrates are those discussed in Chapter 5.0.

- The supply fan dampers and the exhaust fan dampers operate precisely. Unless driven to their stops, they return the system to 2 in. w.g. in the supply plenum and -3.2 in. w.g. in the filter plenum.

- The air washers and filters between the outside and the supply fan inlets provide a fixed pneumatic resistance that obeys Bernoulli's theorem. The same is true of the passage from the filter plenum to the exhaust fans and from the exhaust fans to the stack discharge.

- The 236-Z system does not change flowrates during upsets in Building 234-5Z.

- The flows into Zone 1 are constant.

Procedure for Calculation. The principal heating, ventilation, and air-conditioning (HVAC) system components are discussed in Chapter 5.0.

Purpose. Determine the room air pressures of representative rooms that can be expected in the various ventilation zones of the 234-5Z Building if a failure of one of the outlet dampers attached to the supply plenum occurs. These dampers control the air to the various zones throughout the building. The dampers will fail open, except for the E damper, which fails closed.

The method of analysis was based on *Electrical and Mechanical Networks*, "An Introduction to Their Analysis" (Harman and Lytle 1962). The method uses Kirchoff's law and D'Alembert's principle to set up, in a matrix, a system of differential equations to describe a mechanical or electrical system. The method then provides a means for solving for the desired performances.

The matrix could be addressed as a mathematical model of the system. In this instance the technique has been extended to a pneumatic system. Note that pressure drop through an element does vary as the square of the velocity through the element. However, for small changes the pressure drop can be taken as linear. This would appear to be acceptable within the simplifications used to allow the calculation to be made. It will be used for examining the phases of the system performance and finally solving the model for room pressures after the upset. Although the text gives the technique for solving differential equations, simple equations were used by noting that masses and dampers (mechanical springs) are not involved. The system consists solely of flows and pressure drops.

The pneumatic system servicing the 234-5Z Building consists of six branches. Although the branches do intermingle, for this analysis it is considered of insignificant consequence. One branch services the "front" side of the building. This uses a separate exhaust system and so, for simplicity, is considered to behave independently of the other branches and can be ignored. Another branch provides air to the 236-Z Building and is analyzed in a separate section. On the remaining branches there are supply dampers feeding the branches and connected to the common supply plenum. These dampers are varied by controllers receiving signals from a single room for each branch, except for two of the dampers, which are controlled by a single room; coincidentally, this room receives air from both dampers.

A mathematical model of the system was developed using simultaneous linear equations to describe the various parts of the system (see Figures 9-8 and 9-9). These equations were then entered into a matrix that could be solved to yield system responses. The values of the elements were calculated from existing system operating parameters. The procedure is to change any one of these element values and recalculate the matrix. The element values chosen in this study are those of the supply dampers.

Following an upset of a supply plenum damper, system performance (or response) will vary with time. There will be two phases. The first will be that occurring prior to the controllers responding and the second will be after the controllers have responded. This latter response will be one of two possibilities: (1) the controllers have corrected the dampers to their control points (except where the supply plenum damper has experienced failure) or (2) the controllers have pushed the control dampers to their stops and full return of the control points to normal cannot be achieved without special manual assistance, which will not be discussed here.

Mathematical Model. The following mathematical model was developed from the simplified system description shown in Figure 9-8. The mechanical system shown at the top of the figure was represented by the equivalent pneumatic network in the middle of the figure in which resistors represented pressure loss (energy) components such as air washers, ductwork, dampers, and filters. This network is further developed into the lumped pneumatic network shown at the bottom of the figure. This allows system description with linear equations as required to solve matrices. The supply fans are designated H_S, which is a lumped equivalent source (or pneumatic head) consisting of the supply fans and the system, including duct work, dampers, and air washers, from the outside of the building through the supply plenum. The exhaust fans, with the exception of the Zone 1 fans, are designated H_E, which is a lumped

equivalent source consisting of the exhaust fans and the system, including duct work, dampers, and filter room filters, from the filter plenum to the discharge of the stack. Although H_S and H_E are not linear, they are sufficiently linear in the range of operation to allow use of an equivalent linear equation. The performance of the rooms and system from the supply plenum to the filter plenum also is not linear but is sufficiently linear in the range of operation to allow the use of equivalent linear equations.

The lumped pneumatic network is shown on Figure 9-9. Note that both H_S and H_E take or give air to the atmosphere and thus can have a common base (atmospheric air is at atmospheric pressure).

Setting up loop equations for this Building 234-5Z performance, where the summation of head losses equals zero for each loop arbitrarily drawn and identified as Q (flow) subnumber, results in the following:

$$Q_1(R_B + R_1) + (Q_1 - Q_2)(R_C + R_2) = 0$$

$$(Q_2 - Q_1)(R_C + R_2) + (Q_2 - Q_3)(R_D + R_3) = 0$$

$$(Q_3 - Q_2)(R_D + R_3) + (Q_3 - Q_4)(R_E + R_4) = 0$$

$$(Q_4 - Q_3)(R_E + R_4) = H_S - H_E$$

where: H_S = Lumped equivalent source for the supply side head in inches water gauge

H_E = Lumped equivalent source for the exhaust side head in inches water gauge.

This is based on the flow equation for the rooms (etc.) being linearized to:

Head loss(H) + Flow (Q) * Pneumatic Resistance (R)

These two lumped equivalent sources are represented by a straight line curve of the flow versus pressure into the plenum:

$$H_s = M_S * Q_4 + B_S$$

where: M_S = the slope of the supply system straight line curve and B_S is the intercept of the straight line curve. This is based on fan performance only. The supply fan damper is taken to remain stationary.

$$H_E = M_E * Q_4 + B_S$$

where: M_E = the slope of the exhaust system straight line curve and B_E is the intercept of the straight line curve. This is based on fan performance only. The exhaust fan damper is taken to remain stationary.

Rewriting the fourth line in the loop equations for this Building 234-5Z performance:

$$(Q_4 - Q_3)(R_E + R_4) = H_S - H_E \text{ becomes}$$

$$(Q_4 - Q_3)(R_E + R_4) = M_S * Q_4 + B_S - M_E * Q_4 - B_E$$

Rearranging terms in the loop equations for this Building 234-5Z performance:

$$Q_1(R_B + R_1 + R_C + R_2) + Q_2(-R_C - R_2) = 0$$

$$Q_1(-R_C - R_2) + Q_2(R_C + R_2 + R_D + R_3) + Q_3(-R_D - R_3) = 0$$

$$Q_2(-R_D - R_3) + Q_3(R_D + R_3 + R_E + R_4) + Q_4(-R_E - R_4) = 0$$

$$Q_3(-R_E - R_4) + Q_4(R_E + R_4 - M_S + M_E) = B_S - B_E$$

Setting the values in the loop equations into a 4*4 matrix:

$$\begin{bmatrix} A_1 & B_1 & C_1 & D_1 \\ A_2 & B_2 & C_2 & D_2 \\ A_3 & B_3 & C_3 & D_3 \\ A_4 & B_4 & C_4 & D_4 \end{bmatrix} * \begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \end{bmatrix}$$

where: $A_1 = (R_B + R_1 + R_C + R_2)$

$A_2 = (-R_C - R_2)$

$A_3 = 0$

$A_4 = 0$

$B_1 = (-R_C - R_2)$

$B_2 = (R_C + R_2 + R_D + R_3)$

$B_3 = (-R_D - R_3)$

$B_4 = 0$

$C_1 = 0$

$C_2 = (-R_D - R_3$

$C_3 = (R_D + R_3 + R_E + R_4)$

$C_4 = (-R_E - R_4)$

$D_1 = 0$

$D_2 = 0$

$D_3 = (-R_E - R_4)$

$D_4 = (R_E + R_4 - M_S + M_E)$

$E_1 = 0$

$E_2 = 0$

$E_3 = 0$

$E_4 = B_S - B_E$.

The values of Q1 through Q4 are to be determined.

The values of flow through the rooms are then calculated, noting that the flow through damper B is Q1, through damper C is (Q2-Q1), through damper D is (Q3-Q2), through damper E is (Q3-Q4), and the flow into all the rooms is Q4. These values are absolute.

The resultant mathematical system is solved for the values of flow (i.e., Q_1). To accomplish this, the matrix was programmed on a spreadsheet. The mathematical procedure was that set forth in *Higher Mathematics for Engineers and Physicists*, p. 110, (Sokolnikoff and Sokolnikoff 1941).

The system is checked by comparing the calculated performance against the actual performance of the ventilation system at a known condition, usually normal performance.

As stated, H_S and H_E are straight line equations of the flow through the plenums. To find these equations the actual curve of the performance must be determined. This curve has to be determined from the fan performance

curve and the connecting system. Graphically, the system is shown on Figure 9-9 as that portion of the path, for H_S, from the outside building into fan inlet through the supply plenum and, for H_E, from the filter plenum (the exhaust plenum can be used but will be addressed when used) to the stack exit.

The first step in finding values for the lumped equivalent sources was to address the fans. A quadratic equation ($Jx^2 + Kx + L = y$) that fit the fan curve for the supply and exhaust fans had to be determined. These fan curves were produced from actual test data taken from testing the fans. These data are available in Certified Vendor Information (CVI). To start the curve-fit process, three points on the fan curve are used to set up three simultaneous quadratic equations that can form a 3*3 matrix:

$$\begin{bmatrix} A1 & B1 & C1 \\ A2 & B2 & C2 \\ A3 & B3 & C3 \end{bmatrix} * \begin{bmatrix} D1 \\ D2 \\ D3 \end{bmatrix} = \begin{bmatrix} E1 \\ E2 \\ E3 \end{bmatrix}$$

where: $A1 = X_1^2$

$A2 = X_2^2$

$A3 = X_3^2$

$B1 = X_1$

$B2 = X_2$

$B3 = X_3$

$C1 = 1$

$C2 = 1$

$C3 = 1$

$E1 = Y_1$

$E2 = Y_2$

$E3 = Y_3$.

The values of D1 (J from the quadratic equation), D2 (K), and D3 (L) were determined from the programmed spreadsheet. The resultant equation was then checked by plotting it over the values taken from the fan curve (additional to the three chosen).

The next step in the determination was to integrate the curve fit equation into the performance of the system (e.g., H_S) (see Figure 9-10). Repeating the portion under discussion of Figure 9-9.

The normal conditions and assumptions are:

- The outside is the baseline
- The flow is the total fan flow
- The supply plenum is at 2 in. w.g.
- The fans are operating at their rated capacity
- The pressure drop across each individual air washer will be the same at the same flow through the air washers.

Note that, at the normal conditions, the pressure profile as air passes through the building will look as shown on Figure 9-7. The portion under discussion is reproduced below (Figure 9-11).

The portion of the performance from the outside of the building to point A (across the air washers and ducting) can be deduced by noting that the supply fans are rated at 5 in. w.g. Thus, point A is the supply plenum pressure (2 in. w.g.) minus the head gain from the fans operating at rated conditions (5 in. w.g.) (i.e., -3 in. w.g.). The loss across these air washers and others at other flows can be calculated from Bernoulli's equation for compressible flow. This equation states that flow (Q) is proportional to the square root of head loss across a restriction:

$$Q_f = Q_i * \{[(\text{differential head}_f)/(\text{differential head}_i)]^{1/2}\}$$

where: f = final condition
i = initial condition.

The contribution of the fans represents the remaining portion of the performance. The fan operation can be calculated by noting what each part of the sketch represents. That portion from point A to the supply plenum is the head gain of an unfettered fan (no control damper). That portion from point A to B is the head loss across the supply fan damper, and that portion from point B to the supply plenum is the performance of the fettered fan (with the supply fan damper). Note that the flow from point A to B and from point B to the supply plenum is the same.

At normal conditions the assumption has been made that the unfettered supply fans are operating at rated conditions. The total flow consists of the input from the fettered and unfettered fans. Thus, the flow from the fettered fans is the difference between the total flow and the number of unfettered fans operating times their rated flow each. The head gain from the fettered fans is obtained from the fan curve at that flow. Therefore, the head loss across the supply fan dampers (point A to B) is the difference between the head gain of the fettered and unfettered supply fans:

$$Q_{total} = Q_{fettered} + Q_{unfettered}$$

$$\text{Head loss (A to B)} = \text{Head gain}_{\text{fettered fan}} - \text{Head gain}_{\text{unfettered fan}}$$

Pressure gains necessary to achieve other flows can be determined by reversing this procedure: (1) increment the fettered fan flow, (2) determine the new pressure gain from the fan curve to achieve that flow, and (3) determine the new pressure drop across the supply fan dampers (use the Bernoulli equation). The difference is again the pressure gain across the unfettered fans. The flow from the unfettered fans is determined from the fan curve. The total flow is again the summation of the fan flows. Repeating this several times will yield a loci of points describing the performance of this system. In the area of interest a linear equation can be written. In actual practice this linear curve was a very close fit to the actual curve shape.

The determination of the exhaust system performance was similar to the scheme for determining the supply system performance. It was deducible by viewing the analogous system and the pressure profile. The baseline was the discharge of the stack, which is considered atmospheric or 0 lb/in^2 (gauge). The portion of the system to be discussed is shown in Figures 9-12 and 9-13.

The calculation procedure is identical to that used for the supply side. The only exception is that the performance curve matched or fitted was that of the electrically driven exhaust fans instead of the supply fans.

Part 2, linearizing the room performance, consisted of simply finding resistance numbers for the part of the room system from the supply plenum to the room and for the part of the room system from the room to the filter plenum. These evolved from the simple equation:

$$R = \frac{\text{Head loss}}{\text{Flow}}$$

To offset the minor error introduced by this linearizing, an assumption was made for determining a new resistance for the performance of the ducting to the rooms from the supply plenum after the damper fully opened (the "upset" condition). The new resistance for the supply plenum to room must be estimated. The least resistance the new system could be is if the duct work separated from the supply plenum and only the annulus remained. The resistance for this annulus can be determined from the Bernoulli equation:

Flow (Q) = The cross-sectional area of the annulus times a flow loss coefficient times the square root of two times the gravitational constant "g" times the head loss in feet (of the media being passed)

$$= A*C*(2*g*H)^{1/2}$$

To determine an equivalent pneumatic resistance of the form

$$\text{Flow (Q)} = \frac{\text{Head loss (H)}}{\text{Pneumatic resistance (R)}}$$

or

$$R = H/Q$$

Bernoulli's equation can be roughly linearized by noting the range of H. If H varies in a narrow range of about 2, then $(H)^{1/2}$ is roughly the same as $[(2)^{1/2}*H/2]$. Thus, the Bernoulli equation can be rewritten as:

$$Q = \frac{A*C*H[(2)^{1/2}]*[(2*G)^{1/2}]}{2}$$

Dividing the Bernoulli equation by the pneumatic resistance equation yields:

$$1 = \frac{Q}{Q} = \frac{A*C*H*[(2)^{1/2}]*[(2*g)^{1/2}]}{H*2}*R$$

or

$$R = \frac{2}{A*C*[(2)^{1/2}]*[(2*g)^{1/2}]}$$

where: A = Area of annulus at each supply damper
C = 0.5 for rough annulus
g = 32.2 ft/s^2.

Thus, the fact that the new resistance is smaller than that probably seen will offset the assumption of linearity.

The phases of the system performance are as stated at the beginning of this section (i.e., the first phase will be that occurring prior to the controllers responding and the final phase will be after the controllers have responded).

The first phase can be determined by using the linear values of H_S and H_E found as shown previously. The final phase can take one of two forms:

- Both the supply and filter plenums have returned to the original settings of pressure. The modulating dampers in both fettered fans have adjusted to accomplish this.

- The filter plenum and or the supply plenum is incapable of returning to the preset pressure. The modulating damper on the fettered fan is fully open and the fans are operating at a new position on the fan curve to handle the full flow and/or the supply fan damper is fully open and the fans are operating at a new position on the fan curve to handle the full flow. However, the original straight line equation for H_E is no longer valid. A new equation must be developed, assuming that there are no fettered fans in the exhaust system and all operating fans are operating as unfettered fans.

Condition one of the final phase again uses the simultaneous equations:

$$Q_1(R_B + R_1) + (Q_1 - Q_2)(R_C + R_2) = 0$$

$$(Q_2 - Q_1)(R_C + R_2) + (Q_2 - Q_3)(R_D + R_3) = 0$$

$$(Q_3 - Q_2)(R_D + R_3) + (Q_3 - Q_4)(R_E + R_4) = 0$$

$$(Q_4 - Q_3)(R_E + R_4) = H_S - H_E$$

where: $H_S = 2$
$H_E = -3.2$.

Condition two of the final phase can be evaluated by noting that $H_S = 2$. H_E is again the straight line function $H_E = M_E*Q_4 + B_S$; however, M_E and B_S have new values. These values have been determined based on all exhaust fans operating in the unfettered mode. This final phase condition must be calculated. If the filter plenum pressure is found to be less than -3.2, then this calculation is invalid, as this would indicate that the exhaust damper has not opened fully, which is not the condition indicated by the new H_E.

9.1.7A.3.2 Source Term. Not applicable.

9.1.7A.3.3 Margin of Protection. Several events must occur for a discharge to the atmosphere to occur. A damper supplying ventilation air to an area housing confinement vessels must have failed; there must be loose materials in the glovebox or hood; there must be a breach of the glovebox or hood; the breach must be large enough so that the confinement structure ventilation cannot maintain an adequate DP across the breach to maintain contamination control; and, finally, the flow path to the existing exhaust system must be incapable of sweeping all the materials into the exhaust duct such as would occur if the wall to the outside had opened a large hole. The

wall structure, however, has been determined to have sufficient structural capacity at this pressure to prevent such a hole from occurring. Without detailed examination it is clear that such a series of independent events has a very low probability. When combined with the low onsite/offsite consequences of plutonium spills into rooms postulated in Sections 9.1.1 through 9.1.4, this event will not be considered further.

9.1.7B Excessive Pressurization of 236-Z Building

This analysis examines the mechanism for creating a pressurization of the areas in the 236-Z Building housing sources of radioactive materials.

9.1.7B.1 Postulated Cause of the Event.

9.1.7B.1.1 Starting Conditions and Assumptions. The ventilation air for the 236-Z Building is taken from the ventilation system for the 234-5Z Building. A damper (damper F) is attached to the supply plenum within the 234-5Z Building. The ventilation air is routed in a long outside duct over the roof of the 234-5Z Building to the 236-Z Building.

A cascading system of air usage is used for contamination control. Air is introduced into corridors 20 and 30. From there, a portion of the air is HEPA filtered, more to guard against a reversal than for normal flow, and passed progressively into the canyon, the glove-boxes, a two-stage filter housing, and finally into the main building filtration system (room 26 in the 236-Z Building). The air exits from there into the discharge duct, emptying into the exhaust plenum within the 291-Z Building. At each successive point the air pressure is less than at the previous location (greater negative pressure or vacuum).

Parallel systems for ventilating the office areas, maintenance areas, room 19, miscellaneous treatment (MT) area in room 41, and solvent extraction and S&C gloveboxes (no longer in use) in room 43 parallel the canyon flow system. The gloveboxes in rooms 27, 41, and 43 draw air from the rooms and thus will not be driven to a positive pressure relative to the rooms.

The pressure levels set in the rooms are:

- -0.3 in. w.g. rooms 10, 11, 14, 19 to 21, 25, 30, 31, and 33
- -0.15 in. w.g. rooms 15 to 18, 26, 27, 34 to 38, 40 to 48, 50, 60, and stairs 1 and 2
- The pressure level in room 12 is not controlled.

The pressure is controlled by damper F within the 234-5Z Building. The individual levels (noted above) are preset with manual dampers.

There is a controller on the ducts emanating from the canyon gloveboxes. This has circular chart paper, marked with a range that varies from 0.0 to 1.0, on a chart recorder. There is a marker on a gauge that reads, "Operating Range 0.5 to 2.0 in. w.g." This controller powers a DOV that establishes filterbox and glovebox negative pressure.

Prior to the postulated upset, the rooms are all at the pressures set above. There is no gauge on the canyon, so the pressure within is unknown, except that it lies in a range whose upper limit is less than the pressure existing in room 20 or 30 as these rooms are the sole source of air for the canyon. There is a gauge on the canyon gloveboxes. The controller downstream of the canyon gloveboxes uses a sensor that taps into the canyon glovebox. Each of the four gloveboxes has an individual system. As of July 17, 1989, the controllers on the discharge duct from the canyon gloveboxes were reading from 0.69 to 0.74 on the chart paper. The chart paper is calibrated such that 100% is -1 in. w.g. Normal glovebox pressures are from -0.6 to -0.7 in. w.g. This sets the lower limit to the range of pressures the canyon and gloveboxes can be experiencing.

The canyon and canyon gloveboxes could be at pressures at opposite extremes of the range specified. Air for the gloveboxes passes through the plug holes in the canyon wall separating the canyon and canyon gloveboxes. These plug holes are part of the fastening device that mounts the tanks and dunnage maintained in the canyon to the canyon wall. If sufficient plugs are in use to severely limit the amount of remaining plug holes, a substantial DP would exist across the canyon wall. This would also severely limit the amount of flow passing through the canyon and canyon gloveboxes.

9.1.7B.1.2 Sequence of Events. The entire 236-Z Building, including the production area, can be pressurized above its individual normal operating range by the opening of damper F. Such an inadvertent opening could occur through human error during the semiannual changeout of the damper motor. Such an error may well be as simple as a craftsperson, or other who has a reason to handle the linkage, releasing the damper shaft before securing it to the alternate damper motor or securing the opposite damper motor rod to the wrong end of the damper shaft.

The postulated result of this single event would be the opening of the damper either by being driven open or by being blown open. The air pressure in the 236-Z Building (those rooms normally at -0.15 in. w.g.) would increase to 0.3 in. w.g. and then stabilize. The drop in pressure in the supply plenum would be compensated for by the modulation system on the supply fans. The air that discharges from the 236-Z Building would drive the 291-Z exhaust plenum to an increased pressure (from -6 in. w.g. to -5.9 in. w.g.), allowing the 291-Z exhaust fans to handle the flow. A system instability should then occur as two independent systems both try to correct. The sensor in the 234-5Z Building filter plenum would adjust the damper, throttling an exhaust fan to return the 234-5Z Building filter plenum to its preset pressure, and the 234-5Z Building room sensors would adjust their respective supply dampers to reduce the flow and return the rooms to their preset pressures.

Failure of Damper F. A failure of damper F (the damper opens) would have the following effects (in a rough order of occurrence).

- The 236-Z Building pressurizes.
- The 291-Z exhaust plenum pressurizes until the exhaust adjusts to handle the increased flow. The dampers have not had an opportunity to adjust. All pressures, except the supply plenum, rise.

- The pressure sensor in the supply plenum senses a drop in supply plenum pressure. It then signals the automatic controller for the supply plenum supply system to adjust the damper on the modulated supply fans to open. This increases flow to the supply plenum until supply plenum pressure is reestablished.

- The room pressure sensors in the 234-5Z Building signal the automatic controller for the supply plenum discharge system to adjust dampers to decrease flow to the 234-5Z Building rooms to reestablish zone pressure.

- The sensor in the filter plenum signals the automatic controller for the exhaust system to adjust the damper on the modulated exhaust fans to increase flow from the filter plenum to reestablish filter plenum pressure.

- In the previous step, an alarm will sound if the modulating damper on exhaust fan 3 or 4 adjusts to full-open.

Scoping calculations for the damper F failure scenario show that an opening of damper F would briefly change the ventilation pressure for those rooms normally at -0.15 in. w.g. to 0.35 in. w.g. Those rooms normally at -0.3 in. w.g. would change from their normal range to 0.20 in. w.g.

Failure of damper F would not trip the low pressure alarm for the supply plenum. The instantaneous loss of pressure would be 0.04 in. w.g. The system requires a loss of 1.5 in. w.g. to trip. Lacking a trip of the alarm, the system would reestablish the supply plenum pressure to a positive 2.0 in. w.g. without further incident.

Failure of damper F would probably not trip the position alarms on the exhaust modulating dampers D-95 and D-97 because the magnitude of the total building flow change due to the upset is too small. Failure of damper F would probably not trip the pressure level alarm in the main exhaust plenum.

9.1.7B.1.3 Conclusion. Failure of damper F to full open would not cause a problem with potential releases to the atmosphere, except possibly through the large airlock located at the south end of the 236-Z Building. The canyon could be driven positive with respect to atmosphere. There are no gauges monitoring canyon pressure, so its present status is unknown. The airlock is occasionally found to have spots of contamination. Operating personnel speculate that the contamination seeps from around the canyon door into the airlock. If pressurization were to occur, the change would not be noticeable as the remainder of the building would be similarly pressurized. The outside wall has sufficient structural capability to resist this pressurization. The airlock is sealed against the outside of the building and surrounds the door. A HEPA filter is mounted through the door so that air will flow through the airlock toward the canyon when the outer doors are opened. Other HEPA filters are mounted throughout the airlock. A pressurization of the canyon would cause a backflow through these filters to the airlock. A DP gauge is mounted on the airlock entry door, which could alert someone of the pressurized condition. A portable CAM located in the airlock would sound if canyon pressure caused airborne contamination in the airlock; however, the facility is not continuously manned, and the noise could go unnoticed.

There may be no notification in the power control room (by alarms) that an upset has occurred. The power operators action is to deactivate supply fans to reduce overpressurization. Exhaust fans may be tripped off to keep the balance of the plant from going too negative while bringing the 236-Z Building differential pressure within operating range. If exhaust fans are tripped off to prevent too high a negative in other zone 3 ventilation areas, the zone 3 areas are evacuated. The various DP gauges will show a new setting.

9.1.7B.1.4 Operator Actions. Unless alerted with alarms, the first notification of the problem may be through phone calls from plant operating personnel to the power operators. Upon being alerted to these upset conditions, the power operations personnel check the recorders on the 236-Z Building controller in the power control room (321-A) to verify that a problem exists per operational procedures. Upon verification, they would follow their procedures to deactivate the supply fans and the Zone 1 exhaust fans.

9.1.7B.2 Detection of Event.

9.1.7B.2.1 Methods or Means of Detection. The final differential pressures determined by calculation demonstrate that the impact of damper F failure on the 234-5Z Building is insufficient to trip any of the detection systems. These consist of a pressure level alarm for the supply plenum, position alarms on the exhaust modulating dampers D-95 and D-97, and a pressure level alarm in the main exhaust plenum. The supply plenum alarm will sound if the supply plenum pressure is not within the bounds of 0.5 and 2.4 in. w.g. The position alarms on the exhaust modulating dampers D-95 and D-97 will sound when either damper travels to a fully-open position. These dampers service exhaust fans EM-3 and EM-4. The pressure level alarm in the main exhaust plenum will sound if the pressure level rises above -3.5 in. w.g. This exhaust plenum pressure level alarm system appears to be more directed toward a failure of the exhaust fans than a pressurization of the building.

These means of detection incorporate protective systems that respond with the alarms. The alarm for the supply plenum acts alone, except for a required operator response. When position alarms on the exhaust modulating dampers D-95 and D-97 indicate a problem, an operator response is required to bring the system under control in three minutes, or operations are halted. The pressure level alarm in the main exhaust plenum includes a subsequent automatic shutdown protective system.

The protective system, acting in conjunction with the pressure level alarm in the main exhaust plenum, can shut down the supply fans and the exhaust fans EM-11 and EM-12.

9.1.7B.2.2 Response Time Assessment. The response time would have to include the time for notification of the problem. Without any alarms sounding, the operating personnel phoning the Power Control room inquiring about the ventilation may be the first indication of a problem, unless the power operators notice that their chart recorders are indicating that a jump in pressure occurred.

A period of 2 min is expected to pass before the people in the affected zones call the power operators. An additional 3-min period is allowed for the

power operators to correct the condition before deactivating the electric power to the supply fans and all but the emergency exhaust fans. Although this clears the condition, it is only a backup. If the stabilization effort requires the exhaust fans to be taken out of service, ventilation zone 3 areas are evacuated.

9.1.7B.2.3 Engineered Safety Features and Protective Systems. Ventilation system upset conditions are controlled through automatic or manual shutdown of the supply fans. Control of the PFP ventilation system upsets depend upon deactivating the electric-driven supply fans and all but the electric-driven emergency exhaust fan(s) to stabilize the building ventilation to maintain contamination control. This system does not have the capacity to provide normal flow rates but can maintain negative pressure in most gloveboxes throughout the facility and proper direction of flow. If stabilization activities require shutdown of the exhaust fans, ventilation zone 3 areas are evacuated and power operators are placed on mask.

9.1.7B.3 Analysis of Effects and Consequences.

9.1.7B.3.1 Methods, Assumptions, and Conditions. Calculating room pressures resulting from failure of supply plenum discharge dampers assumes the following conditions:

- Under normal operation, the supply and exhaust fans are operating at rated conditions: 76,100 ft^3/min at 5 in. w.g. for supply fans and 72,500 ft^3/min at 11 in. w.g. for exhaust fans.

- To simplify calculation, the Bernoulli flow equation was linearized. This will yield somewhat smaller values of head drop than those resulting from the use of the straight Bernoulli flow equation. The friction factor used for the calculation for the damper open will compensate for this reduction.

- The friction factor used for the ductwork leading from the supply plenum to the rooms when the damper is full-open is deduced by treating the duct outlet from the supply plenum as an orifice of the same area as the duct outlet. This number is probably lower than the actual butis satisfactory because the linearization of the Bernoulli equation compensates for the lower approximation of the friction factor.

- All doors are closed and remain closed. There is no crossflow from zone to zone.

- The fans operate along their rated fan curves.

- The flowrates are those discussed in Chapter 5.0.

- The supply fan dampers and the exhaust fan dampers operate precisely. Unless driven to their stops, they return the system to 2 in. w.g. in the supply plenum and -3.2 in. w.g. in the filter plenum.

- The air washers and filters between the outside and the supply fan inlets provide a fixed pneumatic resistance that obeys Bernoulli's theorem. The same is true of the passage from the filter plenum to the exhaust fans and from the exhaust fans to the stack discharge.

- The flows from Zone 1 are constant.

Procedure for Calculation. The system is essentially as shown in Figure 9-14. The following procedure was used to calculate the room pressures.

Purpose. Determine the room air pressures of representative rooms that can be expected in the ventilation zone of the 236-Z Building if a failure of outlet damper F attached to the supply plenum occurs. This damper controls the air to the various areas throughout the building. The damper will fail open.

The method of analysis will be based Harman and Lytle (1962). The method uses Kirchoff's law and D'Alembert's principle to set up, in a matrix, a system of differential equations to describe a mechanical or electrical system. The method then provides a means for solving for the desired performances.

The matrix could be addressed as a mathematical model of the system. In this instance the technique has been extended to a pneumatic system. Note that pressure drop through an element does vary as the square of the velocity through the element. However, for small changes the pressure drop can be taken as linear. This would appear to be acceptable within the simplifications used to allow the calculation to be made. It will be used for examining the phases of the system performance and finally solving the model for room pressures after the upset. Although the text gives the technique for solving differential equations, simple equations were used by noting that masses and dampers (mechanical springs) are not involved. The system consists solely of flows and pressure drops.

The pneumatic system servicing the 234-5Z Building consists of six branches. The branch that provides air to the 236-Z Building is covered in this section.

Mathematical Model. To generate a mathematical model of the system, simultaneous linear equations were developed to describe the various parts of the system. These equations were then fit into a matrix that can be solved to yield system responses. The values of the elements are calculated from existing system performance. The procedure is to change any one of these element values and recalculate the matrix. The element values chosen in this study are those of the supply damper F.

Calculation of system performance after a failure of damper F is similar to the procedure used for the 234-5Z Building (see Section 9.1.7A.3.1).

The system description is shown in Figure 9-14. The mathematical model is drawn from that description (see Figure 9-15). The 234-5Z Building model has been lumped into a single resistor. That is justified as the action of the 234-5Z Building is only of interest in this evaluation as it interacts

with the 236-Z Building. The lumped pneumatic network is redrawn below (Figure 9-15).

Setting up loop equations for this Building 236-Z performance is simplified from the 234-5Z Building effort as only two loops are involved (Figure 9-16). The straight line equations are:

$$Q_1(R_1) + (Q_1 - Q_2)(R_F + R_2) = 0$$

$$(Q_2 - Q_1)(R_F + R_2) = H_S - H_E$$

The values of H_S and H_E are the same as for the 234-5Z Building and are again the lumped equivalent sources for the supply and exhaust systems. Again, taking $H_S = M_S*Q_4 + B_S$ and $H_E = M_E + B_E$, these equations change to:

$$Q_1(R_1 + R_F + R_2) + Q_2(-R_F - R_2) = 0$$

$$Q_1(-R_F - R_2) + Q_2(R_F + R_2 - M_S + M_E) = B_S - B_E$$

Setting the values of the loop equations into a 2*2 matrix:

$$\begin{bmatrix} A_1 & B_1 \\ A_2 & B_2 \end{bmatrix} * \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \end{bmatrix}$$

where: $A_1 = (R_1 + R_F + R_2)$

$B_1 = (-R_F - R_2)$

$A_2 = (-R_F - R_2)$

$B_2 = (R_F + R_2 - M_S + M_3)$

$E_1 = 0$

$E_2 = (B_S - B_E)$

The values of Q_1 and Q_2 are to be determined.

These values are used to determine the system flows, $Q_{234\text{-}5Z}$ and $Q_{236\text{-}Z}$, where the value of flow through the 234-5Z Building is Q_1, and the value through the 236-Z Building is Q_2-Q_1. To perform the actual calculations, the matrix was programmed on a spreadsheet. The mathematical procedure was that set forth in Sokolnikoff and Sokolnikoff (1941, p. 110). The programming was according to the instructions for operating the spreadsheet.

A new R value for damper F after the damper has failed open is determined as for the 234-5Z calculations. The Bernoulli equation is solved to determine flow through an orifice of the same size as the duct supporting the F damper. The assumed head is 2 in. w.g. These values are then used in the linear equation to determine the R value.

The system is checked by comparing the calculated performance against the actual performance of the ventilation system at a known condition, which is usually normal performance.

As with the 234-5Z Building, the system will need to be checked with values of H_E that are derived from assuming all the exhaust fans operate unfettered. If this results in the exhaust plenum pressure being less than -6 in. w.g., the run is invalid. This result would indicate that the modulating damper opened to decrease the pressure to this point. In fact, the damper would have stopped at the set point and thus would not be fully open. The exhaust plenum at -6 in. w.g. is used as a set point instead of the filter plenum (within Building 234-5Z) pressure; which is set by sensor and control equipment that adjusts the exhaust modulating damper on one of the exhaust fans to reset the filter plenum pressure to the set point -3.2 in. w.g. Because there has been no physical change in the 234-5Z Building, the pressure drop between the filter plenum and the exhaust plenum will return to the initial value. The pressure relationship between the filter plenum and the exhaust plenum will remain intact and -3.2 in. w.g. at the filter plenum corresponds to -6.0 in. w.g. at the exhaust plenum.

Once all the flows are known the system pressures can be determined. The differential heads across the resistances can be determined from the linear equation used to set up the matrix:

$$\text{Head loss (H)} = \text{Flow (Q)} * \text{Pneumatic Resistance (R)}$$

The actual head at the typical room within the 236-Z Building is then:

$$\text{Room pressure} = \text{Atmospheric pressure (zero)}$$

$$- H_E - (-\text{head loss across } R_2)$$

Following an upset of a supply plenum damper, system performance (or response) will vary with time. There will be two phases: phase 1 will occur before the supply plenum and filter plenum controllers respond and phase 2 will occur after the controllers have responded. This latter response will be one of two possibilities; either the controllers have corrected their control points to the initial settings (except where the supply plenum damper has experienced failure) or the controllers have pushed the control dampers to their stops and full return of the control points to normal cannot be achieved without special manual assistance, which will not be discussed here.

9.1.7B.3.2 Margin of Protection. Several events must occur for a discharge to the atmosphere. A damper supplying ventilation air to an area

housing confinement structures must have failed; potentially loose materials must be available in the glovebox or hood; the glovebox or hood must be breached; the breach must be large enough so that the internal confinement structure ventilation cannot maintain a usable DP across the breach; and, finally, the flow path to the existing exhaust system must be incapable of sweeping all the materials into the exhaust duct. The 236-Z Building is an all concrete structure fully capable of withstanding the small pressurization postulated herein. The only possible bleed to the outside is through the airlock attached to the south wall of the 236-Z canyon. A single stage of HEPA filtration protects this path. Extrapolation of the suspension discussions in Section 9.1.1, involved with a spill of 8 L of concentrated solution to the wet material on the floor of the process cell indicates that the factor of 2,000 provided by the filter is enough. Together, these postulations regarding probability and consequence represent such a low risk of radioactive release that the event will not be discussed further.

9.1.7C Excessive Building Pressurization, 2736-ZB Building

This analysis examines a mechanism for pressurizing areas in the 2736-ZB Building housing sources of radioactive materials. If the pressure level is greater than the surrounding atmospheric pressure, any loose radioactive materials could be forced to the outside environment.

9.1.7C.1 Postulated Cause of the Event.

9.1.7C.1.1 Starting Conditions and Assumptions. The 2736-ZB Building ventilation system is self-contained and independent of other ventilation systems serving the PFP.

The system for the 2736-ZB Building is much newer than the systems serving the other PFP buildings. The instrumentation is considerably more extensive, more sophisticated and uses a distributed control system computer to monitor and control system operation. Two separate systems, which are essentially independent except for sharing an exhaust stack, comprise the system. System one pumps air into the building and into an air duct, which then separates into two streams. Air for the Zone 4 office areas is branched off the main duct circuit and recirculated (except for restrooms, where the air is discharged to the outside) back to the supply fan inlet. The alternate stream is split again prior to recombining in the repackaging room to ventilate that area. This duality provides redundancy for each branch. Part of the split flow is first routed to the east side of the building before entering the repackaging room while the remainder is directly routed to the repackaging room. The total system one flow, now recombined, is dumped into the extensive filtering system and pumped to the stack for discharge. System two also pumps air into the building and into an air duct. Here, however, the air sweeps through the NDA room and then to a separate filtering system. From this section, the air is pumped to the same stack as system one.

The pressure is controlled by variable dampers on both the supply side and exhaust side. On system one these dampers are used on the discharge of the supply dampers (four units total, two units in series off each of the two parallel supply fans) and the discharge of the exhaust fans (two total, one

per each of two parallel exhaust fans). Controllable dampers with motors are also provided on the inlets of the supply fans, the exhaust fans, and the recirculating fans.

The following are the pressure levels set in the zones.

Zone	Reference point	Pressure
1	Repackaging room	-1.0 in. w.g. (glovebox) -0.5 in. w.g. (airlock)
2	Atmosphere	-0.20 to -0.30 in. w.g.
3	Atmosphere	-0.10 in. w.g. (mech. room)
4	Atmosphere	+0.05 in. w.g.

9.1.7C.1.2 Sequence of Events. The ventilation system in Building 2736-ZB includes instrumentation to preclude pressurization.

One of three scenarios is usually responsible when a building is accidentally pressurized. The supply control damper has failed open or been driven open, the exhaust fan has failed, or the exhaust control damper has failed closed or been driven closed.

Failure of the supply discharge damper in this instance seems rather remote. The dampers are designed to close upon loss of pneumatic pressure (fail close). An open condition is required for a malfunction. A general failure of electrical power or instrument air would not cause the dampers to be driven open.

The configuration of the exhaust fans offers the possibility of malfunction. An abnormal event would be if one fan was temporarily out of service for repairs and the other fan failed. A further complication would be that the supply fans are on manual control. In this scenario the system could pressurize the repackaging room, which would be signaled on the annunciator in the control room.

The exhaust dampers are all fail-close units. This includes the dampers on the exhaust fan inlets. Thus, a loss of control air would allow these units to close. Again, if the supply fans were on manual control, the supply fans could not respond to the shutdown signal generated from flow switch FS-5 or FS-6. The repackaging room and most of the east side of the building would pressurize.

Two differential pressure switches, DPS-610-1 and DPS-610-2, sense changes in exhaust fan plenum pressure and NDA Laboratory recirculation fan plenum pressure. Either switch will shut down all Building 2736-ZB fans if a pressure abnormality is detected. These switches are hard wired into the circuitry that disconnects power to the Building 2736-ZB fans. In addition the PFP DCS system that monitors and controls 2736-ZB Building HVAC will, if control is in automatic mode, safeguard against a pressurization upset.

Consequences of a Pressurization. The area could not conceivably be pressurized much above atmospheric pressure. The supply plenum would probably be maintained at 2 in. w.g. as the dampers for the supply fans do not appear to be affected by switching the fans into the manual mode. The repackaging room and the NDA room share a common section of duct beyond the mechanical equipment room. The repackaging room would likely discharge air backwards to the NDA exhaust. This path should be near atmospheric, although no calculations were performed to demonstrate this.

The building should be capable of withstanding such an internal pressure loading. The building was designed to withstand a tornado (Giller 1990, p. 12). Although the interaction of wind with a building is a complex phenomena, a much simplified generalization can be made that high velocity external wind will have the same effect on the roof of the building as a pressurization within the building. The wind will create a reduction in the pressure on the exterior roof of the building with respect to the interior. The effect would be identical to a pressurization of the interior of the building (ASHRAE 1985, p. 146).

The repackaging glovebox, the only normal source of loose contamination within the building, will be affected by this upset but not to the point where radioactive materials could be released. The glovebox is supplied from an independent air source and only becomes common with the room supply on the exhaust side of the glovebox. However, by this postulation, the exhaust pressure, being blocked except by leakage from the room, will rise and the glovebox pressure will rise with it. The automatic controls will prevent the glovebox from exceeding the room pressure because supply to the glovebox will be shut off. The limited amount of flow backwards through the mechanical equipment room into system two should allow the glovebox to remain below the repackaging room pressure.

9.1.7C.1.3 Operator Actions. The upset would be signaled immediately by alarms in the MICON™ power control room (room 714 in the 234-5ZA Building). CRT displays show a description of the alarm and an audio alert sounds. Appropriate action to the trouble indication is taken following investigation of the reason for upset.

9.1.7C.2 Detection of Event.

9.1.7C.2.1 Methods or Means of Detection. Functional explanations and definitions are found on Figure 9-17 (Sheets 1 and 2) and in *Z-Plant HVAC Ladder Diagram*, WHC-SD-RE-SDR-002 (White 1987). Figure 9-17 (Sheets 3, 4, and 5) shows the HVAC airflow and control diagrams. Alarms in the MICON™ power control room (room 714 in the 234-5ZA Building) would alert operators to excess zone pressure.

9.1.7C.2.2 Response Time Assessment. The response time should be 1 to 3 min as the Building 234-5ZA MICON™ power control room (room 714) is continuously manned.

9.1.7C.2.3 Engineered Safety Features and Protective Systems. The main safety features associated with the system are alarms. There are alarms for the supply fans (low flow/fan fail), for the exhaust fans (low flow/fan fail), for the repackaging glovebox pressure (low differential pressure), and for the

2736-ZB Building instrument air. Alarms detected are transmitted to operators consoles in the MICON™ power control room (room 714 in the 234-5ZA Building) and the supervisors console in room 712. The MICON™ system has the capability to run the HVAC system both automatically or in manual mode requiring operator actions in response to changes in field conditions. Power operations personnel are trained in proper responses to system inputs when operating in manual mode.

9.1.7C.3 Analysis of Effects and Consequences.

9.1.7C.3.1 Methods, Assumptions, and Conditions. This scenario requires no calculations. The postulated upset is caused by an additional input to an existing upset condition (i.e., one exhaust blower is out of service).

9.1.7C.3.2 Margin of Protection. The possibility of building pressurization through this scenario is remote. Several factors would have to occur simultaneously: one of the two exhaust fans has to be out of service, the other fan has to fail, and the supply fans have to be on manual.

The majority of work performed in this building is with material sealed for storage or transport. The discussions in Sections 9.1.1 through 9.1.4 show that any slight contamination spread, as experienced infrequently, would not have significant onsite/offsite consequences.

9.1.7D Excessive Building Pressurization, 2736-Z Building

The facility has a hard interlock (fail closed) and a soft interlock (computer). If the supply fan dampers close, the fans are also closed. When supply fans are shut down so are the exhaust fans. This action will not allow pressurization of the facility; however, this scenario is left in as a postulated event.

This analysis examines the mechanism for creating a pressurization of the areas in the 2736-Z Building housing sources of radioactive materials. If the pressure level achieved is greater than the surrounding atmospheric pressure, any loose radioactive materials will be forced to the outside environment.

9.1.7D.1 Postulated Cause of the Event.

9.1.7D.1.1 Starting Conditions and Assumptions. Supply air for ventilation of the 2736-Z Building is provided by the 2736-ZB supply fans via a stainless steel duct. Air from 2736-Z is HEPA filtered and discharged to the environment by exhaust fans located in Building 2736-ZA.

The system for the 2736-Z Building combines two systems: the original ventilation system and the new system incorporated with the 2736-ZB Building installation. The existing system, at least the essential parts for this discussion, had a pair of exhaust fans with diesel generators for standby power located in the 2721-Z Building. The 2736-ZB Building addition provided a supply air system and controls for tying the exhausters into the total ventilation control system for the 2736-Z Building. The system uses LCU-6/DCS to monitor and control system operating parameters.

The pressure level set in the 2736-Z Building is -0.28 to -0.32 in. w.g.

The pressure is controlled through the use of variable dampers on both the supply and exhaust sides. These dampers are used on both sides of the supply dampers (four units total, two units in series off each of the two parallel supply fans) and the inlet of the exhaust fans (two total, one per each of two parallel exhaust fans).

9.1.7D.1.2 Sequence of Events. The sophisticated ventilation system in Building 2736-Z includes considerable instrumentation to preclude pressurization. However, the fan control portion of the system is deactivated and has been since the building went into service.

One of three scenarios is usually responsible when a building is accidentally pressurized. The supply control damper has failed open or been driven open, the exhaust fan has failed, or the exhaust control damper has failed closed or been driven closed.

Failure of the supply discharge damper in this instance seems rather remote. The dampers are designed to close upon loss of pneumatic pressure (fail close). An open condition is required for a malfunction. A general failure of electrical power or instrument air would not cause the dampers to be driven open.

The configuration of the exhaust fans tempers the effect of a malfunction. The two fans are in parallel, which allows one to take over the function of the other in case of malfunction. A trouble scenario would be if one fan was temporarily out of service for repairs and the other fan failed (the inlet damper is a fail closed device). A flow would decrease and pressure would rise, pressurizing the 2736-Z Building. Flow sensors on this line would send an alarm to the control room that flow was dropping. The supply system would receive a signal that flow was dropping. However, beyond these signals there is no automatic relief.

Consequences of a Pressurization. The 2736-Z Building could conceivably be pressurized close to the full 2-in. w.g. available in the supply plenum.

The building should be capable of withstanding such a loading, as this is equivalent to a 65-mi/h wind. The building was evaluated and subsequently upgraded for a 175-mi/h tornado (Giller 1990).

The consequences of this action would not be severe as there is no loose material stored in the facility.

9.1.7D.1.3 Operator Actions. The upset would be signalled immediately by alarms on the operator console displays. The Power Operators would change to a manual mode and have three minutes to correct the zone pressure or initiate facility shutdown.

9.1.7D.2 Detection of Event.

9.1.7D.2.1 Methods of Means of Detection. The schematic flow diagram of the heating and ventilating system in the 2736-Z Building is shown on Figure 9-18. The description of system operation is shown on Figure 9-17

(Sheets 1 and 2). There are flow alarms for the supply fans and for the exhaust fans in the control room and a pressure alarm for the 2736-Z Building. These alarms are signalled on the operator CRT displays and sound on the operator console speaker systems in rooms 712 and 714 of the 234-5ZA Building. The pressure alarm is identified as "7-6 loss of negative pressure 2736-Z."

9.1.7D.2.2 Response Time Assessment. The response time should be quite short as the 234-5ZA control room is continuously manned.

9.1.7D.2.3 Engineered Safety Features and Protective Systems. The use of a computer allows the ventilation system to shut down automatically if the exhaust fans are lost. The computer senses a loss of flow from the exhaust fan or an open exhaust fan contactor and shuts down the supply fans with an automatic interlock. This is a redundancy of the system since the fans can also be shutdown manually. The computers limitation is that it can not transfer the operation between the two supply fans or the two exhaust fans.

9.1.7D.3 Analysis of Effects and Consequences.

9.1.7D.3.1 Methods, Assumptions, and Conditions. No calculations were involved in this analysis. It was assumed that, as the supply plenum is pressurized to 2 in. w.g., any downstream blockage could raise to a maximum of 2 in. w.g. in intervening ductwork, rooms, etc.

9.1.7D.3.2 Margin of Protection. The possibility of building pressurization through this scenario is remote. Several events would have to occur simultaneously: one of the two exhaust fans would have to be out of service, the other fan would have to fail, and the supply fans would have to be on manual.

The possibility of the release of radioactive materials to the environment is even more remote as loose materials would have to be available. As the materials stored in the rooms are packaged elsewhere, there should be no loose materials. An upset of this magnitude would not cause the packaging to rupture. Release of plutonium from containers is discussed in Sections 9.1.1 through 9.1.4. The conclusions drawn in these sections concerning consequences and probability when combined with the small probability of a ventilation upset makes it clear that the risk is acceptable.

9.1.7E Excessive Building Pressurization, 241-Z Building

This analysis examines the consequences of the building ventilation system creating a pressurization of the areas in the 241-Z Building containing radioactive materials. If the pressure level achieved is greater than the surrounding atmospheric pressure, any loose radioactive materials will be forced to the outside environment.

9.1.7E.1 Postulated Cause of the Event.

9.1.7E.1.1 Starting Conditions and Assumptions. Unlike the other facilities examined, the 241-Z Building ventilation does not use a supply system. The air for the ventilation of the 241-Z Building is drawn from the environment through infiltration into the building. In turn, this air is

drawn into the covered vaults. (These vaults are below ground, concrete-lined cavities housing tanks used for temporary storage of contaminated liquids. The vaults are contaminated with smearable surface contamination.) The air is drawn from the vaults through HEPA filtration with two exhaust fans that discharge through the 296-Z-3 stack to the atmosphere.

9.1.7E.1.2 Sequence of Events. Ventilation upsets that could be caused by a ventilation abnormality, a break in a service line, and a chemical reaction in a tank within a vault were examined.

Ventilation upsets caused by some malfunction of the ventilation equipment were found to be an incredible event. There is no published standard for setting the vault pressure, so the only standard to be satisfied is that the vault be at some pressure less than the overhead room.

Two service lines could be pressurized: a 3/4-in. steam line rated at 40 lbf/in^2, used in a steam jet for fluid transfers, and a 1/2-in. air line at 60 lbf/in^2 (gauge), used to supply a small, diaphragm-operated pump used for sampling in cell 8. Both lines, however, are pressurized by valving or other switching devices from outside of the vault confines. Thus, a break would have to occur when the lines are energized; and such a break should be noticed fairly quickly as a weight factor (WF) device in the tank is monitored during the transfer. The WF device would show that there was no diminishment of waste occurring. A break in the airline would be noticed as line pressure is monitored during sampling. A break at any other time would not discharge pressurized gas (air or steam) as these services are deenergized.

As stated in *Waste Gassing Mechanisms at 241-Z*, (Barrington 1989), adding $NaNO_2$ to the D-5 tank of the 241-Z system may lead to outgasing if the tank contents reach a pH of five or less. He bases his statement on observations made when a process tank was used to prepare subsequent solutions of $Fe(NO_3)_3$ and $NaNO_2$. The potential for outgasing was evaluated in *Test Results of Gas Evolution and Foaming When $NaNO_2$ is added to Dilute HNO_3 and $Fe(NO_3)_3$ Solutions* (Barney 1990). Barney reported that under strong acid conditions, $NaNO_2$ forms HNO_2, which decomposes to NO(g) and NO_2(g). At HNO_3 concentrations of 1% or less, solutions of $NaNO_2$ in HNO_3 are stable; however, when small amounts of $Fe(NO_3)_3$ are added, the decomposition reaction proceeds at a rapid rate.

Under worst case conditions a gas flow of 36 ft^3/min is anticipated for 6.6 min or a total gas generation of 237.6 ft^3 of NO_x. The exhaust system for the 241-Z facility is capable of exhausting 1,000 ft^3 of air per minute. This condition thus presents no potential for pressurization of the facility or spread of contamination.

9.1.7E.1.3 Operator Actions. There were no upsets of adequate consequence identified to require operator response.

9.1.7E.1.4 Methods or Means of Detection. Five gauges are available to measure exhaust vault DP with respect to the building (DPI-D4-241Z, D5-241Z, D6-241Z, D7-241Z and D8-241Z).

9.1.7E.1.5 Engineered Safety Features and Protective Systems. There are no engineered safety features or protective systems other than the presence of the ventilation fan.

9.1.7E.1.6 Methods, Assumptions, and Conditions. These were not required, as no substantial upset could be identified.

9.1.7F Building Depressurization--All Plutonium Finishing Plant Operating Buildings

9.1.7F.1 234-5Z Building.

9.1.7F.1.1 Postulated Cause of the Event. Two possible events are considered as possible mechanisms for depressurization: valve adjustment errors and the humidifier pads on the supply unit air washers icing over. Depressurization of portions of the building caused by an inadvertent adjustment of the valves on the control lines leading to damper B or C could cause localized dumping of the control air, in turn causing the damper to fail to its safe position (i.e., open). Because of the common sensor for the control of the two dampers, the common controller would attempt to correct the resultant overpressurization. The working damper would respond and close down. The nonworking damper would remain nonworking. In those rooms serviced by the functioning damper depressurization would occur. The second event concerns icing over of the inlet pads to the supply unit air washers. If the pads ice over, the supply plenum will depressurize, which in turn causes a depressurization of the rooms. The effect would likely be minimal as there are two large automatic dampers, or vacuum breakers, to provide air to the supply plenum if the plenum starts to depressurize below atmospheric pressure.

9.1.7F.1.2 Starting Conditions and Assumptions. The 234-5Z Building is serviced with ventilation air from a supply plenum. This supply plenum is in turn fed with air from four supply fans (eight fans are available). The air for these fans first passes over steam heaters and moisturizing pads to condition the air. The building is exhausted by exhaust fans located in the 291-Z Building. The supply plenum is maintained at 2 in. w.g. Inside the building there is an exhaust air filter plenum that is maintained at -3.2 in. w.g. These plenum settings are maintained by dampers on the supply fans and by a damper on an exhaust fan. The controls on these dampers are automatic.

The pressure levels within the building are set slightly below atmospheric for the processing areas and slightly above atmospheric for the office areas.

9.1.7F.1.3 Sequence of Events. The first scenario for depressurization occurs because of failure of either the B or C supply plenum discharge dampers. However, only certain parts of the building would be affected because the two dampers are tied to the same controller with a single sensor in a room fed from both dampers (see Section 9.1.7A.1.2.1). A failure of one damper will overpressurize the room housing the sensor. The controller will signal the pair of dampers to compensate. Only the functioning damper can respond and will close. Such a closure will starve those rooms served solely by that damper and these rooms will experience a drop in pressure. In general, intervening doors with adjoining rooms will open and air from these rooms will flow into the rooms in an attempt to reestablish the pressure.

The second scenario, depressurization of the building through a failure to sustain the supply air system, would have only a minimal effect. The two vacuum breakers (held closed by weights) on the supply plenum would limit the effect of the occurrence. These vacuum breakers are maintained and tested yearly. The scenario would occur as follows:

- The fan inlets are preheated with steam.
- If the steam failed, the weather was cold enough, and the event happened too quickly to turn off the water, the water impinging on the spray pads would freeze, shutting off the inlet to the fans.
- The modulating dampers on those fans so equipped would open, slowing down the effect but not preventing it.
- As the supply plenum pressure dropped below the 0.5 in. w.g. setting, an alarm would signal in the control room.
- As the supply plenum dropped below atmospheric pressure the vacuum breakers would open, dumping outside air into the supply plenum.
- Downstream, the supply dampers from the supply plenum would open fully.
- The filter plenum would send a signal to the exhaust damper (on exhaust fan EM-3 or EM-4) to reduce the exhaust flow by closing down the modulating damper on the exhaust fan.

9.1.7F.1.4 Consequences of a Depressurization. Depressurization of certain rooms by the failure of dampers B or C could expose certain of these rooms to potential airborne radioactivity from other rooms. If doors are not securely latched, there would be a rush of air from those rooms to the newly created low pressure rooms.

A depressurization of the building through freezing of the supply unit air washer humidifier pads would have a different effect. There would be no severe DPs between the rooms of the backside such as described previously. There may be, however, a reversal between Zone 1 (frontside) and Zone 3 (backside). The reversal would be brief as there is automatic circuitry to shut down the exhaust fans servicing the frontside if an incipient reversal occurs. A pressure reversal occurs because the pressure in the filter plenum on the backside is controlled while there is no exhaust side pressure control for Zone 1. Both sides have dampers emanating from the supply plenum. These would both open fully to attempt to compensate for the falling supply plenum pressure. In Zone 3, the control system for the filter plenum would close down the modulating damper of the exhaust fan. This would effectively remove one of the four exhaust fans from service. There is no similar compensation for Zone 1.

The E-4 system would be impacted as follows. Gloveboxes draw air from the rooms or from the building dry air system; hoods draw air from the rooms. By drawing air from the rooms, the gloveboxes and hoods follow the movement in the room pressure level and maintain the same DP with the room. Those glove-boxes ventilated with the dry air system are equipped with a large, diaphragm-

operated gas valve designed to close if the glovebox starts to pressurize with respect to the room. This would have no effect if the room overpressurizes; the glovebox would be at a negative pressure with respect to the room. However, if the room drops in pressure, the valve would close, shutting off the source of dry air and allowing the glovebox to remain negative with respect to the room.

9.1.7F.1.5 Operator Actions. The Power Operator's response to a depressurization caused by a failure of damper B or C is identical to that for a pressurization (see Section 9.1.7A.2.2). In the event of a depressurization of the building through freezing of the humidifier pads, an alarm will sound as the supply plenum drops below its trigger positive setting. Upon receiving an alarm from the supply plenum, the operator would have three minutes to bring the ventilation system into control or shut down operations and reduce exhaust ventilation to flow through a single exhaust fan. The lack of steam pressure, presented as a factor in the upset scenario, may cause freezing of plumbing lines in the building. A recovery action would be developed, with the circumstances of the shutdown determining the response.

9.1.7F.2 236-Z Building. This analysis examines the building ventilation system for a mechanism for creating a depressurization of the 236-Z Building.

9.1.7F.2.1 Postulated Cause of the Event. There are two possible contributors to a depressurization of the building: collapse of the supply air duct or reversal of the control linkage. In the event of a depressurization of the 234-5Z Building through loss of supply air, the 236-Z Building would also experience depressurization. Building supply air is ported over to the 236-Z Building through a long outside duct, which is fed from damper F on the supply plenum located in the 234-5Z Building. The long duct is exposed and could be damaged (e.g., by a falling crane). Damper F is driven by a linkage system that is mirror-image duplicated on the opposite side of the discharge duct on the supply plenum. These mechanisms are used alternately, each for 1 yr. It has been postulated that during routine switchover the linkage could be accidentally connected backwards. The control system would then drive the damper full-open or full-closed, depending upon the sensing point pressure at the time of putting the damper controls into service. For this scenario, it is assumed that damper F is driven closed. The building could depressurize to the full -6 in. w.g. set in the exhaust plenum.

9.1.7F.2.2 Starting Conditions and Assumptions. The building is serviced by the same supply plenum and exhaust system that supports the 234-5Z Building.

9.1.7F.2.3 Consequences of a Depressurization. Physiological consequences to the people working within the facility at the time of the upset are likely. The sudden drop in pressure may cause earaches and other discomforts. The concrete building would likely suffer no consequences. An air pressure differential of 6 in. w.g. level would be similar to the snow loading for which the roof was designed. The interior of the building should experience no reversals of pressure as the exhaust system controls and fixed damper positions maintain Zone 4 pressures lower relative to Zone 3.

The canyon and, hence, all the gloveboxes use air drawn from the rooms. In a depressurization their internal pressure would follow the room pressure.

9.1.7F.2.4 Operator Actions. There are no specific low level alarms to alert the power operators in the 234-5Z Building control room. Their instrumentation would indicate the nature of the upset, however. The pressure indicating device, a chart recorder, would show a sharp change in pressure. Their first awareness of a problem may well be from personnel telephoning to report the atmospheric change. Again, the power operators response would be to shutdown the PFP ventilation supply system and operate the exhaust system solely with the emergency electric-driven exhaust fans until the problem can be identified and corrected. Ventilation zone 3 areas would be evacuated.

9.1.7F.3 2736-ZB Building. This analysis examines the building ventilation system for a mechanism for creating a depressurization of the areas in the 2736-ZB Building housing sources of radioactive materials. A depressurization would have to be of such a magnitude to cause a rupture of the building and subsequent release of any loose radioactive materials to the outside environment when the depressurization was corrected.

9.1.7F.3.1 Postulated Cause of the Event. There was no credible event that could be postulated to achieve a depressurization of the building.

9.1.7F.3.2 Starting Conditions and Assumptions. The building is serviced with ventilation air from the atmosphere directly. There is a dual system to supply this air to independent parts of the building. The air is ducted through the 2736-ZB Building into each set of parallel supply fans. Here the air is pressurized for distribution throughout the building. Before entering the parallel alternating supply fans, the air is passed through reheat steam coils, steam heat coils, and two stages of HEPA filtration. The system does not use an air washer. The system is controlled by the MICON™ system (LCU-6/DCS).

The pressure levels within the building are slightly below atmospheric for the processing areas and slightly above atmospheric for the office areas.

9.1.7F.3.3 Sequence of Events. Depressurization of the building through a failure to sustain the supply air system would not be credible. Depressurization classically occurs when (a) all supply air dampers are closed, or (b) all supply fans shut off while exhaust fan(s) continues to operate. There are only the filters in the supply system. These would not be expected to sustain a quick change in resistance so that the point where shutoff occurs should not be achieved with any kind of a maintenance program. The automatic control program will sense for flow; failing to find it, the program will shut down the supply fans.

9.1.7F.3.4 Identification of All Protective Systems. The protective systems are built into the LCU-6/DCS computer program that controls the ventilation system. The system, described in Chapter 5, Section 5.4.1.2.1, is defined on engineering drawings and in White (1987).

9.1.7F.3.5 Operator Actions. None are required.

9.1.7F.4 2736-Z Building. This analysis examines the building ventilation system for a mechanism for creating a depressurization of the areas in the 2736-Z Building housing sources of radioactive materials. A depressurization would have to be of such magnitude as to cause a rupture of the building and subsequent release of any loose radioactive materials to the outside environment when the depressurization was corrected.

9.1.7F.4.1 Postulated Cause of the Event. Depressurization can come about from a failure of the automatic controls, human error, or a combination of the two. One such depressurization has been reported. The control system was off to perform maintenance on an exhaust fan. The supply fans were disabled prior to the exhaust fans being shut off, which apparently caused a depressurization to -3 in. w.g. No damage occurred.

9.1.7F.4.2 Starting Conditions and Assumptions. The building is serviced with ventilation air from the atmosphere directly. Air is drawn from the outside, through preheaters and filters, and into parallel supply fans. These fans force the air into the 2736-Z Building. A pair of parallel exhaust fans take the air from the 2736-Z Building and discharge it to the atmosphere through a stack. This system is computer controlled.

9.1.7F.4.3 Consequences. There would be no radiation-related consequences as materials in this building are sealed in containers or equipped with HEPA-filtered vents. A pressure differential of a few inches of water would not cause leakage of the containers. However, if people were in the building, the doors would be pressed shut so that they could not get out.

9.1.7F.4.4 Identification of all Protective Systems. The protective systems are built into the computer program that controls the ventilation system. The system, described in Chapter 5, Section 5.4.1.2.1, is defined on engineering drawings and in White (1987).

9.1.7F.4.5 Operator Actions. During the reported depressurization, the exhaust fans would be deenergized.

9.1.7F.5 241-Z Building.

9.1.7F.5.1 Postulated Cause of the Event. The simplicity and low flowrate of the system precludes any means to significantly depressurize the building. See Figure 9-20 as discussed below.

9.1.7F.5.2 Starting Conditions and Assumptions. The ventilation system consists solely of a pair of parallel exhaust fans drawing infiltration air into the building and forcing it out a stack. The infiltration air is drawn into the building, through multiple locations as the building is a simple, metal shell intended as a weather cover. Air is drawn into the vaults by infiltration paths around the cover blocks, and then into piping through filters, and then into the fan.

9.1.8 Loss of Ventilation

A loss of ventilation would occur if both supply and exhaust fans were to lose power simultaneously. Air in a facility would become essentially

stagnant, except for the very slight movement caused by convection or by the DPs resulting from weather changes. All facilities would have similar effects on loss of all powered ventilation, but only the buildings serviced by the 291-Z-1 stack are analyzed mathematically. This event is initiated when all normal electrical power is lost to the supply and exhaust fans, rendering both systems inoperable. Standby power from the diesel-generators in the 2721-Z Building would also have to fail to maintain emergency fan EM-1 or EM-2 on line. During such an event, the only airflow in the building would be from natural circulation. Except for the two very specialized conditions described below, there would be a flow of air up the 200-ft-high stack. In all but very hot weather, convection can provide significant draft, as can the suction caused by wind blowing across the lip of the stack. The following situations could provide motive force for a slight reverse flow. Reverse flow down the 291-Z stack could occur as a result of (1) summer heat-induced convection or (2) winter weather induced DP from a passing storm front.

9.1.8.1 Postulated Cause of the Event, 234-5Z, 236-Z, and 242-Z Buildings.

9.1.8.1.1 Starting Conditions and Assumptions. A complete loss of ventilation occurs due to a simultaneous loss of electricity and standby power from the diesel-generators. Electrical loss could be local to the 291-Z Building or site wide. Loss of standby power could occur due to failure of the diesel-generators, switchgear or control systems. Such an occurrence would involve three simultaneous, unlikely events (i.e., loss of two electrical circuits and standby power from the diesel-generators).

9.1.8.1.2 Sequence of Events. Upon failure of normal and standby electrical power to the 291-Z Building, the following events would take place.

1. The supply fan dampers would open, and supply fans would stop due to deactivation of electric switch ES-9 by the rise in exhaust plenum pressure.

2. Simultaneously, zone dampers B through E open to their designed fail positions and dampers A and F close to their fail positions, isolating Zones 1 and 3B from the rest of the system. Also, Zone 1 electrically powered exhaust fans EM-11 and EM-12 shut down.

3. Dampers to the EM-3 through EM-7 exhaust fans fail closed.

4. Dampers to the EM-1 and EM-2 exhaust fans fail open.

This sequence of events leaves an open path from the supply louvers through all Zone 3 rooms. Also, an air path is opened through all room ventilated gloveboxes. The supply dampers for the dry air system gloveboxes close, preventing flow through the dry gloveboxes.

9.1.8.1.3 Operator Actions. There would be no operator action possible to correct the problem. An announcement would be made by power operations on the building paging system to evacuate Zone 3. All personnel, except those needed for orderly shutdown, would evacuate to Zone 1. The shutdown personnel would don respiratory protection and evacuate to Zone 1 when the shutdown was complete.

9.1.8.2 Detection of Event.

9.1.8.2.1 Methods or Means of Detection. The loss of ventilation will be immediately detected by an alarm system in room 321. Simultaneously, the building will become much quieter. Filter media from the E-3 exhaust air grilles will fall off, as they are normally held on by suction. Emergency lighting would be supplied by a series of facility emergency lights. Lighting would be very dim. All strip chart recorders indicating pressures within Zone 3 would stop.

9.1.8.2.2 Response Time Assessment. The immediate response for a loss of ventilation would be an announcement via the Private Automatic Exchange (PAX) system that normal ventilation has failed and all Zone 3 areas are to be evacuated. The evacuation could be expected to be complete in 5 to 10 min.

9.1.8.2.3 Engineered Safety Features and Protective System. The safety features and protective systems for such an event are inherent within the ventilation system. In this event, it is possible that air can flow down through the 291-Z stack and into the 234-5Z Building. A comparison of duct areas in the airflow path indicates that there is more area in the E-3 system than the E-4 system. In addition, the air that flows in the E-3 system will encounter three parallel banks of 112 HEPA filters each. It is expected that the pressure drop across these filters will be very small and that the airflow rate will not be greatly reduced. In addition, the E-3 system has only one stage of HEPA filtration, versus four or five stages in the E-4 system. (Counting the filter rooms, the two in-series filters in filterboxes that are tested as one stage, the nontestable filter at the outlet of gloveboxes and glovebox inlet filter.)

Any airflow through the E-4 system will be even further reduced due to the change in areas of the duct geometries, bends in the duct routing, and filter banks. There is much more resistance to airflow in this system than in the E-3. For these reasons the flow to rooms will be higher than to the gloveboxes.

9.1.8.3 Analysis of Effects and Consequences.

9.1.8.3.1 Flow Reversal, Hot Day.

9.1.8.3.1A Flow Reversal, Hot Day, Methods, Assumptions, and Conditions. The following conditions are assumed for this event: (1) it is a hot summer day with an outside temperature of 110 °F and an inside temperature of 80 °F in Buildings 234-5Z and 236-Z and (2) it is windless. Wind would produce a low pressure due to Bernoulli effect at the top of the stack; air within the building would continue to be drawn up the stack. Therefore, to get the effect of airflow down the stack, there could not be any wind. To obtain the condition of the air flowing down the stack, the air in the building must backflow through the ducting into the supply plenum and up into the supply fans. From the fans, the air would backflow through both the wet and dry filters to exit from the fan inlet grilles.

The maximum backflow rate would be about 15,000-ft^3/min, as compared to a normal forward flow of about 225,000-ft^3/min. The upward and downward flow patterns (with time) that might be expected are shown in

Figures 9-21 and 9-22. Note that the downward graph cuts off at about 220 second (plus 3 minute). At this time the stack has emptied of cool air and warm outside air is postulated to flow horizontally through the building duct work. This voided the mathematical model and no further calculations could be made.

If all ventilation goes down at once, the flow through the building would not stop instantaneously. The momentum in about 252,000 lb of air would coast to a stop after about 42 second, as shown in Figure 9-21.

The following calculation was made to determine the rate of ventilation flow decay through the building. The solution is to solve the second law of motion:

$$\text{Force (F)} = \text{Mass (M)} \times \text{Acceleration (A)}$$

where: F = Friction force encountered by airflow passing through building (pounds)

M = Mass of air in buildings

= W/g, where W equals the weight of air and g is the gravitational constant 32.2 ft/s^2

A = Acceleration.

This equation yields an acceleration number that, when integrated over a small span of time, yields a change of velocity. This change of velocity is subtracted from the original velocity. The friction factor is then recalculated at the reduced flowrate and a new acceleration number is achieved. This procedure can be repeated until flow stops.

The whole procedure can be represented by the differential equation:

$$F = M(dv/dt) + D(v)$$

where: M = Mass
D = Friction (damper)
v = Velocity
t = Time.

However, the friction D, is not linear with velocity, v, as indicated. This makes solving the equation much more difficult. The friction, D, varies in pneumatics as the square of the velocity, v. Thus, the solution would be iterative by allowing only small changes in time, t, so as to keep the relationship between v and D nearly linear. The brute force solution makes the iterative process more understandable. A crucial assumption in this calculation is that the shape of the air mass is cylindrical, with diameter equal to the stack diameter. This yields an average velocity fairly representative of the velocity of air in the ducts. The head loss at full flow, in inches water gauge, is assumed to act against this cross-sectional area.

The equation is solved using known data. The mass, initial velocity, and head drop (or friction force) are taken from known operating conditions.

Acceleration is calculated from the second law of motion. A change in velocity is calculated from integrating acceleration over the small space of time. The new velocity is the old velocity minus the change on velocity.

The new head drop (or friction force) is calculated from the fact that the head varies on the ratio of new and old velocity squared.

For the record iteration, the process is repeated: (1) calculate acceleration, (2) integrate acceleration, (3) calculate velocity, and (4) determine new head drop. This procedure is repeated as required until the airflow through the building stops or approaches zero.

The results of the iteration are shown graphically on Figure 9-21, which shows that on a hot day workers would have time to leave the immediate work area. The Vent and Balance personnel working dampers with crews involved in jobs such as panel changes would have time to react. In addition, reversal does not build to half flow until about 50 s have passed (Figure 9-22).

The calculation to determine the acceleration of backflow in the ventilation stack follows the same iterative procedure as for the flow decay rate. The only difference is that a driving force, consisting of the block of cool air existing in the stack above the inlet grille for the building supply fans, is now part of the equations. The same assumption regarding the shape of the air mass is made.

The results of the iterations are shown in Figure 9-22.

9.1.8.3.1B Flow Reversal, Cold Day, Methods, Assumptions, and Conditions. The starting condition of this event is a sudden change of atmospheric pressure while the building ventilation system is inoperable. For this event to occur the building would have had to be without heat for a considerable time because the forces of convection up the stack on a cool day are considerable. Studying the forces involved with the backflow shows that cool day velocities would build to a considerable rate. The drop in backflow rate was due to the fact that the small volume of the stack filled with warm air that then was below the point of pneumatic balance and only dropped as far as it did on the basis of inertia. Flow in the upward direction would continue to build until friction stopped the acceleration. After the reservoir of heat stored in the building structure and equipment cooled convection would cease. This event is being presented primarily for completeness of the reversal scenario and not because it is credible as an abnormal operation.

The Hanford Site weather data collected for 50 years show that an atmospheric condition of this type would only occur during the winter months on the approach of a high pressure front. The worst frontal system recorded by the Hanford meteorological station (HMS) was on November 3, 1958 (Stone et al. 1983, p. VIII-1). The pressure fall averaged 0.082-in.Hg/h over a 6-h period (0.492-in. Hg total). The maximum hourly fall was 0.160-in. Hg.

The method used to calculate the airflow through the 234-5Z, 236-Z, and 242-Z Buildings that could cause a "breathing" effect is very conservative. The calculation assumes no loss of airflow through the ducting or filter banks. A pressure drop of 0.492-in. Hg is used to calculate the airflow.

The approximate volumes of the 234-5Z, 242-Z, and 236-Z Buildings are listed below:

Building	Volume (ft^3)
234-5Z	3,128,000
236-Z	377,000
242-Z	49,000
Total Volume	3,554,000

Standard atmospheric pressure at the Hanford Site, which is 733 ft above sea level, is 29.21-in. Hg. The maximum pressure drop experienced over a 1-h period was 0.160, which lowered the atmospheric pressure to 29.05 in.-Hg.

The ideal gas law is used to determine the volume change of the building air at the maximum hourly pressure decrease, (0.160-in. Hg). Assuming the pressure and volume change occurs at constant temperature, the following calculation is made (Baumeister et al. 1967):

$$V_2 - V_1 = (P_1/P_2) \times V_1 - V_1$$

$$V_2 - V_1 = [(P_1/P_2) - 1] \times V_1$$

$$V_2 - V_1 = [(29.21/29.06) - 1] \times 3.6 \times 10^6 \text{ ft}^3$$

$$V_2 - V_1 = 1.8 \times 10^4 \text{ ft}^3$$

Assuming this volume change equillibrates during the hour that the pressure is changing, the flow rate will be:

$$Q = 1.8 \times 10^4 \text{ ft}^3/60 \text{ minutes} = 310 \text{ ft}^3/\text{min}.$$

9.1.8.3.2 Source Term Convection Scenario (A). The convection scenario is calculated as it is the least unlikely of the two. Since the flow rate for the weather front scenario is only 4 times as great, the consequences for neither scenario are of significance. There is no significant source term or even significant internal-to-building contamination following either the convection or the weather induced flow. This is due to the presence of HEPA filters and building integrity and the lack of a driving force to push plutonium out of the primary confinements. There is a possibility for removal of material normally downstream of open-faced hoods. This is expected to be low level as the airflows would be low.

The velocity of air flowing in reverse through the media of a typical first-stage filter serving an open-faced hood is very low. For example, typically a single filterbox serves four hoods. The filterbox is equipped by a single 24-in. by 24-in. by 12-in. HEPA filter. The hoods are typically equipped with an armported face with a total area of ≈3 ft^2. The face velocity is typically set at 125 ft/min so each hood is drawing ≈375 ft^3/min. The four hoods are then drawing about 1,500 ft^3/min. A normal stack flow is assumed to be 225,000 ft^3/min. Thus, a reverse flow of ≈15,000 ft^3/min is 15,000/225,000 = 0.066 the normal flow. This figure is conservative as most of the airflow would go the path of least resistance through the E-3 system and into the rooms. Thus, it is conservative to assume that the reverse flow out of the four hoods will be 0.066 x 1,500 ft^3/min = 100 ft^3/min. The HEPA filter has a total surface area of ≈216 ft^2 (Gunn and McDonough 1981). Thus, the velocity that would thrust particles back off the filter would be 100 ft^3/min/216 ft^2 or 0.46 ft/min. This is only 0.46 ft/min/88 ft/min/mi/h = 0.0052 mi/h, which is not enough to loosen significant amounts of impacted and electrostatically adhered particles.

Backflow from gloveboxes in an opened condition (e.g., during a panel change) would involve yet another low probability coincidence. In addition, before such work begins the gloveboxes are wiped of much loose material. Flowrates of only 0.066 normal would suspend very little material.

9.1.8.3.3 Margin of Protection. The margin of protection for these abnormal operations is within the ventilation system itself. The ducting is of varied geometric shapes and sizes routed throughout the building by many bends. Also included in the ventilation system are several banks of HEPA filters. These features offer resistance to any backflow of air that may occur. Assuming the airflow would take the path of least resistance, this flow would be directed to the E-3 system, which would go to the rooms. The E-4 system includes several stages of filterboxes with HEPA filters as compared with the one stage of the E-3 system. The dry air system contains a valve upstream of the normal inlet that would close on a loss of air signal.

The margin of protection to the environment between any minor contamination that might result from open-faced hoods would be very high. This is deduced from highest values of historical room contamination incidents which are about 2.5 x 10^{-10} μCi/mL. From the discussions in Sections 9.0.2.2 and 9.1.4.3 it is apparent that a release into even several laboratory rooms would produce an effect many orders of magnitude below the lowest acceptable release for an event having an annual probability of one.

9.1.8.4 Hydrogen Accumulation. The primary and secondary containment barriers for materials in vaults and the steel food pack cans might be breached by pressurization. Pressurization of these materials might come about as a result of heat generation following ventilation loss.

Tanks containing plutonium solutions are constantly evolving hydrogen gas as a result of radiolysis. The vessel vent systems direct this and other gases to the gloveboxes and then to the E-4 vent system. Loss of ventilation would mean that some increase in hydrogen levels would occur within gloveboxes. The two gloveboxes examined in this section previously contained significant quantities of concentrated plutonium nitrate solution and are considered to be worst cases. They were used to receive product solutions

from PUREX and PRF or are used for RMC Line feed storage. The calculations which follow show that, even assuming worst case conditions with no air movement, it would take nearly 4 weeks to accumulate enough hydrogen to result in a structure-threatening detonation. Glovebox HC-227S is located within the concrete walled portion of the RMC Line and glovebox HC-4 is located in vault room 166, so a simple deflagration is not expected to breach the outer building walls.

9.1.8.4.1 Starting Conditions and Assumptions. The conditions and assumptions used in this analysis are presented below with a discussion of any conservatism associated with them.

- **Plutonium Concentration = 450 g/L**--This concentration is the upper limit from the criticality prevention specification (CPS). The nominal concentration of these solutions is 255 g/L as given in the RMC Line flowsheet. This provides a factor of 1.8 conservatism.

- **Acid (H+) Concentration = 1.3M**--This concentration is the lower limit from the CPS. It gives a significant degree of conservatism for hydrogen evolution. The hydrogen evolution rate at 1.3M is 7.3 times as great as that from the 7M acid normally used (Sheppard 1968, Figure 2).

- **Hydrogen Evolution Rate (G_H) = 0.22 molecules/100-eV** (Sheppard 1968).

- **Ventilation = None**--The gloveboxes are assumed to be essentially nothing more than closed bottles with only a capillary vent which reduces any loss of hydrogen by diffusion. In reality, both gloveboxes are ventilated by pulling room air through an 8-in. by 8-in. HEPA filter. Hydrogen generated at a low rate would leave and be diluted by diffusion both ways through this and the exhaust filter. In addition, over the weeks that would be required for buildup, atmospheric effects as discussed above would provide dilution.

- **Detonable Concentration = 14%**--The lowest detonable concentration reported by *Light Water Reactor Hydrogen Manual*, NUREG/CR-2726, p.2-51 (Camp et al. 1983) is 14%. This is lower than predicted by shock-tube experiments. In larger enclosures containing equipment the flame front can become perturbed to the point that deflagration proceeds to detonation.

- **Ignition = Present**--The presence of an ignition source when the ventilation system has been down for an extended period is a conservatism. Procedures call for shut down of processes and evacuation of Zone 3 in the event of even a partial ventilation failure. Equipment within the gloveboxes would not be activated until some time after ventilation had been restored.

- **Free Volume of Gloveboxes**--Glovebox HC-227S = 275 ft^3, glovebox HC-4 = 178 ft^3.

- **Volume of Solution in Each Glovebox**--Glovebox HC-227S = 132 L, glovebox HC-4 = 120 L.

9.1.8.4.2 Calculations. The rate of energy released into the solution in each tank is given by the following expression:

$$E/T = v \times c \times 3.7 \times 10^{10} \times \sum_{i} a_i \times f_i \times e_i$$

where: E/T = Rate of energy production (MeV/s)

v = Volume of plutonium solution in all tanks

c = Concentration of plutonium (g/L)

Ci = Curie = 3.7×10^{10} dis/s/Ci

dis = Disintegration

a_i = Activity of each nuclide (Ci/g)

f_i = Fraction of each nuclide in solution

e_i = Energy evolved with each disintegration (MeV).

The characteristics of the plutonium mixture are presented in Table 9-7 with the summation term of the equation given above. The isotopic distribution in Table 9-7 is based on the greater than 19% ^{240}Pu data in Table-43.

Thus, for the two gloveboxes the rates of energy production are as follows:

HC-227S:

$$E/T = 132L \times 450g/L \times 3.7 \times 10^{10}\text{-dis/s-Ci} \times 1.6\text{-Ci-MeV/g-dis}$$

$$= 3.5 \times 10^{15}\text{-MeV/s}$$

$$3.5 \times 10^{15}\text{-MeV/s} \times 10^{6}\text{-eV/MeV} = 3.5 \times 10^{21}\text{-eV/s}$$

HC-4:

$$E/T = 120L \times 450g/L \times 3.7 \times 10^{10}\text{-dis/s-Ci} \times 1.6\text{-Ci-MeV/g-dis}$$

$$= 3.2 \times 10^{15}\text{-MeV/s}$$

$$3.2 \times 10^{15}\text{-MeV/s} \times 10^{6}\text{-eV/MeV} = 3.2 \times 10^{21}\text{-eV/s}$$

The rate of hydrogen gas generation as taken from *Alpha Radiolysis of Plutonium IV - Nitric Acid Solutions* (Sheppard 1968) is 0.22 molecules (mol) per 100-eV or 2.2×10^{-3}-mol/eV (see above). Thus, for HC-227S:

$$3.5 \times 10^{21}\text{-eV/s} \times 2.2\text{x}10^{-3}\text{-}H_2\text{/eV} = 7.7 \times 10^{18}\text{-}H_2\text{/s}$$

Assume that the glovebox temperature is 25 °C, so a mole of gas occupies 24.3 L.

$$1.3\text{x}10^{-5}\text{-mol/s} \times 24.3\ \text{L/mol} \times 1/28.3\ \text{L/ft}^3 = 1.1 \times 10^{-5}\ \text{ft}^3\text{/s}$$

The free glovebox volume is 275 ft^3. Thus, 14% of this is 38.5 ft^3.

The time required to generate this much hydrogen gas is:

$$38.5\ \text{ft}^3 \times 1/1.1 \times 10^{-5}\ \text{ft}^3\text{/s} = 3.5 \times 10^{6}\ \text{s}$$

$$3.5 \times 10^{6}\ \text{s} \times 1/8.64 \times 10^{4}\ \text{s/d} = 40\ \text{d}$$

For glovebox HC-4, calculated in the same way, the time is 29 d.

As stated above, these figures are based on the assumption that no diffusion and no mixing takes place during this entire period. When the conservatism (see Section 9.1.8.4.1) in concentration of plutonium and acid are excluded and nominal values used, the time is 13 times as great or 373 d for glovebox HC-4.

This event will not be further developed as there is very little probability that the building would be left with no ventilation for a period of 1 month with solution in the tanks.

9.1.8.5 Entrain Downstream Powder. The ductwork downstream of the final filters that lead to the 291-Z-1 Stack is contaminated with an estimated 10 g of plutonium (Schilling 1989). This estimate was based on analysis of surveys of surfaces in the filter room and internal ducting downstream of final filters. Analysis of these samples indicates all were nominally 6% ^{240}Pu material and tightly adhering to surfaces. Historical ventilation transients caused by switching operating fans and switchovers to one and two backup steam-driven exhausters (now deactivated) did not result in abnormal stack releases. This supports the observations that the material is tightly adhered to surfaces. Resuspension due to ventilation transients is not expected.

9.1.8.6 Vault Temperature Rise. The effect of a loss of ventilation to the containers of plutonium in the vaults would be minimal. The calculations in Section 9.2.4.6 show temperatures of about 280 °F and pressure of 20 lb/in^2. The storage cans would not burst under these conditions.

9.1.8.7 2736-Z and 2736-ZB Buildings. Loss of ventilation for the 2736-Z and 2736-ZB Buildings would have similar results as in the 234-5Z complex as presented in Section 9.1.8.1.

9.1.9 Glovebox Glove Breach

Any pressurization of primary confinement relative to a room can be expected to result in a spread of radioactive material. Pressurizations less than required for actual failure of gloves, bags, or sphincter seals should not result in a spread of contamination but, as a practical matter, might do so in some locations due to small holes normally not noticed due to inward airflow. Such spreads are not expected to be great in themselves, but, if a glovebox is even slightly pressurized at the same time as a major breach, an amount of radioactive material could be released into the room which would be significant in terms of occupational exposure.

Penetration of a glovebox glove may result in the release of plutonium-bearing materials to areas occupied by personnel. Plutonium-bearing materials are handled in the PFP in a variety of gloveboxes during many different processing stages, quantities, and concentrations subject to criticality considerations. The handling and maintenance of glovebox gloves and the associated hand tools were reviewed for the potential to breach a glove and cause an abnormal condition or breach of primary confinement, and potential subsequent release into an occupied area. Factors that could lead to glove failure have been identified as hot surfaces, sharp objects, and deteriorated glove material. A breached glove would be a violation of primary confinement but would not necessarily result in the release of a plutonium-bearing material. This section analyzes the conditions and scenarios that could result both in the violation of primary confinement and the release of a plutonium-bearing material into an occupied zone.

9.1.9.1 Postulated Cause of the Event.

9.1.9.1.1 Starting Conditions and Assumptions. This scenario assumes that sources such as a hot surface, a sharp object, or deteriorated glove material will lead to the failure of a glove. A glove breach would cause the violation of a confinement barrier between operational personnel and a contaminated area. For a release to occur as a result of a glove breach, the action involved in penetrating the glove must also spew out contaminants; or during the time of an event that breaches a glove (e.g., incorrectly set ventilation system), the normal negative DP must be missing or reversed, or the event itself must create a reverse pressure pulse.

In addition to the breach of a glovebox glove several other sources could cause the loss of the contamination barrier that the gloveboxes and gloves define. Any object of significant mass and velocity (e.g., a falling maintenance ladder or a missile generated by an explosion or rapid release of gas pressure) could potentially penetrate a glovebox. Slight

overpressurizations (e.g., due to material handling or plutonium hydride reactions) can also fail deteriorated or defective gloves resulting in a release to the room (see Appendix 9H). However, it is expected that these types of events are less likely to occur and the expected consequences no worse than a glove breach.

9.1.9.1.2 Sequence of Events. One sequence of events that could lead to a breached glovebox glove is an operator reacting to a supposed fire situation and attempting to extinguish the fire. Fire extinguishers with wands sharpened to resemble large hypodermic needles capable of penetrating glovebox gloves are provided for control of small glovebox fires. The wands are connected to the extinguishers with quick disconnects so that they can be left in the glove when an extinguisher is emptied. However, if the glove is deteriorated or defective, forcing the wand through the material could rip out a much larger hole than is necessary to insert the probe, thereby violating primary confinement.

Contact with hot surfaces during any operation could produce burns and lead to the potential release of radionuclides should a glove burn through. Normally, prior to the operation of a heating element or furnace in a glovebox the gloves are to be withdrawn to a stowed position, usually tied up to prevent the glove from being drawn into the glovebox by the prevailing DP. A glovebox furnace may radiate heat through joints between lagging blocks and possibly ignite that portion of a glove left in close proximity to the high-temperature portions of the furnace. The opening in the glove then is a direct path which could allow any contamination present to leak into a worker occupied area.

Moving equipment such as the HC-1 conveyor, sweep arms, and rams may contact and cause a hood glove breach which could potentially lead to a contamination release. Normally, prior to the operation of glovebox mechanisms the gloves are to be withdrawn to stowed positions. If a sweep arm were to snag a glove, or a conveyor belt were to pinch a glove, the glove could be breached and primary confinement would be violated.

9.1.9.1.3 Operator Actions. An operator may, through an inadvertent action, cause the breach of a glove. A possible action that could lead to breaching a glove would be the mishandling of a sharp object within the glovebox. The operator's field of view is restricted within many gloveboxes due to the presence of radiation shielding intended to reduce the operator's radiation dose. Also, the area just beyond and below the gloveport is normally a visually obscured area due to the presence of the glove itself and optical limitations of the glovebox windows. An operator's sense of touch is restricted when using a set of gloves and he may not realize that he has grasped a sharp object until the object has penetrated the glove and possibly his hand.

9.1.9.1.4 Engineered Safety Features, Protective Systems, and Administrative Controls. The principal method of preventing breached gloves, aside from reducing the number of operations requiring the use of gloves, is adherence to a good housekeeping program. Gloves are replaced on a routine preventive basis in accordance with established procedures. Glovebox windows must be kept clean and corrodible tools and other objects which could cause punctures must be replaced regularly. Management is responsible for ensuring

that a glove control program is implemented and maintained. Essentially, it is through the exercise of due caution and diligence that the relatively small number of breached glove incidences can remain insignificant.

The DPs are maintained in the ventilation exhaust systems so that airflows are always toward more highly contaminated or potentially contaminated areas up to filtration. Safety considerations and controls on the ventilation systems provide dampers and valves for regulation/isolation, measurement of DP across the filters, continuous radioactive particulate monitoring, exhaust air sampling, and continuous measurement of exhaust airflow.

The fans for maintaining the correct airflow are configured in a redundant parallel system and are used in the number required to maintain the exhausted quantity of air under stable control or the designed flowrate. These fans have dampers that control airflow through the fan as required to maintain a specified DP. They are supplemented by manually operated dampers on several other fans.

On the RMA Line, RMC Line, and certain laboratory locations, gloveboxes are equipped with ventilation control valves. Pressure sensors monitor glovebox pressure and control valves maintain DP in gloveboxes within a specified range and are able to operate from full-open to full-closed within 3 s. As glovebox DP increases above the allowed setting, the valve closes, thus avoiding loss of negative pressure, overpressurization, or discharge of air through an open port. A DP switch connected to an annunciator in the power control room monitors the pressure in the RMC Line gloveboxes and alarms if pressure exceeds the DP set point.

Two similar valves regulate exhaust on an emergency basis. Each parallel valve exhausts to a common duct. The valves are normally closed tight for any upstream pressures within the allowable range. They are set to start opening when the negative DP rises toward zero and to be opened fully before upstream pressure becomes positive.

All glovebox negative pressures and exhaust filter pressure drops are to be verified to meet safety standards before entry into any gloveboxes for testing or maintenance.

Actions taken to minimize the probability of internal deposition include:

- Use of leather gloves over the rubber gloves when handling miscellaneous plutonium-bearing materials
- Training personnel to use special care when handling material that could have sharp edges or working in the vicinity of equipment having sharp edges
- Careful inspection of containers for bulging or other indication of internal pressure buildup
- Use of full-face respirators with HEPA filter cartridges when handling containers suspected of holding reactive material or having internal pressure.

In the past, upon identification of potential hazards which could lead to the breach of a glove, changes have been requested and made to equipment, facilities, tools, and procedures. A conveyor "key switch" shutdown system was installed to lock out the HC-1 or HC-2 conveyors when it was necessary to work in the hood gloves near the belts. The addition of the key switch allows the operator to prevent the inadvertent startup of the conveyors should they find it necessary to use a gloveport near the conveyor while the system is energized.

To prevent glovebox overpressurization due to potential plutonium hydride reaction when opening cans containing brushings or sweeps from plutonium metal, limits on the amount of corrosion products that can be accumulated in containers or exposed to the glovebox atmosphere have been established. These limits are based on USQ evaluation 99-017 "Pu Metal Reaction Upon Opening Item with Paneled Inner Container" and Appendix 9H "Hazards Evaluation of Plutonium Metal Opening and Stabilization". The limits are as follows:

- No more than 150 grams of corrosion products accumulated from multiple metal items in a single container
- No more than 200 grams of corrosion products exposed to glovebox atmosphere at one time.

The impacts associated with a slight glovebox overpressurization are bounded by the glovebox glove breach in Section 9.1.9. Additional analyses addressing plutonium metal stabilization are provided in Section 9.2.10.

9.1.9.2 Detection of Event.

9.1.9.2.1 Methods or Means of Detection. A breach in a glove may be detected in a variety of ways. They range from an operator observing a defective glove or a defect found during the routine inspection of a glove installation to instrumented methods, such as the loss of glovebox/room DP or detection of contamination released out through the breach. Gloves are routinely surveyed. After leaving gloves, operators are required to make self surveys to detect leaks at an early stage.

An operator generally knows when a glove has just been penetrated with a sharp object and will shout for help. This type of penetration would probably not spread contamination over a wide area but might internally deposit radionuclides into the operator. In addition to operator feedback, glove breaches may be identified when ventilation anomalies are investigated and the opening discovered. A breached glove may also be detected through routine inspections of the glovebox exteriors, either by operators or RCTs.

9.1.9.3 Analysis of Effects and Consequences. The event having the most significant consequence would likely be a puncture wound where the penetrating object carries radioactive materials into the tissues. This and other events may lead to contamination within operator occupied areas. Although procedures require operators to survey each time they leave a glove, it is postulated that some contamination is missed and thus, may be spread by contact. This latter type of spread, if the airborne concentrations were significant, would be detectable by room air monitors and be contained by the ventilation system. These events can be expected several times per year and while considered to have a potential for exposure to individuals, the mitigating efforts taken by

RC personnel result in minimal health effect to the people involved (see Chapter 8.0, Sections 8.4, 8.5.2.9, and 8.5.2.8).

9.1.9.4 Corrective Actions. Upon discovery of a breached glove, the immediate action is to keep the worker's hand in the ruptured glove while another worker or RCT wearing a respirator puts a respirator on the worker. The work area is placed on airborne radioactivity status, and the worker is carefully removed from the glove in a manner to reduce contamination spread. After operators secure contamination, the worker is taken to the decontamination facility (Section 8.5.2.9). The worker is evaluated for external and internal contamination and given appropriate treatment.

Once permission is obtained as required by procedure, personnel don appropriate protective gear, move into the area with the breached glove, set up controls for glove replacement, change out the glove, clean up any contamination, and restore the area for normal operations.

9.1.10 Plutonium-Bearing Solution Stabilization Process Using the Production Vertical Denitration Calciner

Two categories of abnormal operations for the plutonium-bearing solution stabilization process using the Production VDC were identified in the HAZOP contained in Appendix 9D. The first category of abnormal operations includes those process upsets that can result in elevated radiological releases inside glovebox HC-230C-2 (See Table 9D-3, Bin ID B). Postulated events that can result in elevated releases of radiological material to the glovebox atmosphere include vessel or pipe leaks within the glovebox, overflows of vessels, toppling of slip lid cans or product collection jars, leaks from the transfer line between gloveboxes HC-227S and HC-230C-2 that drain back via the transfer line encasement to glovebox HC-230C-2, and various upset conditions that result in the Production VDC pressurizing causing a release of PuO_2 powder through the calciner relief cap to the glovebox atmosphere. Of the postulated upset conditions, overpressurization of the calciner presents the bounding case because that mechanism can produce the largest airborne concentrations of dispersible and respirable sized plutonium-containing particulates within the glovebox and hence the greatest challenge to the E-4 ventilation system and filters. The analysis of a pressurized Production VDC is presented in Section 9.1.10.1

The second category of abnormal operations identified from the HAZOP includes those upset conditions that can result in the release of process liquids or elevated quantities of NO_x to the process vacuum system (Table 9D-3, Bin ID I). Scrubber solution containing small amounts of Pu could overflow into the plant vacuum system due to failures of the phase separator and vacuum trap level controllers. Elevated NO_x releases to the process vacuum system could occur due to various hardware and controller failures that result in insufficient scrubbing of the NO_x offgases within the Production VDC scrubber. The specific failure modes that can cause releases of contaminated caustic solution or elevated releases of NO_x gases to the plant vacuum system are identified in the HAZOP Table in Appendix 9D (Table 9D-4).

Liquid contamination of the process vacuum system is possible in other areas and processes within the PFP where the vacuum system is used to transfer

radioactive solutions. The potential for liquid contamination of the vacuum system is not unique to Production VDC operations and is considered to be adequately covered by the plant radiological protection programs. Portions of the process vacuum system are not considered to be criticality safe. Because of the ceramic filters on the calciner, the transfer of significant quantities of Pu to the vacuum system due to overflow of the phase separator tank is very unlikely. The consequences of a criticality in the process vacuum system are bounded by the accident analysis presented in Section 9.2.3. An interlock is provided in the process vacuum system to shut down the vacuum system pumps on detection of liquid in the vacuum system. This interlock is identified as a safety class item in Chapter 4.0 (Table 4-7), to prevent a criticality in the process vacuum system HEPA filters.

Elevated NO_x releases to the process vacuum system could result in accelerated corrosion of vacuum system components (resulting from the production of nitric acid in wet parts of the system such as seal loops). This presents primarily an ALARA issue for plant maintenance personnel. Credible NO_x releases from the Production VDC will be diluted enough by the rest of the E-4 ventilation flowrate that significant degradation of the E-4 filter room HEPA filters would not be expected (the process vacuum system cascades into the E-4 ventilation system). The NO_x production rate of the Production VDC is not high enough to cause significant exposures outside the plant if released unscrubbed through the 291-Z-1 exhaust stack. Elevated releases of NO_x to the process vacuum system from Production VDC operations are therefore not considered further in this section.

9.1.10.1 Pressurized Production Vertical Denitration Calciner. The water vapor, nitric acid vapor and NO_x offgases produced in the calciner are exhausted along with the air fed to the calciner through the plant 26-in.-Hg vacuum system. The vacuum system is relied on to keep the calciner under negative pressure with respect to the glovebox. The Production VDC can pressurize during processing of plutonium nitrate solutions due to a number of causes, including: shutdown or valving out of the plant 26-in.-Hg vacuum system, plugging of the calciner ceramic filters, oversupply of feed solution to the calciner, oversupply of air to the feed injection nozzle, or loss of pressure control on the calciner filter back-pulse system. During prototype testing, the Laboratory Prototype Calciner pressurized when feed solution backed up into the air supply line. A slug of liquid was introduced into the very hot calciner when the pluggage broke free due to the working of the nozzle cleanout needle. The slug vaporized very quickly overwhelming the calciner vacuum system.

The calciner is equipped with a pressure relief cap which is sized to lift when the pressure in the calciner exceeds 1.3 psig. Should the calciner overpressurize due to any of the above discussed causes, PuO_2 particulate from inside the calciner vessel, steam, nitric acid vapor, and NO_x would be relieved through the calciner pressure relief cap into glovebox HC-230C-2. Such a release would be confined to the glovebox and the E-4 ventilation system. The following analysis quantifies the potential release through the 291-Z-1 exhaust stack and compares the release to the screening limits discussed in Section 9.0.2.2.

9.1.10.1.1 Postulated Cause of Event. A rotameter and check valve have been installed in the Production VDC air supply line to minimize the

likelihood of a pressurization event similar to that experienced in the Laboratory Prototype Calciner. For this analysis, therefore, the cause of the pressurized calciner is assumed to be a failure in the vacuum system which results in no vacuum flow from the calciner. Loss of vacuum flow through the calciner could be caused by failure of the plant vacuum pump or the inadvertent closing of a valve in the vacuum system. Equally, loss of vacuum flow can be postulated to occur due to plugging of the calciner ceramic filters.

The Production VDC and supporting systems are well instrumented to detect and respond to loss of vacuum in the calciner vessel. Differential pressure is measured between the calciner vessel and the glovebox. Also differential pressure across the calciner ceramic filters is measured. Through software interlocks, a low vacuum reading in the calciner or a high DP reading across the ceramic filters (indicative of filter plugging) will result in the instantaneous shut down of liquid feed pump (P-230-A), the closing of a solenoid valve on the atomizing air supply, and the closing of a solenoid valve on the filter blowback air supply. These shutdown interlocks limit the severity and duration of the pressurization event and limit the driving mechanisms that can expel PuO_2 particulate through the pressure relief port.

For the purposes of this analysis, the software interlock system is assumed to not respond to loss of calciner vacuum due to hardware failures or a software programming error. This scenario is unlikely but produces conservative results. Software interlock failure on loss of vacuum results in the calciner being continuously fed plutonium nitrate solution, atomizing air, and filter backflow air until the process can be manually shut down by operators. Operators are assumed to shut off the solution feed supply, atomizing air supply, and filter backflow air 30 minutes after the calciner relief cap is forced off. This response period is conservative as operators are required to verify the calciner is under vacuum every 15 minutes. During the 30 minute event time frame, flashing of vapor through the PuO_2 bed in the calciner, sparging of the PuO_2 bed with atomizing air, backflow of pressurized air through the ceramic filters, and the stirring action of the calciner agitator causes significant quantities of PuO_2 particulate to be released through the calciner relief port into the glovebox, contaminating the glovebox air and causing and elevated PuO_2 powder release to the E-4 ventilation system.

9.1.10.1.2 Detection of Event. Operators periodically (every 15 minutes) monitor the calcination process to verify the calciner is under vacuum. Pressure indicators monitor vacuum in the vacuum trap and in the phase separator tank. Operators can detect loss of plant vacuum flow at either one of these indicators. As mentioned in the previous section differential pressure (DP) across the calciner ceramic filters and between the calciner and glovebox are monitored via software. The computer display screen and local panel recorders and indicator lights provide for manual detection of calciner pressurization. Finally, the operator can detect overpressurization events that result in the ejection of the calciner relief cap by observing that the cap has fallen off; by observing steam and brown NO_x gases in the glovebox atmosphere, or by observing dust in the glovebox atmosphere. Prior to the calciner relieving through the pressure relief cap, pressurization of the calciner is also indicated by the presence of water vapor in the glass product collection jar.

9.1.10.1.3 Analysis of Effects and Consequences. The atmosphere in the calciner vessel is expected to contain a fairly high concentration of PuO_2 particulate during normal calciner operations due to the flashing of water vapor within the bed of the calciner, sparging of the PuO_2 bed from the atomizing air, back pulsing of the ceramic filters with pressurized air, and the action of agitator. The Production VDC produces PuO_2 powder that is highly dispersible. The amount of PuO_2 powder in the respirable size range (<4 μm) is expected to range between four and 20 weight percent.

On loss of vacuum, the PuO_2 release to the glovebox through the calciner pressure relief port is the product of the particulate concentration in the calciner vessel atmosphere and the expected vapor/gas flowrate through the relief port. The concentration and particle size distribution of PuO_2 particles within the vapor space of the calciner have not been measured directly. The PuO_2 release to the glovebox atmosphere during a calciner pressurization event is therefore estimated based on particulate concentrations measured in rotated canisters containing UO_2 powder and on general airborne particulate loading measurements from available literature.

Schwendiman (1977) measured the concentration of UO_2 powders inside canisters that had been rotated several times. UO_2 powders have a similar particle size distribution and density to PuO_2 powders. The experiments involved a mass of UO_2 (4.5 Kg) similar to that used in the bed of the calciner. Schwendiman found that the concentration of particles inside the canisters rapidly fell from values as high as 10 g/m^3 immediately after rotating to around 1 g/m^3 5 s later. Based on a curve fit of data from several experiments, Schwendiman estimates an average particulate concentration of 100 mg/m^3 100 s after rotating. The concentration levels off around 50 mg/m^3 1400 s after rotating the canisters. After 100 s, 100% of the particles in the canister were found to be less than 2 microns in diameter. Particles this small are considered to be respirable.

A few other values from Sutter (1982) provide some perspective. This reference reports airborne particulate concentrations ranging from 500 mg/m^3 to 10 g/m^3 for dust storms, 50 mg/m^3 to 500 mg/m^3 for mine air, 10 mg/m^3 for nuisance dust in the atmosphere, and 5 mg/m^3 for a cigarette smoke filled room. The dust storm values are comparable to Schwendiman's measurements a few seconds after rotating the canisters. The mine air values are comparable to the longer term concentrations measured by Schwendiman.

Dust storm concentrations and Schwendiman's measurements a few seconds after rotating the canisters are not representative of the steady-state particulate loading inside the calciner. Those measurements are for conditions that are more severe than the particulate lofting mechanisms inside the calciner. Those measurements also include larger particles that rapidly settle and are not dispersible. The data in the literature indicate an upper quasi-stable loading limit for small (respirable) particles in the 100 mg/m^3 range. The 100 mg/m^3 value represents the inflection point in Schwendiman's curve fit where UO_2 particles larger than 2 um (individual particle densities of 10 g/cm^3) can be expected to settle out by gravity. The particulate concentration inside the calciner, however, can be expected to be higher than nuisance dust in the atmosphere.

Based on the above discussion, the concentration of PuO_2 in the vapor/gas stream coming out of the calciner is assumed to be 100 mg/m^3. The material balance for the Production VDC predicts the following molar flows in the normal calciner offgas stream: HNO_3 -- 16.53 M/h, $H_2O(v)$ -- 84.13 M/h, N_2 -- 38.01 M/h, O_2 -- 13.37 M/h, NO_2 -- 8.53 M/h, NO -- 1.51 M/h. This gives a total molar flowrate of 162 gmoles/h. With calciner vacuum shut down, 100% of this flow can be expected to be expelled through the calciner pressure relief port. The expected temperature of the offgas stream, based on the material/energy balance for the calciner, is 300 °C. Using the ideal gas law, the volumetric flowrate of gas and vapor through the pressure relief port at 300 °C and atmospheric pressure is 7.62 m^3/h, or 0.127 m^3/min.

Over the assumed 30 minute duration of the accident, the PuO_2 release to the glovebox atmosphere is:

$$R = (0.127\ m^3/min)(30\ min)(100\ mg/m^3)$$

$$= 381\ mg.$$

This release is considered to be 100% respirable. It is assumed the operator shuts down the calciner agitator along with the liquid feed, atomizing air feed, and filter blowback air supply at 30 minutes. The residual release of respirable sized particles from the calciner will be small in comparison to the release over the first 30 minutes and is ignored.

The release of hot vapors, gases, and PuO_2 is confined to the HC-230C-2 glovebox. The volume of gas and vapors and the heat released is not high enough to overwhelm the glovebox exhaust system (flowrate through the HC-230C-2 glovebox is 100 cfm). Operators in room 230C are therefore not at significant risk. The E-4 system contains 2 stages of testable HEPA filters (E-4 filter boxes and the E-4 filter rooms). Testable HEPA filters have a minimum collection efficiency of 99.95%. For two stages of HEPA filtration the transmission factor is $(1-0.9995)^2 = 2.5 \times 10^{-7}$. The total release through the 291-Z-1 exhaust stack is $(0.381\ g)(2.5 \times 10^{-7}) = 9.5 \times 10^{-8}$ g. This is orders of magnitude below the 0.015 g release limit to meet the offsite dose acceptance criteria for a stack release of Class Y material (Table 9-51) given a probability of 1.

9.1.10.1.4 Corrective Actions. The PFP has trained plant personnel, administrative procedures, and equipment available to recover from potential calciner pressurization events. Recovery from this event would involve sweeping up the visible PuO_2 contamination in the glovebox, restoring vacuum system flow, and repairing any problems in the calciner low vacuum shutdown interlock system. Working on equipment in the glovebox may require that the calciner bed be drained, that PuO_2 containers be moved out of the glovebox, and that the feed receipt tank and feed pump tank contents be pumped back to glovebox HC-227S receipt or batch tanks to reduce worker exposures. The process could then be restarted in the usual manner. The recovered PuO_2 would be tested for water content, restabilized if necessary in one of the thermal stabilization furnaces, and canned with other PuO_2 for storage.

9.1.11 Reactive Material Thermal Stabilization Process

Ten categories of abnormal operations for the plutonium oxide thermal stabilization process inside Gloveboxes HC-21A, HC-2, HC-21C, HC-18BS, and HC-18M were identified in either the PHA documented in Appendix 9F or in the PHA documented in Appendix 9G. Metals stabilization are addressed in a PHA documented in Appendix 9H. These same categories also apply to seal-in/seal-out operations in glovebox HC-13MD and thermal stabilization operations in gloveboxes HA-28 and HA-22B. These same categories of abnormal operations for reactive plutonium-bearing material thermal stabilization apply to thermal stabilization inside Glovebox HA-21I (excluding thermal stabilization of PRF sludges). This exclusion is due to the absence of capability to provide the required cover gas for sludge processing in Glovebox HA-21I. These event categories are: contaminated wound, dispersal of plutonium oxide powder inside a glove box, dispersal of minor amounts of plutonium oxide powder outside a glove box during bagout operations, dropped container outside glovebox, flammable gas deflagration in glovebox, flammable gas deflagration in a waste drum, loss of glovebox confinement due to mechanical breach, loss of glovebox confinement due to ventilation failure, rupture of container in storage vault, and pyrophoric reaction in furnace. Because most of the abnormal operations that have been identified are not considered unique to the plutonium thermal stabilization process, additional analysis is required for only the flammable gas deflagration in Glovebox HC-21A. Discussion of the ten categories of abnormal operations for the plutonium oxide thermal stabilization process follow.

Postulated events that can result in dispersal of plutonium oxide powder inside a glove box include particulate release from can opening activities and spilling material during filling or moving furnace boats. This type of event is not unique to the plutonium thermal stabilization process and is considered to be adequately covered by plant radiation protection programs. Postulated events involving dispersal of plutonium outside a glove box occur as a result of bagout activities or sample handling. This type of event also is not unique to the plutonium oxide thermal stabilization process and is considered to be adequately covered by plant radiation protection programs.

The potential for dropping a container in an operating area exists whenever containers are handled outside of gloveboxes. The principal mitigative controls are packaging and CAMs. This event is not unique to thermal stabilization operations and is adequately addressed by the analysis of a plutonium powder spill outside of a glovebox presented in Chapter 9, Section 9.1.3.

Flammable gas deflagration in a waste drum was postulated as a potential event resulting from various waste disposal activities related to thermal stabilization of plutonium. This event may occur as a result of radiolytically generated hydrogen from the presence of plutonium oxide in a waste drum being ignited during movement of the drum. The activity of handling and disposing of contaminated material is not unique to the thermal stabilization process. The quantity of material produced during this activity is a small percentage of the total waste being processed at PFP. This event is considered to be adequately covered by considerations of waste drum handling already contained in Chapter 9.

Many causes of loss of glove box confinement due to mechanical breach were postulated in the plutonium thermal stabilization PHA (Appendix 9F and 9H). Included in the causes were operational errors producing holes or tears in gloves and, improper bag-in or bag-out. This type of event is not unique to the plutonium oxide thermal stabilization process and is considered to be adequately covered by requirements specified for the operation of the E-4 ventilation exhaust system and filters.

The loss of glovebox confinement due to ventilation failure could result in a spread of contamination from a glovebox. The E-4 ventilation system maintains a negative pressure differential between gloveboxes and the surrounding operational areas. Either a loss of both supply and exhaust ventilation resulting in stagnant conditions, or a loss of only exhaust ventilation resulting in a pressurized glovebox, could result in a spread of contamination from the gloveboxes. This hazard is not unique to thermal stabilization operations and is considered to be adequately addressed by the analysis of a loss of ventilation in Section 9.1.8 and the analysis of a glovebox breach in Section 9.1.9. In Gloveboxes HC-21C and HA-21I the ventilation system also serves to remove heat generated by furnace operation. Loss of the E-4 system could result in overheating of the gloveboxes leading to a breach of confinement. This hazard is also considered to be adequately addressed by Sections 9.1.8 and 9.1.9. Even though there are total glovebox and boat inventory differences between Gloveboxes HC-21C and HA-21I, these inventories are not involved in the abnormal operations evaluations or do not affect the evaluation conclusions.

The rupture of a container in the storage vault could result in a release of product oxide into the vault atmosphere. The PHA in Appendix 9G identified numerous process upsets and failures that could result in inadequately stabilized plutonium oxide. If this condition was not detected before the oxide was packaged, the container could rupture in storage due to internal pressurization. Should a container rupture while being handled in the 234-5Z Building, any airborne plutonium would be filtered by the E-3 ventilation exhaust system prior to release. In Building 2736-Z, many storage vault pedestals are instrumented to detect bulging cans. Those without this instrumentation are visually inspected monthly. A release from a ruptured can would be confined and filtered by the vault ventilation system. Section 9.1.4 analyzes the rupture of a pressurized plutonium powder container outside of a glovebox.

Pyrophoric reactions in the thermal stabilization furnace located in Glovebox HC-21C were identified as having abnormal operations implications in the plutonium oxide thermal stabilization PHA (Appendix 9F). The processing of unstabilized plutonium oxide may involve the presence of small quantities of pyrophoric material that have been created as a result of the conditions in the storage containers or inadequate reaction of metallic plutonium before the material was placed in storage. If the pyrophoric materials are placed in the thermal stabilization furnace there is the potential for release of small amounts of hydrogen and a minor flammable gas burn in the furnace. There is no significant potential for severe operator injury from the reactive plutonium-bearing oxides to be processed through the stabilization furnaces. The E-4 ventilation exhaust system and glovebox structure would ensure confinement of any material dispersed from the furnace. Previous Loss-on-Ignition (LOI) testing on the material to be thermally stabilized provides

confidence that significant quantities of pyrophoric materials are not present. Plant radiological protection programs are considered adequate to address cleanup and recovery from such an event.

The abnormal operation of a hydrogen deflagration in glovebox HC-21A is discussed in the following paragraphs.

Flammable gases, primarily hydrogen, may be present in multiple overpack containers due to the thermal and radiolytic decomposition of plastic packaging materials and moisture. Only mechanically sealed cans have the potential to hold significant pressure. As shown in the following analysis, the release and subsequent ignition of the hydrogen potentially present in multiple overpack containers does not result in a breach of Glovebox HC-21A.

Scenario

Plutonium oxide and MOX transferred to HC-21A from vault storage are contained in multiple overpack containers comprised of standard food-pack cans. The material may be contained in two, three, or four nested containers. In all cases, the outer container is a crimp-sealed 7-Inch Can.

Pressurization criteria have been developed that correlate storage can deformation to internal can pressure. Based on the degree of deformation, cans are designated as A, B, C, or D. The corresponding pressure ranges are:

- A 0 to 5 psig
- B 5 - 15 psig
- C 15 - 20 psig
- D 20 - 40 psig.

The generation of hydrogen can result in pressurized containers. Pressurization criteria have been developed that correlate storage can deformation to internal can pressure, as shown in Figure 9-37. For the non-product quality plutonium thermal stabilization operations described in this document, it is postulated that only Type A through D cans will be processed, and therefore, opened in Glovebox HC-21A.

For the purposes of this analysis, it is assumed that a Type D can be pressurized to 30 psig is sealed into Glovebox HC-21A and opened. A value of 30 psig was chosen for analysis because containers may vent at their seams beginning at a pressure of 30 psig.

Given a pressure of 30 psig, the quantity of gas in a container can be calculated using the Ideal Gas Law:

$$PV = nRT$$

where: P = pressure, atm
V = volume, L
T = absolute temperature, K
n = number of moles
R = universal gas constant, 0.0825 atm liter/mol K

The volume of a 7-inch Can is 1.5 L. Some fraction of this volume will be filled by the plutonium oxide or MOX, inner can or cans, and packaging materials. After accounting for these items, it is estimated that the free volume within the 7-inch Can is 1.25 L.

Given a free volume of 1.25 L and assuming a temperature of 300 K, the number of moles of gas present at a pressure of 30 psig is:

$$n = [(44.7 \text{ psia})(1 \text{ atm}/14.7 \text{ psia})](1.25 \text{ L})/(0.0825 \text{ atm-L/mol-k})(300 \text{ K})$$

$$n = 0.15 \text{ moles}$$

The 0.15 moles of gas in the 7-Inch Can at 30 psig is comprised of the hydrogen generated by thermal and radiolytic decomposition of plastic packaging materials and moisture and the air initially present in the container. Applying the Ideal Gas Law, the quantity of air in the can before pressurization is 0.05 moles. Therefore, the 7-Inch can contains 0.05 moles of air and 0.10 moles of hydrogen at the time it is opened.

Mechanically sealed storage containers are opened in Glovebox HC-21A by use of an electric can opener. Per procedure, D cans are vented with a puncturing tool prior to being opened. Regardless of method, once the 7-inch can is punctured, a flammable mixture of hydrogen and air will be released. Because of its low ignition energy, nominally small heat producing sources (e.g., friction and static generation) can result in the prompt ignition of hydrogen. Should this occur, the hydrogen would burn as a jet or flare. This short duration, unconfined burn would not pressurize the glovebox.

If the hydrogen does not burn as it exits the 7-Inch Can, it will, given its high diffusivity, rapidly mix with the glovebox atmosphere. Glovebox HC-21A, with dimensions of 10 ft 8 in. by 3 ft 6 in. by 3 ft, has a volume of 3,170 L. Subtracting the 680 L volume of the Inert Atmosphere Confinement portion of the glovebox yields a volume of 2,490 L. Applying the Ideal Gas Law, this volume can contain 101 moles of gas at 300 K and I atmosphere. If the 0.10 moles of hydrogen released from the 7-Inch Can were to mix uniformly within the volume of the glovebox, the resultant concentration would be 0.10 %, which is significantly below the lower flammability limit of 4 %. Accordingly, the hydrogen would not burn but would be swept from the glovebox via the E-4 ventilation system and further diluted.

As the hydrogen is released from the 7-Inch Can and mixes with the glovebox atmosphere, localized concentrations within the flammability range could exist for a short period. If all of the hydrogen is released as a puff and is ignited before mixing below the lower flammability limit, the instantaneous energy release would be:

$$Q = (240 \text{ kJ/g-mole})(0.10 \text{ moles}) = 24 \text{ kJ}$$

where: Q = heat generated
kJ/g-mole = heat of combustion of hydrogen.

Conservatively assuming 100% of the heat from the hydrogen burn is transferred to the air in the glovebox, the increase in temperature can be calculated by:

$$\Delta T = Q/mC_p$$

where: ΔT = change in temperature (K)
Q = heat generated (kJ)
m = mass of air in glovebox (kg)
C_p = specific heat of air (kJ/kg-K).

The mass of air in Glovebox HC-21A is equal to the volume of air multiplied by its density:

$$m = (\text{volume})(\text{density}) = (2.47\ m^3)(1.16\ kg/m^3) = 2.86\ kg$$

Solving for ΔT yields a temperature increase of:

$$\Delta T = 24\ kJ/(2.86\ kg)(1.007\ kJ/kg\text{-}K) = 8.33\ K$$

Applying the Ideal Gas Law and assuming the glovebox is a perfectly sealed space, the pressure in the glovebox given a temperature rise of 8.33 K is calculated as follows:

$$(P_{final}/P_{initial}) = (T_{final}/T_{initial})$$

$$P_{final} = (14.7\ psia)(300\ K + 8.33\ K)/(300\ K) = 15.1\ psia$$

Therefore, the theoretical maximum increase in pressure is 0.4 psig.

A pressure increase of 0.4 psi is not expected to fail the glovebox gloves. Walden (1980) suggests gloves fail at an overpressure of 0.6 psi. A pressure increase of 0.4 psig could breach the glovebox via failed seal-in ports. Although a pressure increase of 0.4 psig can be conservatively calculated, such an increase would not be realized for three principal reasons. First, 100% of the hydrogen released in a puff would not burn as assumed. A stoichiometric mixture of 0.10 moles of hydrogen and air has a volume of 8.4 L, which would fill approximately 0.4% of the glovebox. Accordingly, the hydrogen would burn as an unconfined cloud, the efficiency of which can be significantly less than 100%. As stated in Evaluation of Unconfined Vapor Cloud Explosion Hazards (Pugh 1987), when small, unconfined vapor clouds are ignited, the vapors usually burn without pressure effects and with a low flame speed. Second, 100% of the heat from the hydrogen burn would not be transferred to the air as assumed above, i.e., the system is not adiabatic. Third, Glovebox HC-21A is not a sealed vessel. A 3-ft. by 17-in. opening in the north end of Glovebox HC-21A provides access to conveyor Glovebox HC-2. Qualitatively considering these factors, it is concluded that

the release and subsequent ignition of hydrogen from a pressurized Type D can would likely not breach Glovebox HC-21A since there would be little or no pressure increase. This conclusion is consistent with operating experience at PFP and throughout the DOE complex.

Consequence Analysis

The analyzed scenario does not result in a significant breach of the glovebox. The quantity of plutonium potentially suspended inside Glovebox HC-21A by burning hydrogen is judged to be small relative to that suspended by normal operations (e.g., pouring oxide through a sieve, use of mortar and pestle). The quantity of material potentially released outside the glovebox given the breach of a seal-in or sphincter port, should it occur, is bounded by the release of plutonium from a pressurized powder container analyzed in Section 9.1.4 and by the spill of 2.5 kg of plutonium outside of a glovebox analyzed in Section 9.1.3.

The impact of the thermal stabilization of non-product quality oxide feed materials on the existing FSAR analysis has been discussed above.

9.1.12 Laboratory Prototype Calciner

Abnormal operations associated with the Laboratory Prototype Calciner are identified and evaluated in the Laboratory Prototype Calciner addendum to this FSAR. It is noted that the laboratory calciner is not currently authorized for operation.

9.1.13. Loss of Filtration.

Two buildings were evaluated to determine the potential consequences associated with a loss of filtration. The buildings evaluated are the 232-Z building and the 241-Z building. Both evaluations assume that filtration is lost due to catastrophic breach in the HEPA filters or that a significant leak in the seals occur and the ventilation fans continue operating. Both exhaust systems are aerosol penetrant tested annually and releases from the individual exhaust stacks are continuously monitored. Section 9.1.13.1 describes the accident scenario and consequence calculations associated with an unfiltered release from 232-Z and Section 9.1.13.2 describes the accident scenario and calculated consequences associated with an unfiltered release from 241-Z.

9.1.13.1. Loss of Filtration, Building 232-Z. Building 232-Z originally contained a series of process enclosures housing equipment used for the recovery of plutonium from various waste substrates. The facility has been deactivated and current activities within the facility are limited to routine surveillance and monitoring.

The facility has a maximum total holdup of 661 grams Pu based on NDA measurements performed following equipment removal and cleanout. The majority of this material (i.e., 405 grams) is located in the incinerator in the form of thick slag coatings on the combustion chamber walls; however, it is possible that ash exists outside the combustion chamber but inside the glovebox. The cyclone separator contains 102 grams, which is assumed to be

fixed, and the scrubber cell contains 77g. The remaining 77 grams are located in miscellaneous glovebox ventilation ducting; however, much of this material is fixed to the piping and ductwork. The quantity of material available for resuspension, i.e., ash in the multisection glovebox and piping or ductwork has not been determined. Therefore, assuming no activities are occurring in the gloveboxes, for this analysis it is assumed that 50 grams Pu (ash plus material in the piping and ductwork) is available for resuspension by the ventilation system.

In DOE-HDBK-3010-94 ARF and RF values of 4E-05/hr and 1.0, respectively are recommended for resuspension of loose particulate by the ventilation system. These values are for materials exposed to normal process ventilation flow rates or less. However, it is noted that no applicable data to model aerodynamic entrainment and resuspension, were identified. Applying these values to the quantity of material available for resuspension (i.e., 50 grams Pu) and assuming the filters are not available, it is estimated that a maximum of 2.0E-03 respirable grams Pu/hr can potentially be released to the atmosphere or up to 17.5 grams annually.

The average annual filtered release (January 1996 to July 1999) from the building 232-Z stack is 1.8E-06 Ci total alpha. Assuming the filters are unavailable or failed the calculated average annual unfiltered (assuming the HEPA DF at 5E-04) release is approximately 3.7E-03 Ci total alpha or 7.6E-02 grams Pu (Pu-238, Pu-239/240, Pu-241).

Comparing the calculated annual releases, i.e., releases based on the DOE HDBK-3010-94 and empirical data adjusted for HEPA DF, it can be assumed that, although there is 50 grams of unconfined Pu in the facility, the majority of the material is not available for resuspension by the ventilation system. However, this material can be resuspended and available for release due to activities within the glovebox or in the ductwork. Thus a control requiring an evaluation for the HEPA filters and stack CAM is required prior to performing any activities in the glovebox or the ductwork with the potential to resuspend Pu particulate.

Operator Actions. This analysis assumes that no activities, except for routine surveillance outside of the glovebox or ductwork, are being performed inside the glovebox and ductwork. If activities are being performed inside of these structures, the quantity of material potentially released to the atmosphere, based on the activity, may be substantially increased. Therefore, it can be concluded that the HEPA filters and subsequently the stack CAMs are not required during surveillance activities. If other activities (e.g., glovebox or ductwork cleanout or other waste disturbing activity) are undertaken, the need for HEPA filtration will be reanalyed. If appropriate, based on the reanalysis, the HEPA filters may be reclassified.

Methods or Means of Detection. In accordance with LCO 3.2.1.1 HEPA filters are aerosol penetrant tested annually.

Engineered Safety Feature and Protective Systems. There are no engineered safety feature and protective systems other than the annual DOP test required.

Methods, Assumptions, and Conditions. It was assumed no activities, other than routine surveillance, are performed in the gloveboxes.

9.1.13.2. Loss of Filtration, Building 241-Z. As described in Section 5.2.4 the 241-Z building contains storage tanks ranging from 16,400 L (Tanks D-4 and D-5) to 17,900 L (Tanks D-7 and D-8) and a 700 L overflow tank, that typically contain Pu bearing solutions. With the exception of the overflow tank, each tank is limited to 400 grams Pu. All tanks and tank cells are exhausted through a two-stage testable HEPA filter, and discharged to the atmosphere via stack 296-Z-3. This analysis assumes that the two-stage HEPA filter is unavailable, e.g. catastrophically failed and that the exhaust fans continue operating. There is no supplied air to the tanks or tank cells. Air to the cell and tanks is provided by in-leakage.

This analysis assumes the fans continue operating. The exhaust system is capable of exhausting 1000 cfm (see Section 9.1.7E.1.2) from the cells and tanks combined. For this analysis it is assumed that any residual or fixed contamination in the cells will contribute negligibly to the total release from the facility. That is, any radioactive materials released to the atmosphere will be from the liquid waste stored in the tanks.

Because the exhaust fans continue to operate the release from the surface of the tank waste is modeled based on the resuspension flux from a small pool corresponding to sea spray releases in winds up to 6.6 ft/s (2 m/s). Each tank is 3 ft (0.91 m) in diameter and has a cross sectional area of approximately 0.65 m2 or 3.3 m2 for all 5 tanks. Using a conservative resuspension flux of 1.4E-10 L/m2-s (WHC-SD-WM-CN-049) the release rate from the waste in the 5 tanks is approximately 4.6E-10 L/s (resupension flux times tank cross sectional area). Typically transfers to 241-Z have very low plutonium concentrations (approximately 0.033 g Pu/L). Therefore, the potential airborne release is approximately 1.5E-11 grams Pu/s or 5.5E-08 grams Pu/hr (approximately 5.0E-4 grams Pu annually).

Operator Actions. The quantity of Pu released from this abnormal accident is compared to the annual release from stack 291-Z to determine if additional controls or operator actions are required beyond those currently in effect. Based on the comparison, the potential unfiltered release from 241-Z is less than or equivalent to the annual filtered release from 291-Z. Therefore, no new or additional operator actions are required.

Methods or Means of Detection. In accordance with LCO 3.2.1.1 HEPA filters are aerosol penetrant tested annually.

Engineered Safety Feature and Protective Systems. There are no engineered safety feature and protective systems other than the annual aerosol penetrant test required.

Methods, Assumptions, and Conditions. These were not required as no substantial upset could be identified.

9.1.14 Magnesium Hydroxide Precipitation Process

Abnormal operations associated with the Magnesium Hydroxide Precipitation Process are identified and evaluated in the related addendum (Carson 2000) to this FSAR.

9.1.15 Bagless Transfer System (BTS)

Abnormal operations associated with the BTS are identified and evaluated in the related calculation notes (FH 2000).

9.2 ACCIDENTS

Events discovered in the PHA that appear to have enough energy or other parameters to result in unacceptable onsite or offsite consequences are analyzed in sections 9.2.1 through 9.2.8. During the analysis, all of the events were found to have either probabilities of occurrence less than 1 x 10^{-6} or consequences below the Risk Acceptance Guidelines presented in Section 9.4. The events are maintained in the Accident section because they are considered classical accident events or because they were treated as real events with significant consequences in former SARs.

9.2A PLUTONIUM-BEARING SOLUTION STABILIZATION USING THE PRODUCTION VERTICAL DENITRATION CALCINER

9.2A.1 Accidents Postulated for the Plutonium-Bearing Solution Stabilization Process

Accident categories (bins) identified for the plutonium-bearing solution stabilization process using the Production VDC are summarized in Appendix 9D, Table 9D-3. The accident categories were screened from the HazOp analysis contained in Table 9D-4, as discussed in Section 9.0.2.1A. The accident categories represent types of events associated with the Production VDC operations in glovebox HC-230C-2 that have the potential to breach confinement barriers, resulting in significant spread of radiological or toxicological contamination to Zone 3 or Zone 4 areas within Building 234-5Z and the potential to cause a significant release of radiological or toxicological material from the building to the atmosphere. Each of the accident categories from Table 9D-3 are discussed in Section 9.2.9. Each accident category is compared and evaluated against the original accident analyses contained in Sections 9.2.1 through 9.2.8. For accident categories not bounded or adequately represented by the preexisting accident analyses in Sections 9.2.1 through 9.2.8, new detailed accident analyses are provided in Section 9.2.9.

9.2A.2 Assessment of Plutonium-Bearing Solution Stabilization Process Impacts on Original Accident Analyses

For completeness, the accident analyses contained in Sections 9.2.1 through 9.2.8 were individually evaluated for potential impacts posed by the plutonium-bearing solution stabilization process using the Production VDC. This evaluation was performed to determine if any of the original analyses required changes because Production VDC operations added potential source term to those accidents, made those types of accidents significantly more likely, or posed an accident similar to the original accident but with consequences that were not bounded by the original accident. The results of this evaluation are summarized in Table 9-54. Production VDC operations were found to not impact any of the original analyses with the exception of the RMC line fire and seismic events. The additional release and dose consequences of the postulated RMC line fire spreading to glovebox HC-230C-2 are addressed in Section 9.2.9.2. The additional release and dose consequences in the postulated seismic event from Production VDC operations are addressed in Section 9.2.9.4.

9.2B REACTIVE PLUTONIUM-BEARING MATERIAL STABILIZATION

9.2B.1 Accidents Postulated for the Thermal Stabilization of Plutonium Oxide Process

Accident categories (bins) identified for the thermal stabilization of "clean" plutonium oxide are summarized in Appendix 9F, Table 9F.23. The accident categories were screened from the PHA shown in Table 9F.23 and are discussed in Appendix 9F, Section 9F.4.3.3. Accident categories (bins) are identified for the thermal stabilization of non-product quality feed material as those accident categories represented by hazards with either an "S1*" or an "S2" consequence rank in Appendix 9G, Table 9G.2 The accident categories were screened from the PHA and are discussed in Appendix 9G, Section 9G.4.2. The accident categories represent types of events associated with the thermal stabilization operations in Glove Boxes HC-21A, HC-2, HC-21C, HA-21I, HC-18BS, and HC-18M that have the potential to breach confinement barriers, resulting in significant spread of radiological or toxicological material from the building to the atmosphere. The same catgories also apply to seal-in/seal-out operations in glovebox HC-13MD and thermal stabilization operations in gloveboxes HA-28 and HA-22B. Each of the accident categories from Table 9F.23 and Table 9G.2 are discussed in Section 9.2.10. Each accident category is compared and evaluated against the original accident analyses contained in Sections 9.2.1 through 9.2.9. The accident categories not bounded or adequately represented by the preexisting accident analyses in Sections 9.2.1 through 9.2.9 detailed accident analyses are provided in Section 9.2.10.

9.2B.2 Assessment of Thermal Stabilization of Plutonium Oxide Process Impacts on Original Accident Analyses

For completeness, the accident analyses contained in Sections 9.2.1 through 9.2.9 were individually evaluated for potential impacts posed by the thermal stabilization of plutonium oxide process. This evaluation was performed to determine if any of the original analyses required changes because plutonium oxide thermal stabilization operations added potential source term to those accidents, made those types of accidents significantly more likely, or posed an accident similar to the original accident but with consequences that were not bounded by the original accident. Thermal stabilization of Plutonium Oxide operations were found to not impact any of the original analyses with the exceptions of Glove Box Deflagration, Seismically Induced Deflagration, Fire in Glove Box, and Seismically Induced Glove Box Fire. The additional release and dose consequences of these accidents are presented in Sections 9.2.10.1 - 9.2.10.6. The effect of additional source term potential from inventories in the thermal stabilization gloveboxes has been considered and where applicable has been factored into the appropriate sections.

9.2C LABORATORY PROTOTYPE CALCINER

Accidents postulated for operation of the Laboratory Prototype Calciner and an assessment of the impacts of laboratory calciner operations on the original accident analysis performed prior to calciner operations are provided

in the *Laboratory Prototype Calciner* addendum to this FSAR. It is noted that operation of the laboratory calciner is not currently authorized.

9.2D MAGNESIUM HYDROXIDE PRECIPITATION PROCESS

Accidents postulated for operation of the Magnesium Hydroxide Precipitation Process and an assessment of the impacts of those operations on the original accident analysis performed prior to operation of this process are provided in the Magnesium Hydroxide Precipitation Process addendum (Carson 2000) to this FSAR.

9.2E BAGLESS TRANSFER SYSTEM (BTS)

Accidents postulated for operation of the BTS and an assessment of the impacts of BTS operations on the original accident analysis performed prior to BTS operations are provided in the calculation notes (FH 2000) for the BTS.

9.2F SUMMARY OF ACCIDENT ANALYSES

Table 9-1 provides a summary of the accidents analyzed in this section. The new accidents for the plutonium-bearing solution stabilization process using the Production VDC are included. Provided in the table are the estimated annual probabilities and dose consequences for each accident. The last column gives doses at Highway 240 for information purposes only (see Section 9.3.7 for added information).

9.2.1 Explosions

The accidents discussed in this section are events identified in the PHA which have the potential to result in an explosion with enough energy to disperse plutonium to onsite or offsite people.

9.2.1.1 Summary. Two types of explosions ("red oil" and bottled gas) are described in this section. The term explosion is used to identify any event which the general public believes is an explosion. This includes detonation, deflagrations, or overpressurization due to gas generation. A "red oil" explosion results in either (a) an overpressurization of the vessel due to rapid decomposition of an unstable tri-butyl phosphate (TBP) compound or (b) an explosion of flammable gas generated by the decomposition of TBP. The term "red oil" explosion will be dropped in favor of a more exact description, i.e., the rapid decomposition of heavy metal nitrate-TBP complexes. Section 9.2.1.2 presents a further discussion of the decomposition of heavy metal nitrate-TBP complexes. Such complexes were generated by former PFP operations (e.g. the filtrate evaporator), and decomposition events have been historically analyzed. Current operations do not generate new complexes, nor do they process existing complexes. Because future stabilization activities may process material containing heavy metal nitrate-TBP complexes, the following discussion has been retained for information purposes. The bottled gas explosion is described in Section 9.2.1F, "Flammable Gas Explosion."

9.2.1.2 Decomposition of Heavy Metal Nitrate-TBP Complexes. At elevated temperatures, heavy metal nitrate-TBP complexes decompose exothermically. If the rate of reaction is such that heat is generated faster than it can be removed, the reaction becomes autocatalytic. The accompanying rapid evolution of gases may lead to an explosion. Three such reactions have occurred at DOE facilities--two with explosive consequences. However, none of these were plutonium systems.

The study that has involved TBP-plutonium nitrate complexes is found in *Notes Pertaining to Recuplex Product Evaporation*, HW-32100 (Pugh 1954). The diluent used was CCl_4. With a "TBP-to-plutonium nitrate weight ratio of 0.15 or higher, violent reactions were initiated when evaporations where carried out to pot temperatures over 150 °C." The "heat of reaction was sufficient to raise the pot contents to a red heat in a matter of seconds" (Pugh 1954, pg. 5).

Based on this information, operations conducted within the PFP were reviewed for the potential of elevating TBP-plutonium nitrate solutions to temperatures greater than 135 °C. The 135 °C value is based on the recommendation of *The "Red Oil" Problem and its Impact on PUREX Safety*, ORNL/TM-10798 (Campbell and Mailen 1988). Campbell and Mailen state in Section 5, "Recommendations," that the limit of 135 °C could be raised to 150 °C if operations at 150 °C were verified to be safe. However, in the Abstract they state that "an increase in the maximum permissible temperature has not been recommended." For the TBP-CCl_4-plutonium nitrate solutions typical of PFP operations, this temperature may be conservative by as much as 15 °C, based on Pugh (1954). However, the relationship of Pugh (1954) to present day operations is difficult to determine due to insufficient information regarding experimental design (Pugh's work involves the use of Pyrex™ containers in a laboratory setting) and scaling factors to full-scale process equipment.

Former operations within the PRF, where energetic reactions between TBP and plutonium nitrate are conceivable, is within three inactive process vessels: the filtrate evaporator , the product concentrator, and glovebox MT-5. A postulated accident involving the filtrate evaporator has been previously analyzed in two separate documents. In the *Plutonium Finishing Plant Safety Analysis Report*, WHC-SD-HS-SAR-007 (Roemer 1987), a postulated explosion involving 5 L of nitrated TBP was assumed to occur and severely damage the south wall of the process cell, resulting in a direct release of 1.9 g of plutonium to the environment. The event was assigned a nonprocess-specific, nonfacility-specific probability of 1×10^{-3}. In *Safety and Risk Assessment Technical Information to Support PFP Restart*, WHC-SD-SQA-TI-013, Rev. 2 (Marusich 1988a), a postulated explosion involving nitrated TBP was assumed. The calculated pressure within the cell was somewhat higher than in *TRUEX Pilot Plant Safety Assessment* (Marusich 1987), 0.5 lbf/in^2 versus 0.41 lbf/in^2, but because of modifications to the south wall, it was concluded that the south wall would not be breached. The plutonium release, following HEPA filtration, was calculated to be 1.4×10^{-4} g, and the annual probability was estimated to be 5×10^{-6} given a combination of human error and the failure of a PRV.

Analyses of the product concentrator were not performed as the filtrate evaporator was judged to be the limiting case, particularly as related to probability of occurrence.

In addition to the two PRF evaporators, an energetic reaction involving nitrated TBP is conceivable within the PFPAL waste concentrator, but this system is also out of service. Although mentioned in *Plutonium Finishing Plant Laboratory Safety Analysis Report*, WHC-SD-HS-SAR-011 (Jones 1983), no analysis (neither qualitative nor quantitative), is presented.

Present operations within the PFP that may involve a deflagration are conducted in gloveboxes HC-21C and HA-21I. The bounding accident for thermal stabilization of plutonium-bearing oxides is a flammable gas deflagration in glovebox HC-21C that is generated by the pyrolysis of potential plastic contaminant in the oxide. This accident is discussed in Section 9.2.10.2.

9.2.1A Product Concentrator

The product concentrator is not currently authorized for operation by DOE. If future use of the product concentrator is required in PFP, Section 9.2.1A will be analyzed, incorporated into this SAR, and approved by DOE.

9.2.1B Filtrate Evaporator

The filtrate evaporator is not currently authorized for operation by DOE. If future use of the filtrate evaporator is required in PFP, Section 9.2.1B will be analyzed, incorporated into this SAR, and approved by DOE.

9.2.1C Not Used

9.2.1D Laboratory Waste Concentrator

The Laboratory Waste Concentrator is not currently authorized for operation by DOE. If future use of the concentrator is required, Section 9.2.1D will be analyzed, incorporated into this SAR, and approved by DOE.

9.2.1E Explosion, Hydrogen in Fluorinator

Since plutonium metal is no longer produced at PFP, Section 9.2.1E is not required. The fluorinator is not currently authorized for operation by DOE. If future use of HF is required, Section 9.2.1E will be analyzed, incorporated into this SAR, and approved by DOE.

9.2.1F Flammable Gas Explosion

The types and quantities of flammable gases used at the PFP were reviewed and nominal 465-g (16.4-oz) containers of liquid propane gas (LPG) were found to present the greatest risk. Propane is used on an as-needed basis at the

PFP for a variety of activities which require relatively high temperatures. Examples of applications requiring propane include: soldering, brazing, and small welding jobs as required when making repairs to the HVAC system.

Liquid propane gas containers used in the PFP are restricted to small, commercially available cylinders of 465-g (16.4-oz) capacity which meet requirements established by the DOT and the Compressed Gas Association (CGA). Federal requirements are found in 49 CFR 173, *Shippers General Requirements for Shippments and Packaging*, Section 173, 34(d) (49 CFR 173) and 49 CFR 178 *Shipping Container Specification*, Section 178.65 (49 CFR 178). Applicable national consensus standards are found in *Pressure Relief Device Standards Part I--Cylinders for Compressed Gases*, CGA Standard S1.1-89 (CGA 1989).

The former propane supply line in Building 234-5Z is no longer in service and has been disconnected from a propane supply. The former supply header has been cut into segments, flushed, and capped. The line segments have been sampled and found not to contain explosive concentrations of propane (BWHC 1998). The segments of the former propane supply header will have vents installed in them to ensure propane concentrations in this header stay below the explosive limit (BWHC 1998a). Accordingly, deflagrations associated with the former propane header in Building 234-5Z have not been analyzed.

Testing of propane cylinders by Underwriter's Laboratory (UL), in accordance with *Nonrefillable (Disposal) Type Fuel Gas Cylinder Assemblies*, UL 147A (UL 1992), provides added assurance that the cylinders meet or exceed applicable DOT and CGA requirements. All of the propane cylinders at the PFP are UL listed. Some of the UL 147A requirements are listed below:

- The pressure vessels are constructed in accordance with Specification 39 of 49 CFR 178.65.
- The pressure relief device(s) meets the requirements of 49 CFR 173.34(d) and the UL 147A (UL 1992).
- The cylinders are provided with an integral shutoff valve that closes automatically when the cylinder is disconnected from the gas-consuming equipment.
- Cylinders incorporate a Type CGA No. 600 threaded connection in accordance with *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*, CGA V-1 (CGA 1987).
- The gas-confining parts have a minimum solid temperature of at least 510 °C (910 °F) and a tensile strength of at least 68.9 MPa (10,000 psi) at 204 °C (400 °F). Exceptions: A valve disc, soft seat, seal ring, diaphragm, or gasket need not comply with this requirement.
- The brazing material used for joining parts of a cylinder assembly has a minimum melting temperature of 538 °C (1,000 °F).
- A hydrostatic pressure strength test is performed to demonstrate the strength and design failure point of the cylinders. The pressure strength test is performed at four times the marked service pressure

for one minute. Then the pressure is increased at the rate of 690 kPa/min (100 psig/min) until the tested cylinder ruptures. The manner of failure must be in the side wall of the cylinder parallel with its longitudinal axis.

- Pressure relief valves are tested to assure that the start-to-discharge pressure is not less than 120 percent of the marked test pressure [2,480 - 3,307 kPa (360 - 480 psig)] nor more than 80 percent of two times the marked test pressure [1,970 kPa (286 psig)].

- Fire testing of the relief device, to assure that it operates to reduce the risk of rupture or propulsion, is performed over a charcoal bed 610 by 457 by 152-mm (24 by 18 by 6-in.) in a three sided concrete enclosure. The cylinder is placed horizontally on a wire screen above the charcoal. The test temperature is between 537 and 649 °F).

9.2.1F.1 Propane Release Scenarios. A Preliminary Hazards Analysis (PHA), *Safety Assessment of Flammable Gas Explosion at the Plutonium Finishing Plant*, WHC-SD-CP-SAD-003, Rev. 0 (WHC 1994a) was prepared to identify possible hazards associated with the use of small, 465-g (16.4-oz), LPG cylinders within the PFP (for convenience these cylinders will be referred to a "DOT 39 cylinders" in the remainder of this discussion). The hazards were identified based on assumptions of no more than six DOT 39 cylinders being in the PFP process areas and no more than two DOT 39 cylinders simultaneously located in any single room within the PFP (see 9.2.1F.2). Identified hazards associated with the use of propane are fires, leaks, mechanical failures, and boiling liquid expanding vapor explosions (BLEVEs). The use of propane torches for maintenance activities such as soldering could result in ignition of combustible materials and fire in the PFP. Ignition of fires, including those from the use of propane, is analyzed in Section 9.2.2 of this document and the analysis shows that the risk from fire is acceptable.

Hazards associated with use of LPG in DOT 39 cylinders are divided into two general areas: slow leaks (i.e., releases through the normal discharge orifices) and catastrophic container failures. The release scenarios were chosen to show the consequences of a release over a broad range of release possibilities.

9.2.1F.1.1 Slow Propane Releases. DOT 39 cylinders are constructed of two cylindrical sections of cold-drawn, malleable sheet steel having a minimum thickness of 0.0635 cm (0.025 in.). The two halves are welded together, and the entire cylinder is completely annealed. The working orifice and its allied valve are recessed into the top of the cylinder for protection, and any accessories are screwed to a Type CGA No. 600 threaded connection. Gas-consuming tips which attach to the connection are available with valves having two orifice diameters:

1. 0.11-mm, which at the maximum flow rate will discharge an initially full cylinder in 20 hours (WHC 1994a)

2. 0.23-mm, which at the maximum flow rate will discharge an initially full cylinder in 6 hours (WHC 1994a).

The gas-consuming equipment is designed to fail downstream of the valve in the event of an accident.

An uncontrolled leak from either the 0.11-mm or the 0.23-mm orifices may be encountered, for example, if the gas-consuming equipment were to break off the cylinder while the valve was in the "open" position and the flame extinguished or if the valve was inadvertently open.

The maximum cylinder design pressure is 6.9 MPa (1,000 psig). At a normal temperature 30 °C (80 °F) the internal pressure is 1,035 kPa (159 psig). All DOT 39 cylinders are equipped with a safety relief valve (SRV), 2.2 mm in diameter, which opens if the internal pressure exceeds 2,480 - 3,307 kPa (360 - 480 psig), and closes if the pressure falls below that range. If the SRV remains open, a full cylinder will discharge in less than 20 seconds.

As was shown in WHC 1994a, the discharge of propane through the three orifices (0.11-mm, 0.23-mm, and 2.2-mm diameters) does not result in an explosion. The discharges mix with room air and could potentially result in deflagration under the worst discharge condition. This worst condition of discharge is an uncontrolled discharge of propane from the 2.2-mm orifice (WHC 1994a). A deflagration under these conditions into an unventilated 30 m^3 room, which is considerably smaller than any PFP process room, produces a peak pressure of 0.34 lbf/in^2. *PFP 234-5Z Building Wall Panel Testing*, WHC-SD-CP-TRP-035, Rev. 0 (WHC 1989b) shows that simulated PFP wall panels survive a pressure of 0.49 lbf/in^2. Simultaneous discharge of two DOT 39 cylinders and deflagration of the gas in a 65-m^3 room, which is still smaller than, but much more consistent with, the size of PFP process rooms, also results in an acceptable overpressure, less than 0.35 lbf/in^2 (WHC 1994a).

Thus, it logically follows that, even if the frequency for this event is assumed to be 1.0, the risk associated with an accident such as this is clearly acceptable.

9.2.1F.1.2 Catastrophic Cylinder Failure. A catastrophic cylinder failure is defined as a rupture in which virtually all of the LPG escapes instantaneously. Mechanisms that might cause a catastrophic failure of a DOT 39 cylinder include dropping a full cylinder, crushing a full cylinder, or exposure of a full cylinder to a fire with simultaneous failure of the SRV.

Ceiling areas containing building services such as piping, electrical wiring, and ventilation ducts are the only locations where catastrophic failure of a DOT 39 cylinder by dropping is postulated to occur. The maximum potential height of such areas in the PFP is 4.6 m (15 ft). A propane cylinder dropped from that height onto a hard surface such as concrete might be dented but will not fail because the head space above the LPG will collapse slightly to absorb the energy of impact (WHC 1994a). If the internal pressure from denting exceeding 2,480 - 3,307 kPa (360 - 480 psig), the SRV would relieve the excess pressure and then reseat when the pressure fell below that range. The SRV is designed to survive such impacts and is located in a particularly sturdy part of the cylinder.

One could postulate an event in which the container was dropped from a height of 4.6 m (15 ft) onto a sharp object and punctured. The internal

pressure of the propane on the cylinder might then cause a crack to develop and propagate, ultimately causing a catastrophic cylinder failure. As shown in the cylinder perforation analysis contained in WHC 1994a, because of the materials used in the construction of DOT 39 cylinders, the construction methods employed, and the relatively low pressure in the cylinder, this failure mode is not credible. Thus, for the postulated puncture event, the only wound to the cylinder would be the puncture itself. The consequences of a puncture and subsequent deflagration would be similar to those of a discharge through the SRV.

The potential for crushing-type accidents was also investigated in WHC 1994a; no credible case was identified. Mobile heavy equipment, such as forklifts, which might run over a cylinder, is not used in the plant. Even so, the propane cylinders are engineered to withstand such accidents. A case might be also be made for a heavy object falling onto a cylinder as a consequence of a seismic event. Event trees were constructed in WHC 1994a to determine the probability of a seismic event causing equipment to topple onto a DOT 39 cylinder with sufficient energy to cause catastrophic failure. The frequency for such events was determined to be 1.0×10^{-7}/yr. This event is, therefore, considered to be incredible.

WHC 1994a also investigated the probability of a fire in the PFP involving two DOT 39 cylinders to determine if it was credible to have a simultaneous SRV failure result in rupture of the cylinders with subsequent deflagration of the propane gas. The frequency for an accident of this type was determined to be 4.14×10^{-7}/yr and is, therefore, considered to be incredible.

9.2.1F.2 Controls. The analysis and acceptability of risks associated with the use of flammable gases in the PFP are based on the implementation of specific controls on their purchase, storage, and use. Key elements of the control program are as follows:

1. The use of LPG cylinders is limited to those that meet the requirements of DOT Standard 39 and CGA Standard S1.1 containing not more than 465 g (16.4 oz) of LPG, and the former propane supply header in Building 234-5Z remains out of service and disconnected from a propane supply.

2. The inventory of propane cylinders within the portions of the PFP Building used for storing or containing an inventory of transuranic materials is limited to a total of six. No more than two propane cylinders may be simultaneously located within a single room. Introduction of propane cylinders into gloveboxes is prohibited.

3. There are no restrictions on simultaneous use of propane cylinders within the PFP as long as the restrictions in control No. 2, above, are followed.

4. The acetylene supply manifold from 2734-ZK to the 234-5Z Building, Room 199, is out of service and will remain so through the physical disconnection of supply bottles and by the permanent capping and, thus, physical disconnection of the manifold.

5. Measures are in place, FSP-PFP-5-8, *PFP Administration*, to prevent inadvertent introduction of flammable gas cylinders that have not been analyzed and demonstrated to be acceptable.

6. Use of other flammable gas cylinders requires evaluation in accordance with *Identification and Resolution of Unreviewed Safety Questions*, HNF-PRO-062.

The PFP program for limiting and controlling flammable gases within the plant is defined in FSP-PFP-5-8.

9.2.1G Explosion, Slag and Crucible System Deentrainer

Since plutonium metal is no longer produced at PFP, Section 9.2.1G is not required. The S&C process is no longer used at the PFP. If future use of the S&C process is required, Section 9.2.1G will be analyzed and incorporated.

9.2.2 Fire

Fire hazards at PFP have been evaluated from both a fire protection engineering and a safety analysis perspective. A fire hazards analysis (FHA) for PFP has been performed (McKinnis 1998). The objectives of the FHA were to determine: (1) the fire hazards that expose the PFP facilities, or that are inherent in facility operations, (2) the adequacy of fire safety features, and (3) the degree of compliance with specific fire safety provisions in DOE Orders, related engineering codes, and standards. Safety analyses performed for PFP have historically evaluated the probability and consequences of potential fires. The objective of these analyses was to demonstrate acceptable risk. Because of their differing objectives, FHAs and safety analyses typically employ differing analytical methods yet share many common initial conditions and assumptions.

The FHA identified a fire involving the Analytical Laboratory and spreading to adjacent office spaces as the Maximum Possible Fire Loss (MPFL) fire for the first floor of Building 234-5Z based on the replacement cost of laboratory equipment. This FSAR does not analyze a fire in these areas as the associated onsite and offsite radiological consequences were qualitatively evaluated to be bounded by the worst case glovebox process area fire based on (1) the allowed plutonium inventory, and (2) the FHA determination that the MPFL does not breach containment.

The worst case glovebox process area fire analyzed in the FHA is a fire where the maximum area of fire involvement includes the RMC-Line and RMA-Line glove boxes and several adjoining areas. This area includes the RMC-Line (Rooms 227; 228A, B, and C; and 230A, B, and C), the RMA-Line (Rooms 235A-1, 2, and 3; and 235B and C), and adjacent rooms. The fire area is bounded to the south and north by concrete walls. To the west, the fire area boundary is established by plaster on metal lath walls, which are attributed with at least a 1-hour rating by the FHA, and the absence of combustibles in Rooms 245 and 235C. Plaster on metal lath walls and the absence of combustibles in Rooms 224 and 232 limit the fire spread to the east. The fire could occur in any of

the rooms and spread to the entire fire spread area. The RMC Line was determined to represent the greatest fire risk due to the highest combustible loading and the smallest distance between the plaster ceiling and unprotected structural elements in the ceiling assembly. A fire in the glovebox process area (i.e., RMC and RMA Lines) is analyzed in Section 9.2.2A.

Some similarities exist between the RMC and RMA Lines and the glovebox/conveyor system used at the DOE Rocky Flats Plant (RFP) in Colorado. An extensive fire that occurred at the RFP in 1969 was fueled by plastic windows, gloves, trash, and by significant quantities of PMMA and Benelex shielding inside the gloveboxes. It was propagated by airflow along an extensive system of conveyer gloveboxes and drawn into processing gloveboxes by the glovebox exhaust systems. The Rocky Flats gloveboxes and rooms were not equipped with automatic fire suppression systems as are the PFP rooms and gloveboxes. In addition each glovebox at PFP has an exhaust duct. Propagation down the glovebox line via the conveyors is more difficult at PFP as the air velocity is smaller than that at Rocky Flats. However, at PFP, where gloveboxes are close to one another (less than 10 ft separation distance according to the FHA), the fire can propagate due to radiant heating from the burning glovebox. A similar situation is possible, on a much smaller scale, at the RMC Line except that internal fuel from shielding is not present and significant quantities of trash would only be present as the result of a serious breakdown of housekeeping practices.

The fire analysis concluded that fire propagation through a glovebox process line is a possibility based on the Rocky Flats glovebox fire (Patterson 1970). The fire at Rocky Flats originated in a glovebox having plastic window panels. Once the windows ignited, the fire quickly spread to the connected conveyor box. Since the conveyor was also lined with plastic windows, the fire was able to rapidly spread throughout the process line to other gloveboxes. With no fire suppression or fire separations, a fire in one of the RMC or RMA Line gloveboxes could potentially spread throughout the process lines, similar to the Rocky Flats fire, and potentially involve other globeboxes in close proximity.

The FHA also identified a hydraulic oil fire in Room 321 as the MPFL for the second floor of Building 234-5Z. In the absence of mitigation, this fire could potentially result in collapse of the building roof. Section 9.2.2B summarizes the FHA analysis and discusses mitigative design features.

In addition, the FHA identified an exterior TRU drum storage fire as resulting in the highest level of environmental contamination. Section 9.2.2.D analyzes the consequences of a fire involving a minimum of 200 TRU waste drums stored within the fenced security area outside the PFP buildings.

The potential radiological consequences of all other FHA fire scenarios (e.g., small electrical fire in Building 2736-ZB, trash fire in Building 243-Z) were qualitatively evaluated and determined to be bounded by the above identified FSAR fire analyses.

9.2.2A RMC/RMA Lines Fire

The RMC and RMA Lines were originally designed and operated to produce plutonium metal from plutonium nitrate solutions. Currently, portions of the RMC Line and RMA Line are used in support of plutonium stabilization operations. Chapter 6, Section 6.4.1, provides a description of current and former processes.

The PFP FHA identified an RMC Line fire initiated in Rooms 228A, 228B, and 228C as the worst case scenario for process area fires (McKinnis 1998). The 228A, B, C rooms house a total of 13 process gloveboxes and a conveyor glovebox. One glovebox, HC-7, is a stand alone glovebox; the remaining 12 are interconnected via the conveyor glovebox, HC-1 (Figure 9-3). The majority of the gloveboxes are inactive. Active gloveboxes include HC-7, HC-9B, HC-11, HC-13MD, HC-18M, HC-18BS, and Conveyor Glovebox HC-1. Of the active gloveboxes, HC-18M, HC-18BS, and Conveyor Glovebox HC-1 support thermal stabilization operations. Specifically, Glovebox HC-18M is used for the sampling and packaging of product plutonium oxide, Glovebox HC-18BS is used for plutonium metal and oxide storage, and Conveyor Glovebox HC-1 is used for interglovebox material transfers.

Glovebox HC-18BS in Room 228C is connected to a second conveyor glovebox, HC-2, that extends into Rooms 230A and B. Spread of the RMC Line fire through HC-2 could involve Gloveboxes HC-21A and HC-21C and spread the fire to Conveyor Glovebox HC-3, via an airlock, and into Room 230C.

Room 230C, containing the magnesium hydroxide precipitation process glovebox, is located at the West end of the RMC Line. The FHA postulates that the RMC Line fire spreads to Room 230C by consuming the plastic panels in the HC-2 and HC-3 conveyor gloveboxes. Room 227 is located at the East end of the RMC Line area. This room houses the plutonium solutions load-in/load-out glovebox, HC-227S, and hood, HC-227T. The FHA postulates that the RMC Line fire spreads to Room 227. Fire spread to Room 227 is difficult to achieve since the fire must propagate through a wall separating Rooms 228 and 227. While the fire loading in Rooms 228A, B and C is large, it is comprised almost entirely of plastic glovebox panels (per Appendix J of the FHA) which are not near Room 227. However, since the details of fire propagation for the RMC/RMA Line fire are not known and the fire can spread by means of hot gases flowing through openings between rooms, it is conservatively assumed that Glovebox HC-227S and Hood HC-227T are ignited.

The RMA Line in Rooms 235A, 235B and 235C is connected to Conveyor Gloveboxes HC-2 and HC-3 by connecting Conveyor Gloveboxes HC-4, HC-5 and HC-10.

The RMC and RMA Line gloveboxes are constructed of stainless steel frames and floors and clear polycarbonate and polymthylmethacralate (PMMA) safety sheets, or panels, on the sides and top. The walls and tops of the gloveboxes are constructed of approximately 0.5-in. thick clear plastic panels penetrated by numerous gloveports, bag-in/bag-out ports, sphincter ports, solution transfer lines, and instrument and electrical connectors. The plastic panels are of two types, PMMA and polycarbonate. The PMMA burns readily whereas polycarbonate is self-extinguishing, i.e., the polycarbonate panels will burn if flame or heat impinges on them but the fire will go out if the heat is

removed. Approximately 52% (by area) of those RMC Line panels connected by conveyors are constructed of polycarbonate and the rest of PMMA. This same value (52%) is assumed for the RMA Line even though the majority of the panels are likely PMMA. This is conservative since polycarbonate has higher ash loading for evaluation of filter clogging. The plastic panels comprise the majority of the fuel loading in the glovebox process area.

The maximum area of fire involvement is shown in Figure 6-15 of the FHA. This area includes the RMC-Line (Rooms 227; 228A, B, and C; and 230A, B, and C), the RMA-Line (Rooms 235A-1, 2, and 3; and 235B), and adjacent rooms. For the current revision to the FHA, the rooms and areas comprising the glovebox process area fire were walked down and an inventory of combustible material was recorded. The heat potential for various materials was determined by multiplying the quantity of material by its heat of combustion. The combustible loadings for the rooms in the RMC and RMA Lines are approximately 8,000 lb of wood (fuel equivalent; total for both RMC and RMA Lines) (Table 2 of Appendix J of the FHA). The analysis in subsequent sections quantifies the probability and consequences of a fire limited in area to these rooms.

9.2.2A.1 Scenario. Fire initiation is assumed to occur as a result of maintenance or retrofitting activities which have a higher likelihood of resulting in a fire than equipment or processing failures. Such activities are often conducted by personnel who are less familiar with the facility and operations than are the process operators. To reduce the likelihood of accidents, PFP process operators are assigned to work closely with maintenance personnel to keep them from getting hurt or causing harm.

Maintenance and retrofitting activities typically result in the generation of rags, paper, plastic, rubber, and other combustible materials that are not normally present in significant quantities during routine operations. It is assumed that maintenance and operations personnel fail to prevent such materials from accumulating within the gloveboxes and rooms.

Maintenance and retrofitting activities also typically introduce ignition sources (e.g., welding equipment, power tools) that are not normally present. It is assumed that such a source ignites accumulated combustible materials without being noticed by personnel present or, if noticed, that appropriate corrective actions are taken. After personnel exit the area, the fire is assumed to grow sufficiently large to burn or melt a substantial hole in a glovebox glove. The associated inrush of air fans the fire resulting in further growth and ignition of the glovebox windows.

Section 9.2.10.4 discusses the fire scenario based on failures during operation of the muffle furnaces in Gloveboxes HC-21C or HA-21I. The result of the initiation of a fire either due to maintenance or retrofitting or due to failures during processing are similar and are described below.

Following the RFP fire, the PFP installed a wet-pipe sprinkler system in the RMC Line rooms, and, in 1986, a Halon fire suppression system was installed inside the gloveboxes. When glovebox panels must be replaced, self-extinguishing polycarbonate is used instead of the original PMMA. Although these fire protection features exist at the PFP, for this analysis these features are not relied upon to prevent or mitigate the fire.

The burning plastic windows and panels would generate copious amounts of heat and plutonium-laden smoke that would be exhausted via a combination of the E-4 and E-3 exhaust systems. Appendix J to the PFP FHA revised the HEPA clogging analysis of the original FHA. Because the majority of the heat and smoke generated by even a glovebox fire would be expected to be released into the rooms, which are served by E-3 exhaust system, the E-4 exhaust system was not considered in the filter plugging analysis for conservatism. Clogging criteria in Appendix J uses the Ballinger correlation, which is based on data from large-scale experiments and establishes a relationship between the differential pressure across the filter and the amount of soot on the filter. Appendix J also uses revised combustible loading values and soot yield values rather than heat potential values for determining filter clogging. This is because the ratio of soot yield (gram of soot from material as it burns to gram of soot from burning wood) exceeds the ratio of heat yield. Appendix J also assumes that only 4 of the 7 E-3 filter banks are on-line. This is the normal operating configuration of the E-3 system. The revised analysis of filter plugging include both conservatisms and non-conservatisms. Conservative assumptions include 1) all combustibles are involved in the fire, 2) all soot depletion mechanisms are ignored, 3) the E-4 filters are not included in the analysis, 4) the E-3 filters have an initial differential pressure of 2-in. w.g.; normal operating pressure is about 0.5-in. w.g., and 5) 52% of the panels in the RMA Line gloveboxes are assumed to be polycarbonate, which is about 3.5 times more sooty than PMMA, even though it is considered very likely that most panels are PMMA. Non-conservative assumptions include 1) where a range of soot yield values were available, the smaller values were used, and 2) the soot yield values are derived from cleaner burning (producing less soot) well-ventilated fires that cannot be assumed for the glovebox area fire. It is judged that the non-conservatisms do not override the conservatisms.

Applying the soot yield values and the revised combustible loading, a total fuel loading of approximately 49,500 pounds of wood (soot equivalent) equivalent was calculated. Using the Ballinger correlation, a value of 50,775 pounds of wood equivalent is required to plug the on-line E-3 filters. Based on the revised analysis, it is concluded that the filters would not fail as a result of clogging due to soot from the fire.

The effect of hot gases on the E-4 system filters was also considered. A significant amount of heat would be lost as the air flowed through the E-4 system ductwork (Figures 9-24 and 9-26). Additionally, the hot gases would be significantly diluted by ambient temperature air from non-process line enclosures. The total flow through an in-service E-4 system filter room is approximately 35,000 ft^3/min. Airflow through the RMC Line gloveboxes is at a volumetric flow rate of 340 ft^3/min which is less than 1% of the total. Accordingly, it is concluded that the E-4 system filters would not be affected by hot gases.

As is the case for the E-4 exhaust system, hot gases in the E-3 exhaust system would be effectively diluted by ambient temperature air from other areas exhausted by the E-3 system. The typical air flow through Rooms 228A, B, and C is 3,500 ft^3/min, which is less than 2% of the total E-3 flow of 190,000 ft^3/min.

For this scenario, the percentage of air exhausted via the E-3 versus the E-4 system is not relevant to the analysis since both flowpaths result in a filtered release through the stack because the filters in the filter rooms do not plug sufficiently to fail.

The area comprised of Room 228A, B, and C contains the largest quantity of combustible material. The total combustible loading (from Appendix J) is approximately 36,400,000 Btu (38,400,000 kJ) which exceeds the 38,000,000 kJ value analyzed in the original FHA prior to the current revision. Calculations in Appendix J of the current FHA revision result in an additional 17 seconds of fire duration for column exposure and an additional 8 seconds of duration for joist exposure.

Extrapolation of the additional burn time on Figures 6-8 and 6-14 of the FHA results in temperatures that still remained below the failure criteria for columns (649 °C single point and 537 °C average) and joists (704 °C single point and 593 °C average). No structural failure is expected from the additional combustibles identified in Rooms 228A, B, and C.

Fuel loading (lb of fuel per ft^2 of floor area) is the parameter used for comparison of the areas of other rooms to the area of Rooms 228A, B, and C. In Appendix J of the FHA, a fuel loading of approximately 2.67 lb/ft^2 is calculated. The fuel loading in Rooms 227 and 234 exceeds the value in the original FHA but is less than the fuel loading in Rooms 228A, B and C. The combustible loading density in Rooms 245, 235C, 232, and 224 that are at the east and west boundaries of the fire area remain low.

As discussed above, the combustible loading in Rooms 228A, B, and C did not result in structural failure. The increased fuel loading in Rooms 227 and 234 was determined to not result in structural failure since the loading is less than Rooms 228A, B and C which would not experience structural failure.

The analysis of the probability and effects of a fire in the RMC Line, RMA Line and adjacent areas is presented in the subsequent sections. The analysis follows the approach used in the FHA which is based on the following:

- The E-3 and E-4 Exhaust System filters do not plug or fail as a result of the fire
- The fire would not result in a direct release out of the building
- The fire burns to completion without intervention by the Hanford Fire Department
- No fire suppression is credited for the room sprinklers or glovebox Halon systems
- The fire encompasses the RMC Line, RMA Line and adjacent rooms.

9.2.2A.2 Probability. The annual probability of the postulated RMC/RMA Lines fire without regard for the fire protection features is 1.0×10^{-2} which is in the anticipated category. It is noted that the analyzed fire is not mitigated by any fire protection features but is mitigated by the building structure and

by filtration from the exhaust systems. However, Administrative Control 5.20 (BWHC 1999a) requires:

- maintenance and testing of the fire systems
- minimization of combustibles
- administrative control (e.g., fire watch) when the fire protection systems are impaired.

Considering these controls, the annual probability of the analyzed fire is in the range of 10^{-4} to 10^{-6}.

9.2.2A.3 Accident Analysis. The plutonium inventories evaluated are based on the CPS limits provided in Table 9-25. To estimate the inventory involved in the fire, it is assumed that the active gloveboxes are loaded with plutonium to their CPS limit. The inventory within the gloveboxes that comprise the Magnesium Hydroxide Precipitation Process and the Bagless Transfer System (BTS) are not included in Table 9-25 nor are they included in the list below. The inventory is described in Carson (2000) and FH (2000), respectively. The effect of the fire on these gloveboxes is described in separate paragraphs below.

The following is a listing of the inventories used in this analysis along with other relevant information.

Room	Glovebox/Hood	CPS Limit	Material Type
227	HC-227S	20,000 g Pu	(solution)
227	HC-227T	4,500 g Pu	(solution)
228A	HC-7	3,000 g Pu	(oxide powder)
228A	HC-9B	32,700 g Pu	(oxide powder)
228A	HC-11	30,000 g Pu	(oxide powder)
228B	HC-13MD	2,500 g Pu	(oxide powder)
228C	HC-18BS	50,000 g Pu	(metal)
228C	HC-18M	10,000 g Pu	(oxide powder)
230A	HC-21C	5,000 g Pu	(oxide powder)
230B	HC-21A	7,100 g Pu	(oxide powder)
235A-1, A-2, A-3, "A" Button Line	All	8,000 g Pu-holdup	(oxide powder)
235B	HA-19	2,500 g Pu	(polystyrene cubes)
235B	HA-20MB	10,000 g Pu	(oxide powder)
235B	HA-21I	8,000 g Pu	(oxide powder)
235B	HA-23S	44,000 g Pu	(oxide powder)
235B	HA-22B	2,500 g Pu	(oxide powder)
235C	235-B-2	2,500 g Pu	(oxide powder)

Totals: (not including Magnesium Hydroxide Precipitation Process or BTS)

Total Solution	24,500 g Pu
Total Oxide Powder	165,300 g Pu
Total Metal	50,000 g Pu
Total Polystyrene	2,500 g Pu

Table 9-25 does not provide the material types. These are shown in the above list. Glovebox HC-227S and Hood HC-227T are the plutonium nitrate solution load-in and load-out facilities. Therefore, all the inventory is assumed to exist in solution form. This is conservative since the respirable release fraction, as shown later, from boiling solutions as a result of the fire is much higher than from plutonium powders and plutonium metal is not processed in this glovebox. It is noted that Table 9-26 limits the inventory in Glovebox HC-227S and Hood HC-227T to 5,000 g. However, for purposes of this fire analysis, the higher CPS limits shown in Table 9-25 are used for conservatism. Glovebox HC-18BS is the plutonium button storage glovebox. However, other materials, such as plutonium oxide, may also be stored in the glovebox. It is conservatively assumed that all the material in Glovebox HC-18BS is plutonium metal since burning metal has a higher respirable release fraction than most other materials. Solutions are not processed through this glovebox. However, damp precipitate from the Magnesium Hydroxide Precipitation Process can be transferred through this glovebox. The remainder of the gloveboxes, except Glovebox HA-19 which has polystyrene cubes, are considered to contain plutonium oxide powder. These other gloveboxes may also contain metal and other plutonium compounds but the predominant material being processed is oxide. In addition, assuming Glovebox HC-18BS contains only plutonium metal, even though it also contains plutonium oxide powder and damp precipitate, is judged to account for metal that may be periodically located in the other gloveboxes. Therefore, no attempt was made to vary the inventory in the other gloveboxes between metal and oxide forms. The inventory shown for the gloveboxes in the "A" button line in Rooms 235A-1, A-2 and A-3 does not come from Table 9-25. The button line is inactive and the majority of the gloveboxes were cleaned out many years ago. The inventory shown is based on estimates of residual plutonium, primarily oxide, remaining in the gloveboxes which were obtained from discussions with various PFP personnel.

The CPS limits for the inactive gloveboxes are not included since the inactive designation stipulates that only residual quantities of plutonium are allowed and that no plutonium containers may be introduced. As an example of "residual quantities," glovebox HC-10 has a CPS limit of 2,500 g Pu whereas the best estimate of the inventory is 31 g Pu based on NDA data. Therefore, the inactive gloveboxes are judged not to significantly contribute to the inventory at risk relative to the active gloveboxes. In addition, the potential contribution from filterboxes 14, 20, 21, and 22, which are upstream of the E-4 system filter rooms and are assumed to fail due to fire loading, are similarly judged to be insignificant relative to the active gloveboxes.

Two new processes have been started up, recently. They are the Magnesium Hydroxide Process and the Bagless Transfer System. They are also affected by the RMC/RMA Line fire. The inventory from these process gloveboxes is presented below.

The Magnesium Hydroxide Process is performed in Gloveboxes HC-230C-3 and HC-230C-4 in Room 230-C. Glovebox HC-230C-3 contains plutonium nitrate solutions in precipitation tanks, and precipitate containing plutonium hydroxide, water, magnesium nitrate and magnesium hydroxide in varying states of dryness. Glovebox HC-230C-4 contains solution similar in composition to that in the precipitation tanks but with very much less plutonium.

The total quantity of plutonium in glovebox HC-230C-3 is:

- 11,500 g plutonium hydroxide of varying dryness
- 2,500 g plutonium nitrate solution

The total quantity of plutonium in Glovebox HC-230C-4 is very much smaller than that in Glovebox HC-230C-3 as the solution is filtrate from the process. Therefore, the releases in the fire are also very much less.

The Bagless Transfer System (BTS) is located in Room 235B. The BTS occupies a new glovebox at the end of conveyor HA-28. The BTS contains plutonium oxide that has been stabilized or plutonium metal, both of which are placed in bagless transfer convenience cans. The inventory is 5,000 g as oxide or 4,400 g as metal.

Based on the above discussion, the estimated inventory at risk in the form of powder, excluding the Magnesium Hydroxide Process and BTS is 165,300 g Pu. This inventory is assumed to be present as plutonium oxide.

In addition, it can be seen from the above table, that there is the potential for a total of 50,000 g plutonium in metallic form (Glovebox HC-18BS), and 24,500 g plutonium in nitric acid solution (Glovebox HC-227S and Hood HC-227T). In addition, 2,500 g of Pu are contained in polystyrene cubes (Glovebox HA-19).

For a given inventory, the amount of plutonium aerosolized by a fire is dependent upon many variables such as the chemical and physical form of the plutonium, the matrix in which it is held, and the direction and velocity of entraining gases. The calculation to follow uses the inventory from the list of gloveboxes, at the start of this section. The release from the Magnesium Hydroxide process gloveboxes and BTS are shown later.

Considering the plutonium oxide powder, recommended airborne release fractions (ARF) and respirable fractions (RF) for various materials are documented in the DOE handbook for airborne release of materials (DOE 1994). For non-reactive solid compounds, such as plutonium dioxide, the handbook recommends an ARF of 6×10^{-3} and an RF of 1×10^{-2}. Application of the recommended ARF and RF values is judged appropriate in that the sampling period (one hour) for the tests upon which the value is based is of the same order as the estimated duration of the postulated fire.

The recommended values are based on tests in which small quantities of plutonium powders are placed in a depression in a stainless steel planchet that is about 7 cm in diameter. Air was drawn up along the sides of the planchet and into a chimney. Combinations of airflow rates of 0.1 m/s and 1.17 m/s and air temperature of ambient and 800 °C to 900 °C were used. The

respirable airborne fraction varied from 2.5×10^{-6} to 5.6×10^{-5} for plutonium oxide at an air velocity of 1.17 m/s. The DOE Handbook recommended value was based on ambient temperatures. It will next be shown that a more realistic value is smaller.

Section 4.4.4.1 of the DOE Handbook (DOE 1994) discusses the results of air entrainment of powders from a variety of surfaces under ambient conditions. The recommended value for respirable particulate entrainment rate is 4×10^{-5}/hr. Using an assumed duration of 1 hr, this value is very close to the respirable airborne fraction for the resuspension of heated plutonium oxide by ambient air. Section 4.4.4.1 also states that the respirable release is an order of magnitude less for conditions where the powder bed is shielded by structural debris. This implies that respirable release of heated plutonium oxide that is shielded will also be less.

In all cases considered (except for Gloveboxes HC-11, HC-21A, HC-21C, HA-23S, RMA Button Line holdup and HA-21I), the oxide powder is assumed to be enclosed either within a piece of equipment or within a can. The action of the fire may cause the can to fail, but the failed can will still provide some shielding. In many cases, the powder is located near the panel that is burning. The air over the oxide is therefore hot. The respirable release of heated oxide by air at 800 to 900 °C is 5% of that assuming air at ambient conditions. As a result the respirable release fraction for oxide initially contained in cans involved in the RMC/RMA Line fire should be one-tenth that recommended by the handbook. The handbook value is based on ambient air flow over unprotected heated powder. With the exception of oxide in furnace boats or powder pans, a reduction factor of 0.1 is taken. This is because the air is likely heated at the location of the powder or the powder is shielded by the can or both occur.

A fire could result in the pressurization of the cans with some release if they fail. The recommended values of the respirable release fraction are somewhat greater than those used here. However, those values are based on quantities of oxide that are much smaller and whose respirable fraction is very much larger. Applying reduction factors to make the test results more applicable to the conditions in PFP cans results in a similar respirable release factor as used here.

From the glovebox plutonium loadings given in Section 9.2.2A.3, the total plutonium in powder pans, furnace boats or otherwise unprotected (found in gloveboxes HC-11, HC-21A, RMA Button Line holdup, HC-21C, and HA-21I) is 58,100 g. Plutonium enclosed in equipment or within a can is the remainder of the 165,300 g total, or 107,200 g Pu. Of the 107,200 g, 44,000 g are stored in Glovebox HA-23S. This oxide is stored in polyjars which are similar to the polycubes. The release from Glovebox HA-23S is discussed later.

Applying these values, the quantity of respirable plutonium made airborne by the RMC/RMA Line fire is:

$$58{,}100 \text{ g} \times 0.006 \times 0.01 = 3.5 \text{ g}$$
$$63{,}200 \text{ g} \times 0.006 \times 0.01 \times 0.1 = 0.4 \text{ g}$$

$$\text{Total} = 3.9 \text{ g}$$

With respect to the plutonium metal, the recommended ARF and RF for thermal stress of solid reactive plutonium are documented in an NRC accident analysis handbook (NRC 1998). For thermal stress of undisturbed, reactive, plutonium metal, at or above ignition temperature, the NRC handbook recommends an ARF of 5×10^{-4} and an RF of 0.5.

The recommended value came from a set of experiments in which large specimens of plutonium metal were ignited. The airborne release fraction (ARF) ranged from 4×10^{-6} to 5×10^{-4} with most of the data being greater than 3×10^{-5}. In the experiment, the specimen was placed in a ring and set upon insulating material. The Handbook stated that if the specimen of plutonium metal rested on a heat conducting surface, it would not sustain ignition due to heat transfer to the conducting surface. In the experiment, the metal could only be ignited by direct contact of the flame from a heliarc torch for 60 s.

In the condition that exists in Glovebox HC-18BS, the plutonium metal is packaged within a can. It is not bare metal. The glovebox is 8 ft. long and almost 7 ft. wide. The can is placed on a metal storage location, which is on a metal conveyor belt that snakes through the glovebox. The belt essentially results in storage along 4 rows within the glovebox. Two of the rows are close (about 8 in.) to the exterior walls of the glovebox. However the other two rows are each about 2 ft. from the exterior walls.

The storage condition given a fire scenario differs from the experiment in that:

- The plutonium metal is stored on a conducting surface, not on an insulating surface, however due to the fire, this surface is hot. This minimizes heat conduction and makes the situation closer to that of the experiment.
- The metal is in a can. The oxide formed by ignition is at least partially shielded from the airflow from the flame
- Half of the metal is far from the flame

As a result, the ARF will be reduced by a factor of 10 consisting of a factor of 5 for partial shielding and a factor of 2 for the half of the cans that are far from the fire. This yields a value of ARF times RF of 2.5×10^{-5}. As a check, it is noted that the DOE Handbook shows that other data for self oxidation of bare plutonium metal has a mean of 7×10^{-6} and a 95th percentile value of 10^{-4}. The value of 2.5×10^{-5} is in between these two values. As a result, the reduction of the recommended valued by a factor of 10 due to protection, and distance from the fire is justified.

Applying these values, the quantity of respirable plutonium made airborne due to the RMC/RMA Line fire is:

$$50{,}000 \text{ g} \times 2.5 \times 10^{-5} = 1.3 \text{ g}.$$

The bounding ARF and RF applicable to the plutonium in the polystyrene cubes are provided in the DOE handbook for airborne release of materials (DOE 1994) as 1×10^{-2} and 1.0, respectively.

The ARF for polystyrene comes from experiments in which small, angular beads of polystyrene were coated with a solution of uranium nitrate hexahydrate (UNH). The report on the experiments with burning contaminated materials (Halverson, et. al. 1987) discussed the polystyrene experiments and stated that the uranium release from burning contaminated polystyrene occurred prior to ignition of the polystyrene. The report concluded that the uranium release was due to evaporation of the UNH solution. The release ceased after the polystyrene ignited and turned into a thick, viscous mass. The report concluded that the uranium which remained sunk down into and became entrapped in the mass of molten polystyrene. This implies that the plutonium encased in the polystyrene cubes in the case being analyzed here will not escape the polystyrene cube to any significant degree. The data in the report also shows that the ARF of 2×10^{-3} for the large quantities tested (35 g) was less than the ARF of 8×10^{-3} found for the small quantity tested (6 g). Since the polystyrene cubes are much larger than the beads used in the experiment, the ARF for the largest quantity of beads (2×10^{-3}) is initially used. In addition, since the plutonium is in a non-volatile oxide form within the polystyrene, not as volatile solution on the outside, the ARF is reduced by a factor of 5 to 4×10^{-4} based on the observation described for the experiment discussed above. While the factor of 5 is somewhat arbitrary, it is noted that the value of 4×10^{-4} is slightly larger than that for a release of uranium from a pool of kerosene - TBP burning to extinguishment as discussed in the DOE handbook (DOE 1994). The uranium in kerosene and TBP is an example where the radioactive material is within the organic material.

Applying these values to the quantity of plutonium in the cubes results in the following airborne release:

$$2{,}500 \text{ g} \times 4 \times 10^{-4} = 1.0 \text{ g}$$

Glovebox HA-23S is a large, tall glovebox containing 4 levels. The conveyor is shaped like a race track. The straight sections are 123 in. long. The glovebox is 48 in. wide. The radius of the curved section of the conveyor is 16 in. Each of the 4 conveyors are 346 in. long. On each conveyor are 11 pallets. The pallets are 13.5 in. in diameter and contain "T" shaped spacers so that up to 8 polyjars can be loaded on each pallet. The edges of the "T" are 2.5 in. tall. There is a metal plate that partially covers the top of the polyjars. The plate is bolted to the pallet. As a result, the polyjars are about half shielded from the top and three-quarters shielded on the sides from the direct flame. The pallets are located about 7 in. below the bottom of the plastic panels. The gloves are not in the gloveports under normal operation.

If a fire spreads through the glovebox, radiant heat from the plastic panels could impact the top of the polyjars and possibly the side near the windows. If the heat is great enough to ignite or melt the polyjars, some of the release will be captured within the structure of the pallet. At least two of the polyjars are near the center of the glovebox far from the fire.

The material within the polyjars could have organic associated with it as the polyjars can be used for sludges. The ARF most appropriate for this condition is that developed for the polycubes. The ARF developed was 4×10^{-4}. This value will be decreased to 10^{-4} to account for capture of the aerosol within the pallet structure and other melting or burning polyjars and the fact that some of the polyjars are far from the fire.

Using this value the release from Glovebox HA-23S is:

$$44{,}000 \text{ kg} \times 10^{-4} = 4.4 \text{ g}$$

The total quantity of plutonium released by the fire from the inventory of plutonium oxide powder, plutonium metal, plutonium in polystyrene cubes and the polyjars in Glovebox HA-23S is:

$$3.9 \text{ g} + 1.3 \text{ g} + 1.0 \text{ g} + 4.4 \text{ g} = 10.6 \text{ g}$$

This material is designated as Class Y lung clearance, as defined in Tables 9-46 and 9-47, and is assumed to contain >10% ^{240}Pu. The ^{240}Pu content assumption is conservative since it has the highest unit dose value.

With respect to the plutonium nitrate solutions in Glovebox HC-227S and Hood HC-227T, it is assumed that the solution in the tanks and containers in the glovebox and hood will boil as a result of the fire and be released to the building. The glass tanks containing solution in Glovebox HC-227S could fail and the solution could fall to the glovebox or room floor but it is still assumed to boil after the fall. The ARF resulting from such a fall of liquid is approximately 10^{-6} whereas the release fraction from boiling is about 10^{-3}. Therefore, the release of material from breakage of tanks and solution spilling is neglected.

The DOE airborne release handbook (DOE 1994) provides a bounding ARF of 2×10^{-3} for boiling of aqueous solutions with an RF of 1.0. The DOE handbook characterizes the value of 2×10^{-3} as very conservative and that a value of 1×10^{-3} also bounds the data. The data for the ARF for conditions in which boiling occurs ranges from an estimate of 2×10^{-3} to a measured value of 3×10^{-4}. Other similar data show even lower values.

The data from boiling solutions comes from experiments in which 100 ml of plutonium nitrate solution in a 180 ml beaker was heated by a hot plate. The beaker had a fully open top. Air was drawn up along the side of the beaker, over the top and then up a chimney. The solution was boiled for 60 min. The ARF ranged from 3×10^{-4} to 2×10^{-3}. The ARF for similar conditions but for conditions between simmering and boiling resulted in ARF values about a factor of 5 less.

For the conditions present in Glovebox HC-227S, the solution is held in long thin glass tanks, each 6 in. in diameter. The top of the tanks is capped; out of the top of the tank are three ½-in. stainless steel tubes. Out

of the bottom is a ¾-in. line. The glovebox is 2 ft 2 in. wide. The surface of the tanks is 10 in. from the glovebox.

A fire could heat the solution to boiling. That may be difficult due to the large surface area available for heat transfer to the air in the glovebox, and to the large mass of solution (tens of liters) typically in the tanks when in use. If the solution does boil and the fire is large, the tanks could fail. The solution would fall to the bottom of the glovebox where the temperatures are much less. Under these conditions boiling is much more difficult. The glovebox is large (about 12 ft wide and 2 ft deep). A 2 in. deep pool can hold over 100 L. The bottom of the glovebox is 1 ft above the floor. The nearest plastic panel is about 1.5 ft above the pool. The other panels are a greater distance above the pool. Once lit, the panels will need to burn for a very long period of time to boil away many liters of plutonium nitrate solution.

Because of the spread in the values of ARF discussed in the DOE Handbook, the effect of plateout of the aerosol, and the difficulty in boiling all of the solution. The ARF times RF is reduced a factor of 4 to consider a more realistic (but still judged to be conservative) value for ARF and the likely case that all of the solution will not boil. Using this factor yields a respirable release factor of 5×10^{-4} which is still above the measured experimental value of 3×10^{-4} and one-half of the bounding value of 10^{-3}.

Therefore, the respirable release from the boiling plutonium nitrate solution is:

$$24{,}500 \text{ g} \times 5 \times 10^{-4} = 12.3 \text{ g}$$

This material is designated as Class W lung clearance, as defined in Tables 9-46 and 9-47, and is assumed to contain >10% ^{240}Pu. This is conservative since >10% ^{240}Pu has the highest unit dose value.

The Magnesium Hydroxide Precipitation Process addendum to this FSAR (Carson 2000) provides the consequences of accidents involving that process. Section 3.4.2.2 of the addendum provides the analysis of the glovebox fire. The respirable release is given as 5.698 g. The major contributors to the release is the 5 g respirable release due to solutions boiling and entrainment of plutonium powder due to hot air. The ARF and RF for both accidents come from the recommended values from the DOE Handbook (DOE 1994). The solution boiling scenario is very similar to that discussed above. Release of 5 g of solution would be reduced by a factor of 4 as discussed above. However, an additional consideration here is that the fire is small because of the lack of combustibles inside of the glovebox and the case of wire glass panels. The ARF times RF for a "disturbed surface" (non-vigorous boiling) is 2×10^{-4} to 6×10^{-5}. This value is more appropriate as there is likely not enough heat to rapidly boil all of the solution. The respirable release fraction is, therefore, decreased by a factor of 10 to 2×10^{-4}. The respirable release quantity is:

5 g (Pu in solution released) x 0.10 (release factor reduction) = 0.5 g Pu in solution

The release of 0.698 g of powder due to heating exposed oxide is not adjusted as the oxide is in a furnace boat. As a result, the total respirable release from the fire in the Magnesium Hydroxide Precipitation Process is:

- 0.5 g Pu in solution
- 0.7 g Pu oxide

The calculation notes for the Bagless Transfer System (BTS) (FH 2000) provide the accident analysis associated with that process. Section 4.2 of the calculation notes discuss the BTS fire scenario. The respirable release is determined to be 1.14 g. The major contributors were the burning of plutonium metal (1.1 g) and entrainment of plutonium powder (0.036 g). Again, the ARF and RF used were the recommended values from the DOE handbook (DOE 1994). However, conditions for the respirable release of plutonium metal were the same as that discussed previously in this section. Therefore, the reduction of a factor of 5 is applicable as well. The release from hot powders is not reduced, as the quantity of powder is small. The resultant respirable release is:

1.1 g (1/5) + 0.036 g = 0.26 g of oxide

The addition of the respirable release from the Magnesium Hydroxide Process and BTS increases the respirable release of oxide from 10.6 g found previously to 11.6 g, and increases the respirable release of solution from 12.3 g to 12.8 g.

As stated in the scenario, hot gases and smoke generated by the fire would be exhausted via a combination of the E-3 and E-4 exhaust systems, both of which would provide at least one stage of HEPA filtration. The E-3 and E-4 filters are tested to verify a minimum removal efficiency of 99.95% which equates to 0.05% of material passing through the filters. Therefore, the quantity of respirable plutonium discharged from the 291-Z-1 stack is:

$11.6\ g \times 5 \times 10^{-4} = 5.8 \times 10^{-3}$ g of >10% ^{240}Pu, lung clearance Class Y

$12.8\ g \times 5 \times 10^{-4} = 6.4 \times 10^{-3}$ g of >10% ^{240}Pu, lung clearance Class W

The doses due to the release of the above quantities of plutonium are calculated as follows:

$$D(rem) = Q(g) \times X/Q'(s/m^3) \times R(m^3/s) \times C(rem/g)$$

where:

D = Dose, rem
Q = Quantity of plutonium released
X/Q' = Atmospheric dispersion coefficient for elevated release, 1.62×10^{-5} s/m^3 for onsite receptor and 5.73×10^{-6} s/m^3 for offsite receptor from Tables 9-39 and 9-40, respectively.
R = Breathing rate, 3.3×10^{-4} m^3/s from Table 9-48.
C = Dose conversion factor for plutonium, Class Y or W, >10% ^{240}Pu, from Tables 9-46 and 9-47.

Applying the atmospheric dispersion factors for an elevated release, the 90th percentile dose conversion factors for class Y material greater than 10% ^{240}Pu and class W material greater than 10% ^{240}Pu, and the breathing rate for an acute release, the onsite and offsite EDE and organ doses (bone) are calculated as follows:

>10% ^{240}Pu, Class Y

Onsite EDE:

$$(5.8 \times 10^{-3}\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^{8}\ rem/g)$$

$$= 5.3 \times 10^{-3}\ rem$$

Onsite Organ:

$$(5.8 \times 10^{-3}\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.7 \times 10^{9}\ rem/g)$$

$$= 8.4 \times 10^{-2}\ rem$$

Offsite EDE:

$$(5.8 \times 10^{-3}\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^{8}\ rem/g)$$

$$= 1.9 \times 10^{-3}\ rem$$

Offsite Organ:

$$(5.8 \times 10^{-3}\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.7 \times 10^{9}\ rem/g)$$

$$= 3.0 \times 10^{-2}\ rem$$

>10% ^{240}Pu, Class W

Onsite EDE:

$$(6.4 \times 10^{-3}\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.0 \times 10^{8}\ rem/g)$$
$$= 6.8 \times 10^{-3}\ rem$$

Onsite Organ:

$$(6.4 \times 10^{-3}\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.6 \times 10^{9}\ rem/g)$$
$$= 1.2 \times 10^{-1}\ rem$$

Offsite EDE:

$$(6.4 \times 10^{-3}\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.0 \times 10^{8}\ rem/g)$$
$$= 2.4 \times 10^{-3}\ rem$$

Offsite Organ:

$$(6.4 \times 10^{-3}\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.6 \times 10^{9}\ rem/g)$$
$$= 4.4 \times 10^{-2}\ rem$$

The total onsite and offsite radiological consequences are:

Onsite EDE = $0.01.2 \times 10^{-2}$ rem

Onsite Bone Surface = 2.0×10^{-1} rem

Offsite EDE= 4.3×10^{-3} rem

Offsite Bone Surface = $0.7.4 \times 10^{-2}$ rem

9.2.2A.4 Conclusion. A fire in the RMC/RMA Lines and adjacent areas is considered an anticipated event with an annual probability of 1.0×10^{-2}. However, due to the presence of several defense in depth features (e.g., automatic fire suppression systems, Halon and wet pipe sprinklers, glovebox airlocks, fire watches, and HFD), the potential for the fire to spread to the entire analyzed region is considered to have an annual probability in the range of 10^{-4} - 10^{-6}. Because the HEPA filters in the E-3 and E-4 filter rooms are not clogged or damaged by the fire and, therefore, provide filtration of any release, the calculated onsite and offsite consequences are below the Radiological Risk Acceptance Guidelines (Table 9-49) for essentially all probability categories. The doses for the RMC/RMA Lines fire are summarized in Table 9-1.

9.2.2B Hydraulic Oil Fire in Room 321.

Previous PFP SARs have analyzed a fire on the second floor of Building 234-5Z. Following upgrades to the building roof, it was concluded that a fire that started on the second floor and spread to the E-4 filter rooms via the roof was incredible (i.e., annual probability < 1 x 10^{-6}) based on the Class 1 roof construction, general construction of the building, low fire loading on the second floor, wet pipe sprinkler system, and HFD response.

The PFP FHA (McKinnis 1998) identified a hydraulic oil fire in Room 321 as the MPFL for the second floor of Building 234-5Z. In an unmitigated scenario, such a fire could potentially collapse the building roof assembly and spread to the E-4 filter rooms. The FHA recommended that a diked area be provided around the hydraulic elevator pump in accordance with NFPA 30, *Flammable and Combustible Liquids Control*. This facility modification has been completed. The following sections summarize the unmitigated analysis presented in the FHA and the mitigation provided by the diked area.

9.2.2B.1 Scenario. The FHA assumed that a breach occurs in the hydraulic elevator pump, piping, or reservoir located in Room 321 resulting in a spill of hydraulic oil. The oil is used in the elevator hydraulic lift, and the amount that can potentially spill into Room 321 depends on the location of the elevator. As a worst case scenario, all 150 gallons available is assumed to spill.

The FHA assumes that the oil is ignited. The size of the resulting fire would depend on the rate at which the fuel was spilled and the area in which the oil spreads out over the floor. Calculations presented in the FHA show that larger areas of oil yield more intense fires.

Most of the structural members on the second floor are exposed steel columns and beams. Typically, steel will begin to lose its structural integrity at temperatures of about 600°C. ASTM E-119, *Standard Methods for Fire Tests of Building Construction and Materials*, which is used to determine fire-resistive properties of materials and assemblies, specifies that no single point on the steel column can exceed 649°C and the average temperature cannot exceed 537°C during the fire exposure. For direct fire exposures, the FHA calculations show that the steel column temperatures would exceed both the ASTM E-119 single point and average temperature criteria within 2 to 5 minutes.

The number of unprotected members that would be directly exposed to the pool fire depends on the size of the pool. In the FHA, as a conservative estimate, it is assumed that exposed columns can withstand no more than a two minute hydrocarbon pool fire exposure. The maximum number of columns which can fail is determined by the largest size fire which will consume all 150 gallons of fuel in 2 minutes. This corresponds to a 970 ft^2 spill configuration having an equivalent diameter of 35 ft. While a number of spill configurations are possible, a circular spill centered at column Ba-15 will expose and fail columns A-14, A-15, -16, Ba-14, Ba-16, and C-16.

Multiple column failures resulting from direct flame exposure can potentially result in collapse of the Building 234-5Z roof assembly. This can have several impacts on the facility. For one, collapse of the roof can

provide an opening to the exterior. If areas of contamination are involved in the fire, this provides a means for releasing contamination to the outside. Second, failure of the columns and ceiling assembly can potentially cause the walls separating adjacent areas, including the backside of the facility, to collapse.

The FHA postulates that the fire spreads to the E-4 filters rooms but states fire spread to this area is unlikely due to the limited amounts of combustible materials present.

9.2.2B.2 Mitigation. The principal means of mitigation is the containment berm that has been constructed in accordance with the FHA recommendation. This berm consists of a 6 inch high concrete curb placed inside the wire mesh fencing that surrounds the hydraulic elevator components. The elevator components are mounted on or near a wall, such that the concrete berm comprises three sides of the containment, with the wall serving as the fourth. The berm is 13 ft long across the front and extends 7 ft back to the wall, and can hold a volume of 340 gallons. The berm limits the spread of the fire thereby limiting the number of steel columns exposed.

The hydraulic oil system is pressurized. It is likely that a system failure (e.g., pipe failure) would result in a spray of oil. Conceivably, such a spray could result in an accumulation of hydraulic oil outside the berm. To prevent oil from spraying outside the berm, guards have been placed around exposed, pressurized components. Should a spray occur, the oil would impact the guard and collect within the berm.

A combustible liquid oil fire presents a special problem in that water flowing from the sprinklers may carry the floating, burning liquid from the source to other areas. Although the sprinklers are not expected to extinguish the fire, sprinklers in adjacent areas would prevent fire spread. In addition, while the pool fire can spread out and continue to burn after sprinkler activation, the cooling effect of the water is expected to prevent significant damage to the structure.

9.2.2B.3 Probability. Taking credit for the containment berm, a hydraulic oil fire resulting in collapse of the 234-5Z Building roof assembly is judged to be an incredible event.

9.2.2B.4 Accident Analysis. Taking credit for the containment berm, there are no radiological consequences associated with a hydraulic oil fire in Room 321.

9.2.2B.5 Conclusion. The PFP FHA concluded that an unmitigated, worst case hydraulic oil fire in Room 321 could potentially result in collapse of the 234-5Z Building roof assembly. In accordance with FHA recommendations, a containment berm has been constructed. This passive, physical barrier limits the area of the fire thus limiting the number of steel structural members exposed to the fire.

The 234-5Z Building structure has been designated a Safety Class SSC. Because the containment berm serves to protect the building structure, it too is a Safety Class SSC (refer to Table 4-7).

9.2.2C Not Used

9.2.2D Waste Drum Events

This section presents a safety analysis for TRU temporarily stored within the fenced security area outside the PFP. The purpose of this section is to establish a limit on the amount of plutonium-equivalent TRU that can be stored within the fenced security area outside PFP to ensure that the radiological consequences of an accident involving this waste fall within the WHC Risk Acceptance Guidelines presented in Section 9.4.

9.2.2D.1 Process Description. Radioactive wastes from PFP, including waste to be handled by the Waste Isolation Pilot Plant (WIPP), non-WIPP TRU solid waste going to 20-year retrievable storage, and low-level waste (LLW) solid wastes are temporarily stored at the PFP in waste drums for eventual transfer. Based on previous safety analyses (Olson 1991, Cain 1991), the major hazard in outside storage areas is the release of TRU material following container rupture and fire. It was shown in these references that the contribution due to radiation doses from LLW, contained along with gram quantities of TRU material, is very small compared to the resulting dose from the release of the TRU. As a consequence, in this analysis where accidents or events affect material in storage, only the TRU release is considered.

Very few waste containers contain 100% of any one waste type. They typically include a mixture of combustible (e.g., paper, plastic, rubber) and noncombustible (e.g., metal and glass) materials. Table 9-18 is a summary of the contents of the waste drums transferred from the PFP from 1978 to 1988. It is anticipated that new waste generated from the PFP will be similar and that this description represents the container content for future waste to be stored outside the PFP.

The material in the waste containers consists mainly of combustible materials such as paper, metals, and rubber, with surface and/or internal contamination, packaged in multiple layers of plastics. Based on the fraction of combustibles for waste drums from Table 9-18, all scenarios involving the burning of waste container contents will assume that 85% of the material in the waste drums is combustible.

The waste drums containing newly generated TRU waste must meet the following requirements:

- Newly generated TRU waste must be placed in noncombustible packaging that meets DOT requirements (DOE Order 5820.2A and WIPP 1989). Liner(s) will be a minimum of 5 mils thick.
- All TRU waste drums must be equipped with a method to prevent pressure buildup (DOE Order 5820.2A).
- All waste packages shall be handled in accordance with 49 CFR Part 173 (DOT 1990) and/or *Test and Evaluation Document for DOT Specification 7A Type A Packaging*, WHC-EP-0558 (WHC 1992a).

Other considerations already impose limits on the conditions for storage of waste within the fenced security area outside the PFP. Plutonium, under the provisions of Section 51 of the Atomic Energy Act of 1954, has been determined to be SNM. As SNM, it is designated Category I, II, III, or IV based on the attractiveness level of the material and the amount of material present. Attractiveness level D in Category IV limits the storage of ^{239}Pu in the yard to 3 kg with no absorbed liquids exceeding 25 g/L (DOE Order 5633.3A). Establishing a limit greater than 3 kg would change the category designation and require additional safeguards.

In addition to the safeguard limits, there are also criticality safety-control limits for TRU storage in 55-gal drums.

- The TRU content of any 55-gal drum intended for storage at the Hanford Site cannot exceed 187 ^{239}Pu fissile gram equivalents based on HNF-EP-0063 (HNF 1993).

- Fissionable material totaling 3% of a minimum critical mass or less is exempt from criticality-safety packaging and transportation requirements. For ^{239}Pu, 3% of a minimum critical mass is 15 g. Outside storage of drums with 15 g or less ^{239}Pu fissile gram equivalent is exempt from additional nuclear-criticality safety controls (HNF-PRO-334, HNF-PRO-537)

9.2.2D.2 Accident Analysis. The analysis and acceptability of risk documented below are based on the implementation of specific controls on the storage of TRU in waste drums within the security area outside of the PFP. Key elements of the control program are as follows.

- All TRU waste drums stored within the fenced area outside of the PFP must meet DOT requirements for noncombustible packaging.

- All TRU waste drums will be equipped with a method to prevent pressure buildup.

- Outside storage of TRU mixed waste is not permitted. Mixed waste is defined by WAC-173-303, Dangerous Waste Regulations.

- The amount of transuranic material in any single 55 gallon drum stored outside a facility building shall be less than 15 g.

- The total amount of transuranic material stored outside in waste drums shall be less than 3,000 g.

Potential accidents dominating the risk to outside waste-drum storage have either high estimated probabilities or large estimated consequences. These events include the vehicle crash with ensuing fire, mechanical release due to puncture, and drum explosion (Crowe 1994). By limiting the amount of TRU waste stored within the security fence outside of the PFP, it will be shown that any release from these mechanisms will not expose onsite or offsite individuals to radiation doses above the Risk Acceptance Guidelines.

To evaluate the consequences of potential accidents, the limit of 3,000 g TRU is used for an outside drum-storage with no more than 15 g TRU in a single

drum. The validity of these limits is presented in the following subsections by demonstrating that radiological guidelines are met when these limits are followed.

9.2.2D.2.1 Scenarios.

9.2.2D.2.1.1 Fire Release. A vehicle crash with ensuing fire could potentially involve a number of the waste drums being stored outside. Therefore, vehicle crash with resulting fire is analyzed as bounding fire release in this section.

For the vehicle crash with ensuing fire, it is postulated that a vehicle traveling within the fenced security area of the PFP crashes into stored waste drums. Upon impact, the fuel tank of the vehicle ruptures and quickly releases its fuel. The fuel is ignited and burns as it spreads as a pool fire encompassing the storage containers breached by the crash. The pool fire lasts only a matter of minutes before the fuel is consumed. However as the vehicle fuel burns, the contaminated, combustible material from the breached containers begins to burn and release the contamination. Once released, the path for the contamination to the atmosphere is tortuous. It must pass through the residue from the uncontaminated combustible packaging and other debris before it can be released. Based on the average combustible material in the waste drums from 1978 to 1988, 85% of the breached container contents is assumed to be consumed in the fire.

An ARF of 5.0×10^{-4} with an RF of 1.0 is applicable as a conservative value for the combustible material based on the assumption that everything released is in the respirable range (Crowe 1994). No credit is taken for the steel drums. This provides a very significant degree of conservatism in the calculation. The recommended ARF of 1.0×10^{-2} with an RF of 0.001 for the release caused by thermal stresses is used for the noncombustible component. The resulting source term for the vehicle crash with ensuing fire is the product of the inventory of the storage containers, the percentage of material involved, and the ARF x RF. Based on a limit of 3,000 g of TRU stored outside, the upper bound of the source term for the vehicle accident is:

$$\begin{aligned} \text{Pu (respirable)} &= [(\text{amount stored})\ (\text{percent involved})\ (\text{ARF})\ (\text{RF})]_{\text{fire}} \\ &\quad + [\text{amount stored})\ (\text{percent involved})\ (\text{ARF})\ (\text{RF})]_{\text{stress}} \\ &= (3{,}000\text{ g Pu})\ (85\%)\ (5.0 \times 10^{-4}\text{ ARF})\ (1.0\text{ RF}) \\ &\quad + (3{,}000\text{ g PU})\ (15\%)\ (1.0 \times 10^{-2}\text{ ARF})\ (0.001\text{ RF}) \\ &= 1.28\text{ gm respirable plutonium oxide.} \end{aligned}$$

For the 3,000 g of TRU to be at risk requires at least 200 drums to be breached and burned.

9.2.2D.2.1.2 Mechanical Release. The release of contaminants from a waste drum breached by mechanical forces (e.g., vehicle impact without fire, over-pressurization, falling, forklift puncture) would be very limited because the items in the containers are enclosed in multiple layers of plastic. Some

contamination could be released from puncturing the container contents, but the amount would be much less than for a vehicle crash with ensuing fire. The velocity and volume of air available to entrain contaminants is much less than for a fire. Only a small fraction of the plastic packaging would be compromised resulting in a smaller material inventory subject to release.

An ARF x RF of $(5.0 \times 10^{-5}) \times (1.0)$ is used for the mechanical release (Crowe 1994). It is also assumed that two drums are punctured.

$$\text{Pu(respirable)} = \text{(amount stored) (percentage involved) (ARF) (RF)}$$

$$= (30 \text{ g Pu}) (100\%) (5.0 \times 10^{-5} \text{ ARF}) (1.0 \text{ RF})$$

$$= 1.5 \times 10^{-3} \text{ g respirable plutonium nitrate.}$$

9.2.2D.2.1.3 Drum Explosion. A drum pressurization or gas explosion should involve only a single container while a vehicle crash with ensuing fire has been seen to potentially involve a number of drums and most of their contents. The explosion accident scenario results in much higher releases than a pressurized drum that vents. Thus the explosion is the limiting case. A drum explosion could breach the container and scatter some of the contents of the container releasing some of contaminants to the atmosphere. The explosion could also ignite the combustible material in the drum releasing additional contaminants.

The ARF x RF value used for the explosion is 1.0×10^{-3} (Crowe 1994). The ignition and burning of the combustible contents of the containers following the explosion releases additional contaminants based on the fire ARF x RF of $(5.0 \times 10^{-4}) \times (1.0)$. An ARF of 1.0×10^{-2} with an RF of 0.001 for the release caused by thermal stresses is again used for the noncombustible component. Again, the use of these values is conservative as no credit is taken for the structural integrity of the steel drums.

Based on a limit of 15 g per waste drum, the source term for the drum explosion is

$$\begin{aligned}
\text{Pu (respirable)} = & \; [(\text{amount stored})\ (\text{percent involved})\ (\text{ARF})\ (\text{RF})]_{\text{explosion}} \\
& + [(\text{amount stored})\ (\text{percent involved})\ (\text{ARF})\ (\text{RF})]_{\text{fire}} \\
& + [(\text{amount stored})\ (\text{percent involved})\ (\text{ARF})\ (\text{RF})]_{\text{stress}}
\end{aligned}$$

$$\begin{aligned}
= & \; [(15\text{ g Pu})\ (100\%)\ (1.0 \times 10^{-3}\text{ ARF})\ (1.0\text{ RF})]_{\text{explosion}} \\
& + [(15\text{ g Pu})\ (85\%)\ (5.0 \times 10^{-4}\text{ ARF})\ (1.0\text{ RF})]_{\text{fire}} \\
& + [(15\text{ g PU})\ (15\%)\ (1.0 \times 10^{-2}\text{ ARF})\ (0.001\text{ RF})]_{\text{stress}}
\end{aligned}$$

$$\begin{aligned}
= & \; [0.015\text{ g respirable plutonium nitrate}] \\
& + [0.006\text{ g respirable plutonium oxide}].
\end{aligned}$$

9.2.2D.2.2 Accident Probabilities.

9.2.2D.2.2.1 Vehicle Crash.

9.2.2D.2.2.1.1 Sequence of Events for Vehicle Crash. For the vehicle crash with ensuing fire, it was postulated that a vehicle traveling within the fenced security area of the PFP crashes into the storage containers. Upon impact, the fuel tank of the vehicle ruptures and quickly releases its contents. The vehicle fuel is ignited and burns as it spreads as a pool fire encompassing the storage containers breached by the crash. The contents of the ruptured waste containers begin burning. The fire spreads to all the containers stored.

9.2.2D.2.2.1.2 Assumptions for Vehicle Crash.

- The drums are at a level and position where they can be impacted by a vehicle but are located away from the traffic lanes.
- All the drums stored are breached and burn. No credit is taken for the structural integrity of the drums or for their storage configuration. In reality only a few drums may be breached and their contents spilled and subsequently burn. The majority of the drums will retain their contents and not contribute to a release.
- The amount of TRU involved in the accident is the total amount being stored because no credit is taken for container integrity.
- The fire release fraction (ARF x RF) is (5.0×10^{-4}) x (1.0); the mechanical release fraction (ARF x RF) is $(1.0 \times 10^{-2)}$ x (0.001).
- Eighty-five percent of the breached containers' contents are combustible and are consumed in the fire. No credit is taken for container integrity.

- It is assumed that 60 gal (0.277 m^3) of fuel is spilled based on an estimate by WHC transportation personnel that the typical transportation vehicle has a fuel tank with a capacity of 30 to 50 gal.

- The drums are stored primarily on a porous surface, such as gravel or sand. On porous surfaces, the gasoline spreads in the range of 2 to 4 ft^2/gal depending on the porosity of the soil. On an impervious surface, the range is estimated to be 3 to 5 ft^2/gal (Mishima and Schwendiman 1973). A 60-gallon spill of this magnitude on an impervious surface would have a diameter of 15 to 20 feet (4.6 to 6.0 m). On a porous surface, the pool fire diameter would be 12 to 17 ft (3.8 to 4.6 m).

9.2.2D.2.2.1.3 Event Probabilities for Vehicle Crash.

Vehicle Crashes Within the Fenced Area--The probability of a truck accident occurring is 2.45×10^{-6} per mile (Clarke et al. 1976). Annual mileage for vehicles within the PFP facility is estimated to be about 6,400 km/yr (4,000 mi/yr) based on 3 to 4 vehicles per hour, 0.8 km of travel per vehicle and 2000 day-shift hours per year. Therefore, the annual probability of a vehicle accident within the fenced area is less than 1.0×10^{-2}.

Data specific to the Hanford Site have been used to develop accident frequencies and probabilities based on truck accident statistics. The Hanford Site had 114 reportable truck accidents (gross vehicle weight over 8,500 lb) over a period in which 26 million recorded miles were driven. Of these reportable accidents, 31 (27.2 percent) resulted in major damage. The annual probability of a major damage accident, based on 6,400 km/yr within the fenced area, is estimated from these statistics to be 5.0×10^{-3}. A major truck accident on the Hanford Site is about half as likely as that predicted from national transportation statistics.

Crashed Vehicle Impacts the Stored Waste Containers--A vehicle accident within the PFP fenced area would not necessarily involve the stored waste containers. A vehicle traveling around the PFP completes a loop of approximately 0.8 k (0.5 mi). Only half of the single vehicle crashes would be expected to be directed outward towards the waste containers stored along the fence perimeter. The waste containers will occupy only a fraction of the length of the fenced perimeter. For example, a storage location with a width of 50 m would cover less than 10% of the total perimeter of a 0.8-km (0.5-mi) loop. Therefore, less than 5% of the vehicle crashes with the fenced area should involve the stored drums.

Crashed Vehicle Ignites Due To Crash--Fires occur in approximately 1.6% of all truck accidents (Clarke et al. 1976) or a probability of 1.6×10^{-2}. Because the posted vehicle speed limit within the fenced area is 20 mph (32 km/hr), this probability is conservative relative to normal highway speeds.

Container Failure Results From Impact--The amount of TRU stored in an individual waste drum is limited by criticality safety requirements to

15 g TRU per waste drum for uncontrolled outside storage. It therefore requires a minimum of 200 drums to reach the outside storage limit of 3,000 g TRU. Since the posted vehicle speed limit within the fenced area is 20 mph, the possibility of breaching all the waste drums is incredible. However, for additional conservatism in this analysis, all the waste drums are assumed to be breached.

Crash Ignites Contents of Breached Containers--Since it is not possible to determine what fraction of the drums are involved in the fire, the analysis conservatively assumes the entire contents of the waste drums burn. Thus, the entire inventory at the location is at risk.

9.2.2D.2.2.1.4 Frequency of Vehicle Crash. A vehicle crash into the waste containers with or without a fire requires the combination of a number of unlikely events. For such an accident to involve the entire inventory of containers is judged incredible. However, instead of actually quantifying the likelihood, it is easier to demonstrate using risk acceptance guidelines for unlikely events and a deterministic analysis that the consequences of such an accident are acceptable when the total amount of TRU stored is limited to 3000 g.

9.2.2D.2.2.2 Drum Explosion

9.2.2D.2.2.2.1 Sequence of Events for a Drum Explosion. Many organic materials can decompose when exposed to radiation. Alpha radiolysis of organics in TRU wastes can cause gas generation and possible drum pressurization. Flammable gas also can be generated in waste containers containing radioactive materials and hydrogenous materials. Hydrogenous material is being used here to mean any material that can generate hydrogen through radiolytic degradation. For example, the radiolytic decomposition of plastic waste packages found in many waste storage drums can produce hydrogen and other flammable gases. For a closed, unvented waste container, the buildup of an explosive mixture of hydrogen and oxygen within the void space inside the container can be postulated. If this mixture were ignited, the ensuing explosion could breach the container, scatter some of the contents of the container, and release some of the contaminants to the atmosphere.

TRU waste containers are required by procedure to have either vent clips or filtered vents to prevent these potential hazards. Hydrogen-oxygen recombinant catalysts to deplete oxygen and prevent explosive concentrations of hydrogen and oxygen are also required in TRU waste containers.

9.2.2D.2.2.2.2 Assumptions for Drum Explosion.

- Outside storage is temporary and only used to support the storage of waste containers inside the PFP. Only a portion of the approximately 1,000 drums being transferred per year will be stored outside. (An average of 924 drums were transferred per year from the PFP to the burial grounds from 1986 to 1988 [Anderson et al. 1990]).

- The explosion release fraction (ARF x RF) is $(1.0 \times 10^{-3}) \times (1.0)$; the fire release fraction (ARF x RF) is $(5.0 \times 10^{-4}) \times (1.0)$; and

the thermal stress release fraction (ARF x RF) is (1.0×10^{-2}) x (0.001).

- The drum fails by blowing the lid, and the contents of the drum are ignited and burn. Surrounding drums are not breached based on historical evidence (DOE 1993).

- Plutonium is released from the explosion as a nitrate; the plutonium is released from the fire as an oxide.

9.2.2D.2.2.2.3 Event Probabilities for Hydrogen Explosion.

Vent Device not Installed--The waste is packaged per PFP Procedure Z0-170-015, which requires a 10 mil polyliner, a catalyst pack, and either a filtered vent or vent clip. Multiple vents are required if the gas generation rate is high (WHC 1993). Because of the simplicity of the design of the vent clip and filtered vent, it is unlikely that they will fail within the time period of the outside storage. However, the vent clip and filtered vent could fail to be installed. The failure of a worker to complete a task falls within the realm of human reliability. The probability depends on the complexity and time constraints associated with task and ranges, for a relatively simple task, from 1.0×10^{-2} to 1.0×10^{-3} per demand (Swain and Guttmann 1983).

Catalytic Recombiners not Installed--A catalyst pack is required by procedure to deplete the oxygen and prevent explosive concentrations of hydrogen and oxygen. Failure of the function of the catalytic recombiner because the combiner is not installed should range, for a relatively simple task, from 1.0×10^{-2} to 1.0×10^{-3} (Swain and Guttmann 1983). Failure of the catalytic recombiner while the waste drum is being stored is judged to be much less likely than the failure to install the device because it is a passive device which relies on physical principles.

Hydrogen Reaches an Explosive Concentration--In containers containing both radioactive materials and hydrogenous materials, hydrogen-oxygen is being generated by radiolysis. However, not all the waste containers will have sufficient quantities of both these materials to reach flammable concentrations of hydrogen and oxygen within the time period the waste containers are stored outside the PFP. An Idaho National Engineering Laboratory study (EG&G 1985) shows that of 184 RFP drums and 33 Los Alamos drums, only one drum (an eight-month-old drum) had an explosive mixture. These data give this event a probability of 4.6×10^{-3} per drum.

Flammable Mixture Ignited--The presence of an ignition source is required to ignite a flammable hydrogen-oxygen mixture. The most likely source is static electricity; this probability is assigned a value of 1.0.

9.2.2D.2.2.2.4 Annual Frequency for Waste Container Explosion. A drum explosion during outside storage requires the combination of a number of unlikely events. For example, a total of 37,641 waste drums were transferred to the burial grounds from all the sites, including the PFP, during the 19-year period from 1970 to 1988 (Anderson et al. 1990), and no explosions were reported. In addition, such an accident would involve the contents of only a single drum. However, again due to the complexity of actually quantifying the

likelihood, it is easier to demonstrate with a deterministic analysis that the consequences of such an unlikely accident are acceptable.

9.2.2D.2.2.3 Mechanical Release. The potential for single-drum rupture is greater than that for the previous accident scenarios and therefore is included. It is assumed that two drums with the maximum amount of TRU are punctured by a forklift. Some of the contents of the drum are released. The amount of contaminated material released by the puncture would be very limited, because the items in the containers are enclosed in multiple layers of plastic. Only a small fraction of the plastic packaging would be compromised resulting in a small material inventory subject to release.

Forklift Punctures Drum--Even though the forklifts are operated by qualified operators, this event is anticipated with a probability of (1.0×10^{-2} to 1.0×10^{-1}). The annual probability of 1.0×10^{-1} is used.

9.2.2D.2.3 $\bar{\chi}/Q'$ Calculations. The purpose of this section is to describe the way the atmospheric dispersion coefficients $\bar{\chi}/Q'$ were calculated for use in the waste drum fire accidents. They are based on identified release point, receptor location and atmospheric condition.

This release scenario is applied to a postulated ground level fire with an attendant plume rise such as that from stored combustible waste. The buoyancy of the plume depends upon the sensible heat generated.

Due to the short duration of the fire, no credit is taken for plume meander. Additionally, plume trapping due to building turbulence is invoked using the liftoff criterion. The buildings near enough to cause this effect are single story structures. A building height and width of 6.1 m (20 ft.) and 10 m (33 ft.) are used, respectively. Credit for building wake is taken if conditions prevent buoyant plume rise (i.e. plume trapping).

The distance to the onsite receptor is measured from the PFP perimeter fence to the nearest occupied onsite facility. It is assumed that such a fire occurs in waste drums stored in the southwest corner of the PFP fenced perimeter.

The waste drum mechanical rupture scenario involves two drums assumed to be breached and to release some portion of their contents. No credit is taken for any plume rise, wake effects or plume meander. This accident is modeled as a point source ground level release.

The estimation of $\bar{\chi}/Q'$ was performed with the computer program GXQ (Hey 1993a, 1993b, and 1994). The methodology and models used are briefly described in Section 9.3. For more detailed information on the GXQ's models and their applicability, the reader should refer to the above references.

Table 9-19 lists the calculated $\bar{\chi}/Q'$. Also given are the atmospheric conditions that most closely correspond to the 99.5% meteorology. For the waste drum mechanical rupture ground level release, the 99.5% meteorology corresponds to extremely stable atmospheric conditions and relatively low wind speeds. This is a typical result for ground level releases and receptors. Although the wind rose frequency plays a part, the maximum receptor is usually the closest.

The plume for the waste drum fire $\bar{\chi}/Q'$ calculation is initially at ground level and then rises. A relatively unstable (highly dispersible) condition was selected for the onsite receptor. This is due to the ability of a more dispersible plume to "touch down" at a shorter distance. A lower wind speed, in this case, gives the plume more time to spread out vertically before reaching the receptor. The letter designation represents the Pasquill atmospheric stability class, class A being the most unstable and class G being the most stable. The numerical value refers to the corresponding wind speed.

The receptor of concern is normally defined as a human having a standard breathing rate and metabolism. The standard man breathing rates are from recommendations from the International Commission on Radiological Protection, *Report of the Task Group on Reference Man* (ICRP 1975).

9.2.2D.3 Accident Consequences.

9.2.2D.3.1 Radiological Consequences. The diverse plutonium inventory in the PFP has been characterized in a safety document (Crowe and Szempruch 1994) and summarized in Section 9.3.5. Unit dose inhalation values (rem/g) are provided in the reference for plutonium for two ranges of ^{240}Pu content. The term unit dose describes the dose a person receives if they inhaled one gram of an isotope.

The principal exposure pathway in the PFP postulated accidents is via dispersion in air and subsequent inhalation by individuals.
Tables 9-46 and 9-47 present the committed EDE and the bone surface unit doses for plutonium compounds with two different lung clearance classes. Compounds other than oxide, such as plutonium nitrate, which have relatively short clearance times in the lungs are considered as Class W (Eckerman et al. 1988). Oxides of plutonium are considered as Class Y (Eckerman et al. 1988). It is assumed that the plutonium is being stored as nitrate; but, as a result of the postulated fire, would be released as an oxide.

The mass-weighted average unit doses from Tables 9-46 and 9-47 are used for calculating the consequences of the waste drum fire. Crowe and Szempruch (1994) demonstrate the acceptability of using average values when a significant number of Pu items (i.e., more than 16) are involved in the operation. When more than the minimum number of items is implicated, the Central Limit Theorem in the field of statistics provides a defense for the use of average values. This theorem describes mathematically that the distribution of the average of a series of random samples from a given population tends to be distributed with the mean of the averages equal to that of the parent population.

For the waste drum fire involving 3,000 g in a minimum of 200 drums, the use of the mass-weighted average to calculate the consequences is considered justifiable for the following reasons:

- First, it is assumed that all the drums are loaded to the maximum allowable TRU content.
- Second, the waste generated to fill 200 drums will typically involve several gloveboxes or operations (cleanup, decontamination, etc.) that should include a significant number of Pu items approaching a

random selection. A specific operation that nonrandomly selects the high activity plutonium will require an Unreviewed Safety Question screening to demonstrate the authorization basis and safety envelope are not exceeded.

- Third, it should be recognized that burning 200 drums is highly conservative. A more realistic fire, based on the size of a fire from the spill of the 60 gallons of gasoline, would more likely involve 20 drums. The dose consequence from 200 drums at the mass-weighted average is five times greater than 20 drums at the 90th percentile. The use of 200 drums at the mass weighted average provides a conservative way of addressing the uncertainty in the number of drums involved in the fire.

- Fourth, the mass weighted average of the >10% ^{240}Pu is roughly equal to the 65th percentile for the >10% ^{240}Pu and greater than the 80th percentile for the total inventory.

For the other accidents, involving single drums, the 90th percentile for the greater than 10% ^{240}Pu is used.

Consequence limits depend on the likelihood of the event. The Radiological Risk Acceptance Guideline curves presented in Figure 9-34 assign an acceptable consequence based on the frequency of an event. As seen in Table 9-20, all the consequences of the waste drum accidents fall within the risk guidelines. With the exception of the waste drum puncture, all the accidents identified for the waste drums storage emerge as "unlikely" to "extremely unlikely" based on a review of the anticipated annual frequencies.

9.2.2D.3.2 Nonradiological Consequences. TRU waste containing dangerous waste as defined in WAC 173-303-040 is packaged, labeled, and certified in compliance with *Hanford Site Solid Waste Acceptance Criteria*, WHC-EP-0063-4 (WHC 1993). Drums of mixed waste are not allowed to be stored outside. Therefore, the concentrations of nonradiological hazardous materials in TRU waste drums stored outside will be extremely low, and the offsite concentrations will be immeasurably low.

9.2.2D.4 Conclusion. Based on the release guidelines in Section 9.4, this section demonstrates that the maximum allowable gram quantity of contact-handled transuranic waste (CH-TRU) that may be stored in waste drums outside of the PFP is not limited by a waste drum accident but is limited by the following requirements:

- No more than 3,000 g of TRU stored within the security area based on SNM Control considerations.

- No single drum can contain more than 15 g of TRU based on criticality requirements.

Based on these limits, the onsite and offsite radiological dose consequences of a postulated release satisfy the Risk Acceptance Guidelines for an unlikely event (i.e., likelihood between 10^{-2} to 10^{-4}/yr). In addition, the exposure to an onsite worker is less than 5 rem EDE.

A significant accident involving the waste drums stored outside of the PFP requires the combination of a number of unlikely events to occur. For such an accident to involve all the stored waste drums is believed to be incredible (less than 10^{-6}/yr). However, due to the difficulty of actually quantifying the likelihood, it is easier to identify a storage limit and demonstrate with a conservative analysis that the consequences of the accident fall within acceptable limits for unlikely (10^{-2} to 10^{-4}/yr) events.

9.2.3 Criticality

Examination of dose consequences in Table 9-21 shows that a criticality in a facility ventilated by the 200-ft-tall stack would be below the guidelines for an event with an annual probability of 6.9×10^{-2}. The onsite and offsite radiological consequence of a criticality at the PFP is minimal because of the isolation of the plant within the Hanford Site and the large size of the site. This would be the case for a criticality in either of the main processing buildings, 236-Z or 234-5Z. A ground-level release (Table 9-22) would represent an event in either the 2736-Z complex or 241-Z and only exceeds the guidelines for an event with an annual probability of 3.8×10^{-2}. The probability of a criticality is shown to be less than 3.8×10^{-2}. In addition, arguments in Section 9.2.3.2 and in *25 Rem Boundary for PFP* (Brown 1989) show that the figure of 1×10^{19} fissions used in the analysis is high by a factor of at least three. Historical evidence and the arguments presented in Section 9.2.3.2 indicate that the actual number of fissions, in most instances, would be much lower.

The criticalities discussed in this section are limited to those that could result during plant operation and not as a result of an earthquake. The subject of earthquake-induced criticalities is discussed fully in Section 9.2.4, Seismic Event.

The conditions for an accidental criticality are most likely to occur during an off-normal condition when people are trying to cope with the obvious problem and in the process create another. Training and a variety of administrative controls, as well as good design, are used to minimize the chance of such a situation. Training classes emphasize that off-normal situations have been involved in the criticalities that did occur.

9.2.3.1 Scenario. No detailed scenarios were developed for criticality in the PFP. The parameters that determine criticality are multiple and exist as continua, so deciding on a particular set of errors at any of dozens of locations is exhausting. For example, in a typical solution system the variable parameters could be plutonium mass, plutonium concentration, nitrate ion concentration, moderation, and reflection. These parameters do not exist in discrete units. Criticality safety is achieved by limiting the extreme end of each parameter and not by trying to limit all the ways that the parameter could be varied. Instead of many separate scenarios, the design basis criticality from U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 3.35 (NRC 1979b) is used to assess the consequences. While fully developed scenarios are not presented, example cases are discussed.

9.2.3.1.1 Metal, Scenario. Plutonium metal can exist in the RMC Line gloveboxes during repackaging operations in amounts that could go critical

without flooding. This could only happen if a person were to willfully neglect or bypass all safety constraints operating and controls. Discussion in Section 9.2.3.4, Probability, shows that to do so would not only mean breaking formal rules but would be an awkward thing for an operator to do. In addition, security concerns require two people in attendance when handling category-1 material so a criticality involving Pu metal would take willful misconduct by two people. As bare metal, only a compact stacked, three dimensional array of plutonium buttons would reach criticality (Altschuler 1989b).

9.2.3.1.2 Powders, Scenario. No criticality scenario exists in the PFP involving dry PuF_4 or PuO_2 powder under the conditions of only nominal neutron reflection found in the dry air gloveboxes. *The Criticality Handbook*, ARH-600, Vol. 2, Figure III.A.9(100)-5 (Carter et al. 1969) shows PuO_2 in a spherical configuration at a density of 3 g/cm^3 to have a critical mass of 140 kg. Typical PuF_4 powders have bulk densities closer to 2 g/cm^3, which means a spherical critical mass would require 290 kg. A high figure for the total plutonium mass on the RMC Line as powder is that found in 12 powder pans at 2,500 g per pan, or 30 kg. Criticality safety limits are based on the addition of moderating and reflecting materials not normally encountered. For example, addition of water to an array of fissile material makes a profound difference in the mass required to achieve criticality. A spherical PuO_2-H_2O mixture with the same 3 g/cm^3 density as the dry material discussed above has a critical mass of only 18 kg. Given full water reflection and the same type and arrangement of material, the critical mass goes down to only 12 kg. The critical mass and spacing limits are based on an assumption of a mass or spacing violation concurrent with glovebox flooding or the presence of other moderating materials, such as finely divided polyethylene. Twenty-one different combinations of spacing, moderation, reflection, and mass involving PuF_4 powder were examined in order to establish bounding conditions (Altschuler 1989b). The only two arrangements with a k_{eff} greater than 1 involve: (1) a stacked array of three powder pans containing 2,500 g Pu as PuF_4 (k_{eff} = 1.0082) and (2) a powder pan of the same material with two stacked metal buttons in the middle (k_{eff} = 1.0701). To achieve the degree of moderation modeled, a conservatively high density is assumed for the powder as there is not enough space left in a powder pan of normal density powder to fit the required amount of moderating material. A simple spill or spacing error with dry powder that could result in a criticality is not credible as will be discussed further under probability in Section 9.2.3.4.2.

9.2.3.1.3 Liquids, Scenario. The majority of vessels in the PFP are constructed in a manner to maximize criticality safety. Gloveboxes cannot be of a critically safe geometry should they become flooded with water, but by enforcing strict administrative controls on mass, spacing, and the chemical or physical form of materials, the results of an accidental flooding are minimized and criticality prevented. Gloveboxes are equipped with drains and protected from plugging with large mesh screens, which help prevent flooding. However, simultaneous breakdown of several controls and flooding could result in a criticality.

One facility in the PFP complex is not equipped with critically favorable tanks. The vaults beneath the 241-Z Building contain four active and one inactive waste handling tanks. These are stainless steel with a diameter of

10 ft and a domed top approximately 12 ft high. They can hold about 15,480 L (5,000 gal) before overflowing to the D-7 overflow tank.

9.2.3.1.3.1 Operation of 241-Z Tanks. The operation summarized below is more completely described in Chapter 7.0, Section 7.2.2.2. Note that the PRF is inactive and that High Salt Waste (HSW) is no longer generated. The following analyses have been retained for historical purposes.

Solutions received in the 241-Z complex of tanks originate from three main sources as described in Section 7.5. These are the PRF (which is not in operation) and the two laboratories.

The CAW waste stream is the highly acidic waste from the PRF extraction column (CA column). The plutonium concentration is controlled by criticality specifications to no greater than 1 g/L. Normally the plutonium concentration ranges from 0.002 g/L to 0.2 g/L with a flowsheet concentration of 0.0057 g/L. The CUU and CXP solutions are generated from the organic cleanup process with flowsheet plutonium concentrations of 0.016 g/L and 0.01 g/L respectively.

The combined waste streams, are collected in TK D8 and neutralized with sodium hydroxide in TK D5 by a reverse strike caustic addition. The plutonium concentration in solution transferred to Tank Farms is limited to a maximum of 0.033 g/L (0.12 g/gal). The total plutonium in the tank, both in solution and as solids, is limited to 400 g. After treatment, the waste is sent to the Tank Farms. The reverse strike procedure is used to ensure that an excess of caustic is present throughout the mixing process to prevent precipitation of metal hydroxide solids from the HSW. In reverse strike, caustic is present in the receiving tank before the solution is added as $Al(OH)_3$ precipitate does not form under high pH conditions. The iron is added in order to assure that the concentration of neutron absorbers to plutonium is high enough, and that the concentration of combined hydroxide precipitates is low enough in plutonium to be noncritical in the large Tank Farms tanks.

9.2.3.1.3.2 Scenarios, 241-Z. Three general scenarios are envisioned for criticality in the 5,000-gal tanks of the 241-Z facility. Two involve transitory conditions that would exist only during introduction of liquid during a time when the agitator was not running. The third involves introduction of enough plutonium to cause a sustained series of pulses that would continue until enough liquid evaporated to cause spontaneous shutdown.

Before solutions are transferred from tank D-5 the acid waste solutions must be neutralized to avoid corrosion of the lines and tanks within the Tank Farm system. This is done through a process known as reverse strike in which NaOH is added to tank D-5 in preparation for receiving the waste solution. The amount of NaOH to be added is determined from a sample of the waste. The solution, following transfer, is required to have a excess OH^- concentration. During the waste addition the plutonium and iron forms a flocculent precipitate. The assumption used for the basis of criticality control is that the precipitate forms a conical pile. Such a pile with an apex angle of something less than about 140°, resting on the bottom of a tank that rests directly on a concrete pad, approaches the neutron loss properties of a hemisphere (Friar 1990). This assumed geometry coupled with assumptions as to density and safety factors is used in *Underground Waste Storage Tanks and Associated Equipment*, CSAR 79-007, Rev. 0 (Friar 1990) to establish the

criticality limit of 400 g. During a criticality in an aqueous system, the resulting burst of radiation causes intense ionization of the surrounding water with the formation of small bubbles. The bubbles and steam formation would disrupt the pile and spread it over a larger area of floor. The waste enters the D-5 tank through a riser located near the high side of the tank bottom that would facilitate spreading. At angles of less than about 150° the reactivity of the precipitate falls steeply and the system becomes noncritical.

The second scenario is for a criticality resulting from the addition of a solution with a concentration well in excess of the minimum critical concentration of 7.2 g/L to a tank when the agitator is not turning. As the solution drops into the tank it forms a roughly spherical cloud of solution and fine precipitate that momentarily achieves criticality near the point of entry into existing solution. Due to both the transitory nature of such a highly special geometry and formation of the micro-bubbles, the criticality stops without continued pulsing.

The third scenario involves critical concentrations uniformly distributed throughout the tank which, while possible, is even more unlikely than the first two scenarios. Such concentrations would require nearly half of the total inventory of the PRF, a piping modification, and numerous other independent errors and peculiar operating modes.

One such scenario might involve the inadvertent transfer of concentrated solution to tank D-8 from the laboratories or a stabilization process. The conditions for the lowest critical mass are taken from Carter et al. (1969), for 0M excess nitrate, 0% ^{240}Pu, and full water reflection. The minimum critical mass is reached with a total solution depth of 7 in. and an areal concentration of $\approx 245\ g/ft^2$. The floor of the 9.93-ft inside diameter tank has an area of 77.6 ft^2. The total amount of plutonium required to achieve sustained criticality in this tank is $77.6\ ft^2 \times 245\ g/ft^2 = 1.9 \times 10^4$ g. With a more realistic ^{240}Pu content of 5%, the minimum areal concentration is $\approx 270\ g/ft^2$ for a total of 2.1×10^4 g (Carter et al. 1969). This is considerably more plutonium than would be contained in a tank of product solution or laboratory container.

9.2.3.2 Mitigation. The primary mitigation of an accidental criticality is due to physical phenomena which result from the fission process itself. These phenomena include heat and bubble formation in liquids. The following calculations will help the reader comprehend the energy release from the 1×10^{18} fissions initial burst of the prescribed 1×10^{19} fission event (NRC 1979b). Each ^{239}Pu fission releases energy of approximately 200 MeV. The major portion, 84%, of the fission energy, 168 MeV, appears as kinetic energy from the fission fragments and is manifested as heat within the system.

The remaining 16% is released in the form of gamma rays and neutrons which effectively leave the immediate fissile system (Glasstone 1955). Thus, for 1×10^{18} fission, the heat to the fissile system is:

$$(1x10^{18}\ \text{fissions}) \times (168\ \text{MeV/fission}) \times (1.6x10^{-13}\ \text{W-s/MeV})$$

$$= 2.7 \times 10^{7} \text{ W-s}$$

$$\frac{2.7 \times 10^{7} \text{ W-s}}{3.6 \times 10^{3} \text{ s/h}} = 7.5 \times 10^{3} \text{ W-h}$$

$$7.5 \times 10^{3} \text{ W-h} \times 860 \text{ cal/W-h} = 6.4 \times 10^{6} \text{ cal}$$

This amount of energy is more than enough to change the geometry of most fissile systems. At the PFP, the prompt fissile system geometry changes result in lower reactivity. The 6.4×10^{6} cal are enough to bring 10.5 L of water from 25 °C to steam with a resulting volume of 1.8×10^{4} L. Thus, where reactivity will be achieved by damp materials, the system would be shut down before 1×10^{18} fissions were achieved through loss of water or other moderating materials, through evaporation, or by physical disruption of the system by steam. A more detailed discussion follows for each of the major material types; metal, powders, and liquids.

9.2.3.2.1 Metal, Mitigation. A bare array of alpha-plutonium metal buttons would lose reactivity by heat-related mechanisms. Since the metal density decreases as it is heated. The density of plutonium metal phases is shown in Table 9-23 (Wick 1967, 34, 36). Thus the stacked buttons, referred to in the scenario, would be physically pushed out of alignment by their sudden expansion. Although Pu metal will not be processed, this section is still required due to potential storage and repackaging operations.

The critical mass of a dry, unreflected system varies inversely as the square of the density. Expansion of the metal could cause a fissile system to shut down. Another possible shutdown of a metal system would be from melting. Based upon specific heat and heat of phase transition information (Wick 1967, pp. 34 and 37), the heat needed to melt a 2,000-g button from 25 °C would be 6.4×10^{6} cal (Fisher 1990). Normal methods of heating involve considerable heat loss by radiation, convection, and conduction; however, when 6.4×10^{6} cal is delivered from within the metal during a span of 0.5 s, heat loss mechanisms would be of little effect. Thus, if one assumes no heat loss, a 1×10^{18} fissions criticality could theoretically melt 100 2,000-g buttons.

A closely packed, unreflected, three-dimensional array of more than five 2,500-g buttons of 5% 240 content, on the floor of glovebox HC-21C would be needed to achieve criticality (Altschuler 1989b). Such an array could only be achieved by intentional stacking in gross violation of security, mass and spacing requirements. The hand doing the stacking would contribute some measure of reflection and might lower the number to something below 5. But, typical buttons have masses of 2,000 g to 2,200 g and a nominal ^{240}Pu content of 6% that would make them less reactive. As the last button was placed in the array, heat effects would be likely to shut down the criticality before it reached 1×10^{18} fissions. Force from the rapidly expanding metal would be likely to disrupt the array. The 6.4×10^{6} cal energy release from 1×10^{18} fissions is roughly equivalent to the daily energy expenditure of two actively working people. Thus even without a well-defined scenario, it is

clear that there is sufficient energy to perturb such a system and make it subcritical before all 1 x 10^{18} fissions are achieved.

9.2.3.2.2 Powder, Mitigation. If enough loose, dry powder could be found in the process to achieve criticality, shutdown would occur when the interstitial air heated and expanded rapidly. The powder would be widely scattered. A stacked array of cans filled with powder, if possible to assemble, would react similarly. Cans would swell and possibly burst from heated air, and very quickly perturb the critical array.

9.2.3.2.3 Liquid, Mitigation. In solutions, micro-bubble formation from radiolytic breakdown of the water molecules rather quickly lowers the density of the solution. In both solutions and in mixed solid and water systems, heat generated through the fission process can cause evaporation that may then lead to system shutdown. Nearly instantaneous formation of steam could, in some circumstances, be expected to physically disrupt the fissile materials into a nonreactive geometry.

The same design features that prevent criticality such as small size and mechanical spacing work to limit the extent of super criticality and the duration of phenomena such as the pulsing that took place in Recuplex in 1962.

9.2.3.2.4 Personnel, Mitigation. The standard criticality prescribes a certain amount of plutonium to be made airborne due to boiling of solution. The E-3 and E-4 filter systems mitigate the onsite and offsite dose. Mitigation of the effects to plant personnel following an accidental criticality is achieved by quickly putting distance between personnel and the reaction. Prompt medical help is provided to victims in order to mitigate the radiation effects. Radioactive particulates are filtered out of the Zones 3 and 4 gas streams, but gaseous iodine and noble gases are carried out the exhaust without effective mitigation.

9.2.3.3 Recovery. Formal recovery is required by procedure and would be performed under high-level Hanford Contractor and DOE scrutiny. All aspects would be performed in accordance with formal, written procedures. Any contamination in adjoining portions of the building could be cleaned quickly but cleanup of the immediate criticality site would, in all likelihood, have to be delayed until radiation levels to cleanup personnel from activation and fission products declined to acceptable levels.

9.2.3.4 Probability. The probability of criticality in the PFP can not be calculated without a detailed analysis for all the places where criticality is possible. But with the low consequences shown in this analysis it is sufficient to use statistics from the historical record of the six major DOE sites; Hanford, Idaho Falls, Rocky Flats, Los Alamos, Oak Ridge, and Savannah River. In the approximately 40 year history of these sites there were six criticalities involving chemical processing. Other criticality accidents happened with test reactors or test critical assemblies for research purposes (Stratton 1989). Of these, five took place through 1964 with the last one in 1978 at Idaho Falls. Thus with overall, raw statistics the annual probability of any one site suffering a criticality would be six in 240 site-years or 0.025. Lessons learned about criticality from DOE incidents have been rigorously applied so the probability of inadvertent criticality is actually much lower.

The present criticality prevention program, as defined by DOE Order 5480.24, has probability defined in terms of the double contingency principle. The contingencies considered in criticality analyses are discussed in Section 6.1.3.1. A contingency is the event or series of events considered in analyses which, should they take place simultaneously with other unrelated events, could lead to criticality. An example of an event might be assembly of all masses in one close-packed array. Administrative limits are set to require spacing between units of material. Implementation of administrative controls is based upon a concept in which action limits are set well before a full event is achieved. In this example, a particular location might have a spacing requirement of 10 in. between any two containers. Violation of spacing by even 1 in. is considered a serious matter that requires shutdown of the affected work area and a recovery plan authorized by Nuclear Facility Safety (NFS).

9.2.3.4.1 Metal Systems Probability. In dry systems, a considerable amount of attention is given to spacing requirements in order to limit the mass of material assembled in one place. For example, on the RMC Line materials are transported on pallets located along a conveyor. The pallets have a diameter large enough to maintain minimal spacing even if administrative rules are violated. The most sensitive location (assuming RMC Line is operating) would be glovebox HC-21C, where buttons were sealed in tuna cans for seal-out. In this glovebox, operators manipulated buttons with their gloved hands and the glovebox is free of any but administrative controls to place them in any configuration. The glovebox was limited to eight buttons. More buttons could be conveyed there, but this would require the cooperation of the control room operator who manipulated the conveyor controls. This information has been retained due to metal storage and packaging operations still occasionally undertaken. During normal working conditions, with no reflection present, more than 19 large, 2,500-g buttons with 5% ^{240}Pu could be crowded together, without stacking, on the glovebox floor without exceeding a K_{eff} of 0.92. As stated above, depending on the reflection provided by the hand, four or five buttons could be stacked without going critical. But other aspects of the work besides criticality rules limit the probability that this would happen. The nature of work flow or the physical arrangement of a work place can have more effect than management directives. Requirements for accountability control are present to keep an operator from assembling such an array of buttons in that numbers stamped on buttons must be read. The number was generally stamped on the convex surface as the most stable configuration while stamping is to have the flat side down. Since one of the faces is convex, stacking would not be an action that even a busy but preoccupied operator would be likely to do, even without the need to read the numbers, as the stack would tend to fall over. Also, a two-person rule means that an individual is not working alone and thus has someone present to correct gross errors. In crowded, awkward gloveboxes people have been known to push unit masses such as used sock filters into improperly spaced arrays in preparation for maintenance. The size and arrangement of the work space in glovebox HC-21C is such as to preclude the need to stack buttons in order to get them out of the way. In addition, the fixed-array wagon used to transport buttons is designed for only five positions so there is a tendency to send no more than five at a time to the glovebox by way of the glovebox HC-2 conveyer.

9.2.3.4.2 Powder Systems Probability. Spills or upsets of dry powder in RMC Line gloveboxes would not lead to a criticality. The critical mass of

dry, PuO_2 with 0% ^{240}Pu, nominally reflected, with a conservative density of 3 g Pu/cm^3, is 140 kg (Carter et al. 1969, 111.A.(100)-5). This is in contrast to the maximum mass of 8 kg that can be put into glovebox HA-21I. Criticality limits are based on the double contingency principle which, on the RMC Line, includes flooding the gloveboxes with water.

9.2.3.4.3 Solution Probability. The probability of solution system criticalities presents another set of control problems. For example, pipes, tanks, and other designed process containers can easily be made critically safe. They are officially referred to as geometrically favorable rather than geometrically safe as there are conditions under which criticality could be achieved. However, for the kinds of solutions and wet solids normally encountered, they are, for all intents and purposes, critically safe. On the other hand, solutions can travel from their intended locations by a variety of processes. The force of gravity can move fluids by vacuum, by syphon, or in an ordinary downward course. In addition, through the processes of evaporation, leaching, and solvent extraction, solutions can change their characteristics.

The probability of a criticality in the 241-Z tanks is governed by both formal criticality controls and the nature of the processes upstream. The nature of the upstream processes was originally governed in part by criticality prevention considerations but that has no bearing on present probabilities. As stated in Section 9.2.3.1.3.2, three different criticality scenarios are envisioned within the 241-Z tanks. The criticality prevention specifications for the tanks are based on the scenario involving the smallest critical mass. This would be a criticality involving a conical pile of precipitate. In addition to the conical shape, the plutonium is assumed to be all ^{239}Pu, fully water reflected, and the plutonium density in the pile is 30 g/L or 0.03 g/cm^3 (Friar 1990). The material assumed in Friar (1990) is a somewhat artificial material with a lowered plutonium density made necessary to maximize the water content. The precipitates formed in tank D-5 are of low viscosity and would tend to slump into a slab form rather than remain in a 140° cone. Even the concept of cone formation is largely the result of the need to establish conservative limits. The incoming solutions drop in through pipes that end near the top of the tank. For solution depths greater than 10 in. the agitator runs continuously and no pile could form. Below 10 in. the thought was that without stirring a cone of precipitate could form but this would be very unlikely to result beneath a stream dropping in from more than 10 ft above. If any regular geometric formation was to be created it would more likely resemble a low profile impact crater. Additional spreading would tend to occur because the inlet pipe is located on the side of the tank above the high side of the sloping floor so there would be a tendency for the crater to be distributed in a fan shape. Friar (1990, Figure 2) shows that at the 97.5% confidence level, $k_{eff} = 1$ for 1,040 g in a cone with an apex angle of 130°. The k_{eff} falls off rapidly as the cone flattens past this angle on its way to a slab shape. As stated in Section 9.2.3.1.3.2, the minimum areal mass for a criticality to occur in these tanks is approximately 245 g/ft^2. As long as the solutions are basic, precipitate will form with essentially no plutonium in solution as the solubility product constant for Pu(IV) hydroxide is 7×10^{-56} (Cleveland 1970, p. 83). Thus the areal concentration represents precipitate. It makes little difference whether or not the plutonium is present as a suspension or precipitated layer for, as stated in Section

9.2.3.1.3.2, there is less than half this amount of plutonium in the entire primary solvent extraction system.

The Criticality Specification for transfer of waste to the Tank Farms limits the plutonium concentration to 0.033 g/L. The specification also requires specific neutron absorber to plutonium ratios, and maximum and minimum percentages of solids in the transferred waste. This is to ensure that the waste additions of plutonium from PFP will remain noncritical in the large Tank Farm tanks.

Another scenario from Section 9.2.3.1.3.2 involves a criticality resulting when an acidic solution of high plutonium concentration from PRF (if operating) pours into a tank and forms a sphere-like region that goes critical. In no case could a solution of less than 7.2 g/L go critical as this is the lowest critical concentration for a 0% ^{240}Pu system (Paxton and Pauvost 1986, p. 59). One of the every 2 h surveillances on CA column operation is to monitor the color of the aqueous solution as it leaves the disengaging section at top of the column. This solution is readily visible as the top of the column is made of glass pipe and is located only a foot or so from viewing windows in the 6th floor column glovebox. A fractional gram/liter solution is essentially colorless. A 7-g/L Pu solution has a definite brown or blue color depending upon valence state. One of the procedural requirements is to note abnormal color and report it to supervision. Before CAW solutions are transferred to tank D-8 they are sampled and sent to the PFPAL for analysis of plutonium content among other attributes. During sample preparation laboratory technicians are trained to bring obvious differences in characteristics to the attention of their managers. Thus the unusual color would be a clue at this point, in addition to the analysis, that high concentration material was destined for tank D-8. In addition, such a high concentration of plutonium in the CAW would be indicative of a major upset in the solvent extraction system. Loss of significant amounts of plutonium out the top of the CA column would soon become apparent in a number of ways and would not likely be ignored because, if for no other reason, it would adversely affect production. The CAF is nominally only 4 g/L and a greater than 7.2 g/L escape through CAW represents nearly double this amount. Thus even if the formal criticality control mechanisms fail there are numerous operational controls in place which cause the probability of exceeding the minimum critical concentration to be very low.

Should a solution of greater than 7.2 g/L be discharged into a 241-Z tank there is a low probability that conditions would be right to cause a criticality. For solution depths of less than 10 in. the agitators are not on but as discussed with the precipitation scenario, there would be mechanical agitation due to the greater than 10-ft fall. With the agitator running, the event becomes incredible.

Certain laboratory sink drains lead to the 241-Z tanks but can not be considered as sources for the concentration or quantities necessary to generate a criticality.

Gradual solids accumulation is a potential source of unknown plutonium in the large tanks so NDA measurements are made on a regular basis. The analysis is designed to detect violations of the 400-g criticality limit. As was

discussed above, the probability of having a conical pile is very low, so in reality the analysis would only have to detect somewhat uniform deposits of plutonium approaching 19 kg. The probability that the NDA system would fail to detect such a quantity involves multiple failures. These kinds of quantities would only accumulate after the passage of many analyses. The addition of iron before transfer to Tank Farms is done to dilute the plutonium in the Tank Farm tanks to a subcritical concentration. The same tendency would be true in tank D-5. The presence of a voluminous, iron hydroxide insures that the plutonium hydroxide is kept in suspension so that it is transferred with the solution. Another aid to complete transfer is that the transfer lines are only 1/4 in. off of the tank floor.

As with solid materials, the criticality limits for liquid systems are enforced at a level far below a full contingency violation. But even close approach to the limit is considered a serious administrative matter and exceeding the value by even a fraction of a gram/liter requires shutdown of the affected process and implementation of a formal recovery plan.

The probability of a criticality during normal operating, maintenance, or emergency situations is considered to be very low due to the engineered barriers and multiple administrative barriers. Should a criticality occur, it would be most likely in concurrence with some otherwise highly unlikely situation. People whose attention was diverted by an emergency situation might attempt an apparent fix to the obvious problem and, as a result, create a situation that ends in a criticality. Another possibility is that plutonium, thought not to be present, might be placed in a critical array during decontamination and decommissioning (D&D) operations. Both of the above possibilities are considered extremely unlikely. Managers and operators undergo periodic training that highlights the fact that the historical criticalities took place during non-normal circumstances. Locations under going D&D are routinely surveyed by gamma scan to determine plutonium inventory and cleaned to very low levels of plutonium.

An extensive system of design controls is in place to reduce the probability that personnel could erroneously create a criticality in either a dry or liquid system. Before any configuration changes can be made, the design must be reviewed for criticality considerations by a specialist in criticality evaluation. Work control plans ensure that modification or maintenance is done properly and checked before use.

During day-to-day work, a set of general limits addresses such items as the size and location of containers or potential containers even on the outside of a glovebox or the use of plastic sheeting for covers or drapes. The number and size of cleaning rags are carefully controlled as a pile of saturated rags may approach an unfavorable shape and could draw solution by absorption. Gloveboxes are equipped with special drains that reduce the probability of deep accumulations of liquid occurring. The size of each drain is specified in relation to the potential for liquid flow and each drain is equipped with a large, coarse screen to prevent plugging. Some drains flow liquid onto the room floor and while such an event can cause a radiological problem, it does prevent formation of a critical system.

The volume of containers, both individual and total, is specified for each glovebox to reduce the probability of accumulating excess liquid. In

addition to process container volumes there are specifications that describe non-containers. At times in the past, hardware was brought into gloveboxes or hoods for purposes other than liquid handling which, in case of an accident, could become containers. For example, years ago a metal box or a quart ice cream carton were commonly used to store tools. Now such containers must have a specified number, size, and arrangement of holes near the bottom. People are taught that even a section of pipe set on end could contain liquid if the liquid was introduced faster than it would leak away.

Avoidance of a criticality depends upon people who are well trained so they can follow the rules of criticality safety even when unusual conditions are outside procedures. Compliance with rules by operators and technicians provides the primary enforcement of the criticality safety program. Probability of criticality is lowered when management strikes the correct disciplinary balance: a balance between enough tolerance to encourage voluntary reporting of posting violations, and the toughness and ingenuity to prevent such low-level violations from becoming prevalent and from escalating to more significant violations.

9.2.3.4.4 Transport and Storage, Probability. Once metal buttons are sealed in tuna cans, the probability of a criticality drops sharply due to the spacing provided by the cans. For buttons in undented tuna cans, the number needed to achieve criticality would be approximately 60, under low or no reflection conditions (Altschuler 1985). This far exceeds the number of buttons that would ever be found in this location because of considerations of criticality control, security, and radiation protection.

Spacing violations do occur during operations in gloveboxes. Normally, the violations involve only a few inches. In boxes which involve clumsy work positions, poor visibility, and crowding, violations of spacing are more likely.

The preceding discussion concerning probability was based on the assumption that the mistakes would be made during normal operating periods when water or other moderators were not present. In addition to normal operations and human errors, the glovebox limits are established with consideration for other contingencies (e.g., water flooding). The presence of water or other reflecting and moderating materials lowers the critical mass significantly so the limits are established with the assumption that the presence of these materials could happen concurrently.

Proper geometric design is used more frequently to control liquid systems but plays a part in dry systems also. Process equipment size and shape is dictated by criticality considerations when some other design might be more efficient from a processing standpoint. Storage vaults are typically equipped with individual storage locations that prevent stacking containers or placing them too close together.

As discussed with regard to bare metal buttons and plutonium powder, rules for handling of material during transport or storage involve contingencies for flooding. The probability of an operator or maintenance person making a mistake which would directly lead to a criticality is quite remote. For example, the critical mass of an array of large 2,500-g metal units, in 4.25-in. diameter by 7-in. high cans in a neatly stacked array,with

full concrete reflection on three sides, would be about 150,000 g. Without being stacked neatly in a corner of a concrete vault, the critical mass would be higher; however, the mass would be lower if the cans were dented in a way that provided less separation. The critical mass for 1,000-g units of $^{239}PuO_2$ in 7-in. cans at a bulk density of 2.6 g/cm^3 would be approximately 450,000 g with full water reflection and approximately 290,000 g for full concrete reflection (Carter 1987). While these are not highly refined numbers or conditions, it is clear that no transport wagon or single storage cubicle contains anything near this amount of material. No quick series of acts on the part a person could cause a criticality. Emphasis in this analysis is placed on the aspect of a short time for initiation and upon a short duration because the probability of a system being left in a nearly critical condition for very long is low also. Should material be left for long, the probability rises for another unrelated event (e.g., a water pipe break) occurring during this period.

9.2.3.5 Accident Analysis. The criticality analyzed is that presented in Regulatory Guide 3.35 (NRC 1979b).

9.2.3.5.1 Assumptions. This criticality produces an initial burst of 1×10^{18} fissions in 0.5 s followed successively, at 10 min intervals, by 47 bursts of 1.9×10^{17} fissions for a total of 1×10^{19} fissions in 8 h. The excursion is assumed to be in a liquid system that is terminated by evaporation of 100 L of solution.

Assumptions related to the release of radioactive materials are as follows:

- All of the noble gas fission products and 25% of the iodine radionuclides are released directly to a ventilated room with no holdup
- The criticality is assumed to occur in a solution; therefore, an aerosol is assumed to be released due to evaporation directly into the room atmosphere. The aerosol is assumed to comprise 0.05% of the salt content of the solution that is evaporated or 1 mg PuO_2
- Since Regulatory Guide 3.35 (NRC, 1979b) is intended for a reprocessing plant, the specified isotopic mixture contains approximately 28% ^{240}Pu rather than the normal weapons grade material with only 6%
- No credit is given for holdup mechanisms in the room or duct work, but the filter system is assumed to be functional. The transmission factor for a single stage of HEPA filters is used as 5×10^{-4}
- The gases and the small residual of plutonium are released to the environment through the 200-ft-high stack and the shorter stacks as a second case
- The amounts of radionuclides assumed to be produced are presented in Table 9-24.

9.2.3.5.2 Methods and Models. This accident includes two models. One is assumed to take place in one of the buildings ventilated via the 200 ft 291-Z-1 stack and the other via the short stacks. The two scenarios differ in the dose to onsite and offsite personnel due to differences in atmospheric dispersion and direct dose.

9.2.3.5.3 Calculations. For calculations, see the general discussion of the GENII code (Van Vleet 1990) and the following sections. The GENII code was used to calculate doses since the methods discussed in Section 9.3 are for inhalation dose, and the NRC accident considered releases noble gases with significant submersion doses.

9.2.3.5.4 Uncertainty. Not applicable as there are no specific scenarios. However, the NRC accident is considered bounding.

9.2.3.5.5 Concentrations Within Facility. As noted above, Regulatory Guide 3.35 (NRC 1979b) requires the assumption that the gases and plutonium aerosol from boiling be released directly to a room. Concentrations within the facility would depend upon the size of the room, exhaust flowrates and conditions from the prescribed model. The model calls for pulsing of the system till reactivity stops after 8 h due to evaporation of 100 L of solution. The event is assumed to take place in one of the smaller rooms. The volume of a small room is taken to be 1.8×10^2 m^3. The air is exchanged at a nominal rate of six changes per hour. The buildup in concentration follows a first-order function so that equilibrium is reached in about six changes or 1 h. Thus, the concentration of plutonium-americium inside the room would reach an equilibrium level and would remain at this level for the next 7 h assuming a constant generation rate. The calculation of the alpha emitting nuclides concentration from the Table 9-24 value is presented as follows:

$$\text{Volume of the room} = 19.5 \text{ ft} \times 33.9 \text{ ft} \times 10 \text{ ft} = 6.6 \times 10^3 \text{ ft}^3$$

$$6.6 \times 10^3 \text{ ft}^3 \times 2.8 \times 10^{-2} \text{ m}^3/\text{ft}^3 = 1.8 \times 10^2 \text{ m}^3$$

$$\frac{1.87 \times 10^{-2} \text{ Ci}}{8 \text{ h} \times 6 \text{ changes/h}} = 3.9 \times 10^{-4} \text{ Ci}$$

Each change is one room volume or 1.8×10^2 m^3.

Therefore:

$$\frac{3.9 \times 10^{-4} \text{ Ci}}{1.8 \times 10^2 \text{ m}^3} = 2.2 \times 10^{-6} \text{ Ci/m}^3$$

The equilibrium concentrations of fission product gases are summarized in Table 9-24. The noble gases were determined by dividing the 0.5 s to 8 h release period values by 7.5 to give the rate per hour; dividing by 6 to give the release per air change; and then dividing by 180 to give the concentration in Ci/m^3. The concentration of the iodine isotopes was calculated similarly except that the concentration was divided by 4, as stated in Section 9.2.3.5.1.

Filter buildup would be insignificant. There would be no ground-level release as all effluents would exhaust from the stack.

9.2.3.6 Dose. Dose calculations used the GENII computer code (Van Vleet 1990) and calculations of direct dose from NRC Regulatory Guide 3.35 (NRC 1979b).

9.2.3.6.1 Assumptions. Assumptions used in the calculations of airborne gases are summarized in Section 9.2.3.6.2. An assumption of the direct dose calculation is that the building offers no shielding. This is a significant conservatism for some locations as several concrete walls may be in the path. The figures given would be very much worst case.

9.2.3.6.2 Methods and Models. In addition to the dose due to the release of radioactive gases there is an external dose received from the prompt gamma rays and neutrons. In the absence of plant-specific calculations, Regulatory Guide 3.35 (NRC, 1979b) presents the following two semi-empirical formulas for the prompt gamma and the prompt neutron dose:

$$D_g = 2.1 \times 10^{-20} \frac{N e^{-3.4d}}{d^2}$$

$$D_n = 7.0 \times 10^{-20} \frac{N e^{-5.2d}}{d^2}$$

where: Dg = Gamma dose, rem
Dn = Neutron dose, rem
d = Distance, km
e = Base of natural logarithms
N = Number of fissions.

For the 2736-Z and 2736-ZB Buildings, the gamma dose is reduced by a factor of 2.5 and the neutron dose rate by a factor of 2.3 to account for the shielding afforded by 8 in. concrete walls. There would be no direct dose to onsite personnel from the 241-Z Building as the tanks are underground.

The submersion, inhalation, and ingestion doses were calculated using the GENII code (Van Vleet 1990). The concentrations of fission product gases and TRU aerosols were used as specified in NRC 1979b and summarized in Table 9-24.

The dose information summarized in Table 9-21 includes the fraction of the EDE due to the direct gamma and direct neutron radiation.

The workplace external to the PFP complex receiving the highest dose due to this criticality is 272-WA, which is 0.63 km to the west-northwest. For a release from the 200-ft-high stack, the onsite MI is expected to receive a 50-yr committed dose of 0.16 rem EDE and 0.27 rem to the thyroid. For a release from one of the short stacks, calculated as a ground-level release, the EDE is 0.73 rem and 2.4 rem thyroid. All onsite doses are below the dose guidelines (Section 9.4) for an event with an annual frequency of 0.1.

The place on the site boundary at which the highest dose is expected is located 13.2 km (8.2 mi) west-northwest of PFP. This also corresponds to a hypothetical site of food production. Thus, the receptor expected to receive the maximum dose due to passage of the cloud is also the receptor expected to receive the maximum dose due to the growing of all nourishment on this one contaminated farm. This person is expected to receive a 50 yr committed dose of 0.032 rem EDE and 0.97 rem to the thyroid from a 200-ft stack level release. For a ground-level or short stack release, the receptor who also lives there and grows all of his own food would receive an EDE of 0.053 rem and a thyroid dose of 1.6 rem.

9.2.3.6.3 Consequences. The consequences are summarized in Tables 9-21 and 9-22 and can be compared with the dose guidelines in Table 9-49.

Since no specific scenario was provided, no specific probability could be calculated. It should be noted however, that the onsite doses for release from the 200-ft-high stack or from the short stacks are below the guidelines for an event with a frequency of 1.0×10^{-1}/yr. The most limiting case is the offsite thyroid dose due to a release from a short stack, which meets the RAG (Section 9.4) for a frequency of 3.8×10^{-2}/yr.

9.2.3.6.4 Uncertainties and Conservatisms. Uncertainties in modeling such as that done in determining both the release fraction and the resulting dose calculation are better thought of as conservatisms. Uncertainties are generally thought of as some kind of a mathematically symmetrical distribution around a central, "best" or "true" value. The deviations from best value in these calculations are generally believed to be skewed entirely to the high side. Thus, the term conservatisms appears to be more appropriate. In addition to the conservatisms discussed in this section, see those in regard to the GENII code (Van Vleet 1990).

It is conservative to include the standard solution criticality for the 2736-ZB facility because solutions are not handled there and solutions tend to give a higher fission yield.

9.2.4 Seismic Event

9.2.4.0 Introduction. The seismic event as it affects the PFP has been reviewed on two separate occasions in the recent past. The results of this review have been presented in Rev. 0 of Marusich (1988a). The seismic event accident analysis presented in Marusich (1988a) was based on the presumed collapse of the facility resulting in large-scale destruction. The analysis presented in Rev. 2 of Marusich (1988a) was based on new, more detailed structural analysis which showed that the facility and the large internal concrete walls did not collapse in the event of a design basis earthquake (DBE); however, it was presumed that the gloveboxes toppled. Since that time some of the gloveboxes have been modified so that they will not collapse or topple.

The analysis of the seismic event presented in WHC-SD-CP-SAD-002, *Safety Assessment for PFP Inventory Sensitivity of the Seismic Event* (Marusich 1994) as incorporated into WHC-SD-CP-SAR-021, Rev. 0, provides the authorization basis for the inventory limits provided in LCO 3.3.1, of the *PFP Operational Safety Requirements* (WHC-SD-CP-OSR-010, Rev. 0). The authorization basis seismic event analysis (presented in Marusich 1994) shows an onsite dose of 20 rem for the 1.0×10^{-4} annual probability seismic event (See Table 5-1 of Marusich 1994). The glovebox inventories used in that analysis are provided in Table 9-61.

The analysis presented below is based on the present glovebox and hood CPS limits. The limits are less than that shown in Marusich (1994) as a result of the inactivation of a number of gloveboxes. The onsite consequences of a 1.0×10^{-4} annual probability seismic event are shown in Tables 9-32 and 9-33. Consequences of additional seismic event analyses are provided in Tables 9-34 and 9-36. The analysis of the seismic events presented in this section includes the effects from seismic induced fires in thermal stabilization Gloveboxes HA-21I and HC-21C, and the seismic effects on Buildings 241-Z and 232-Z. The releases and resultant consequences from the Laboratory Prototype Calciner due to a seismic event are summarized in Section 9.2.4.9 and the details are included in the Laboratory Prototype Calciner addendum to this FSAR. The contribution to the seismic event doses from the calciner are not included in the seismic event summary tables, Tables 9-32, 9-33 and 9-34, since the laboratory calciner is not authorized for operation. The seismic event impacts from operation of the calciner will be reevaluated and included, as appropriate, prior to any future authorization for operation.

For the seismic event, the initiating event is the DBE. However, the task of "choosing" one or more failures to maximize the release within the annual probability limit of 10^{-6} becomes quite difficult because the probability of the design basis natural phenomena is already low (10^{-3} to 10^{-4} annual probability). The PFP is safe without an operational ventilation system and without the operation of many other systems due to the low stored energy of the process, good choice of process materials, and intelligent grouping of process steps in particular gloveboxes. So if it is assumed that everything not "qualified" fails, the facility could still have acceptable consequences provided the facility remains intact (exterior and interior major walls and floors).

For the purposes of this Seismic Event accident analysis the assumption is made that if a component is not qualified, it will fail in the way that results in the largest release. The probability of the aggregate of these selected, specific, simultaneous failures in combination with the earthquake is judged to be extremely low. However, this cannot be proven. Therefore, the approach taken here is to assume the earthquake occurs and to choose failures so as to maximize the release.

The analyses assumed that the gloveboxes, hoods, and filterboxes that are seismically qualified will remain standing. Those that are not qualified are assumed to fail. Glovebox seismic qualification, shown in Table 9-25, is based on engineering analyses (Ocoma 1988, Ocoma 1990a, Ocoma 1990b, Marusich 1988a, Vollert 1987a, and Vollert 1987b). It has been shown that the facility structure will survive the effects of the earthquake. The situation presumed for this seismic accident analysis is one in which the facility structure remains upright, but within the structure and gloveboxes, it is referred to as "abnormal operation." Abnormal operation is taken as process operation under the conditions where, due to the earthquake:

- Normal flow streams may not be present
- Normally open active (not manual) valves may suddenly close or closed valves open
- Lines may sever
- Tanks may fail
- Glovebox panels may fall out
- Structures on the main facility (e.g., the covered walkway on the east side of 234-5Z Building) may fail
- Pumps which were off may start and continue operating.

9.2.4.0.1 Organization of Section. A seismic event is different from other events analyzed in Chapter 9.0 in that the seismic forces are applied simultaneously at all places in the facility. The 234-5Z Building was designed and built in the late 1940s when the technology of seismic evaluation and design was not as well developed as today. Subsequent structures were generally built to standards near to those in effect today but equipment design generally did not address seismic considerations. (Analyses performed for the section have determined that most facilities and much of the equipment will withstand seismic loads.) Thus, this section on the seismic event is large. The normal rules of paragraph designation become overburdened as the logic of organization sets up eight or nine levels of paragraphing. It becomes difficult for the reader to cope with such a string of alpha and numeric characters. Thus, at the lower levels of paragraphing, a dual system of decimal characters and word descriptions is used.

The paragraphing and logic behind it are presented in the sections as follows:

- **9.2.4.1**--Step 1 is presented to understand the response of each facility and glovebox to seismic loads. Facility or glovebox survival or failure is important to scenario development.

- **9.2.4.2**--Step 2 is presented as an examination facility by facility and, within each facility, glovebox by glovebox to determine what accidents can occur as a result of seismic loads. The accident scenarios are based on facility and glovebox response assuming that there are no preexisting failures and that the process is proceeding normally (e.g., flowsheet).

- **9.2.4.3, 9.2.4.4, 9.2.4.5, and 9.2.4.6**--Step 3 is presented to determine the release into each facility from the scenarios developed in Section 9.2.4.2. This is done by choosing the worst case accident scenario for each glovebox, applying appropriate release fractions, or developing a method which determines the release of plutonium into each facility. This is done for each glovebox within each facility. Section 9.2.4.6.3.12 summarizes the total release for each facility by room.

- **9.2.4.7**--Step 4 is used to present methods used to calculate the fraction transported out of the facility. Exhaust fan and wind pressure induced flow were investigated. Particle deposition was also factored into the release fraction.

- **9.2.4.8**--This section is presented to summarize the calculated doses due to the bulk of facility release. A refinement to the transport-out-of-the-facility method is presented and then the dose as a result of the release is calculated.

- **9.2.4.9**--This section presents the results of the seismic event analysis for the Laboratory Prototype Calciner in Room 188 of the PPSL. The results are not included in the seismic event consequence totals for the facility since the calciner is not authorized for operation.

- **9.2.4.10**--This section presents the contribution to the seismic event from the Magnesium Hydroxide Process in Glovebox HC-230C-3 and HC-230C-4.

- **9.2.4.11**--This section presents the contribution to the seismic event from the Bagless Transfer System Glovebox.

- **9.2.4.12**--This section presents the summation of the doses to the onsite and offsite receptors from a seismic event from Sections 9.2.4.8 (bulk of the facility including Buildings 232-Z and 241-Z), 9.2.4.10 (Magnesium Hydroxide Precipitation Process), and 9.2.4.11 (Bagless Transfer System).

9.2.4.0.2 Summary. The release of respirable Pu from PFP and Building 232-Z given the occurrence of a DBE is calculated for two cases. In the first case, the ventilation systems are assumed to be either failed off or shut down. In the second case, it is assumed that the exhaust fans continue running.

The radiological consequences associated with releases for these two cases are presented in Tables 9-32 and 9-33. The radiological consequences are below the Risk Acceptance Guidelines except the no ventilation onsite consequence. The seismic analysis related to the Laboratory Prototype Calciner is discussed in Section 9.2.4.9 and the details are found in the Laboratory Prototype Calciner addendum to this FSAR. The laboratory calciner is not currently authorized for operation. Therefore, the consequences of a seismically initiated release are not included in the total facility consequences for a seismic event.

The release of hazardous materials (specifically HNO_3) was also evaluated and found to be below the Risk Acceptance Guidelines.

9.2.4.1 Building Seismic Analyses.

9.2.4.1.1 Building Response During a Seismic Event. The older major structures, 234-5Z, 291-Z, 242-Z and 236-Z, and the stack at the PFP have been analyzed by J. A. Blume Engineers. The 2736-Z, -ZA, and -ZB structures were designed to withstand seismic forces. The 232-Z structure was analyzed and shown to have favorable load to capacity ratios but has not been qualified to withstand a DBE. The chemical storage tanks have not been analyzed for currently required seismic loads and, therefore, are assumed to fail in the analysis. The 241-Z facility has been analyze. A summary of the analyses taken from their reports follows.

234-5Z Building Response (URS 1987). Previous preliminary seismic analyses indicated that 0.25-g DBE motions may produce nonlinear responses and possible structural distress in the 234-5Z Building (i.e., the facility may collapse). It was recognized, however, that the building had considerable capacity to resist DBE loads in the nonlinear range. Therefore, the comprehensive linear and nonlinear 234-5Z Building seismic analyses and evaluation described here were undertaken. The objectives of this study included consideration of all the building elements that realistically contribute to its lateral (seismic) resistance and determination of whether the building could resist the DBE without collapse.

The scope of the seismic analysis and evaluation of the 234-5Z Building required a rigorous dynamic seismic analysis using a detailed, three-dimensional, nonlinear model of the building. Element properties for the model were based on detailed review and onsite measurements inside the building as well as mockup cyclic testing of beam-column connections to determine moment rotation relationships. Equivalent static analyses were conducted to understand details of the structure's lateral-force-resisting system. Seismic demand on the structure was calculated using direct integration time history dynamic analyses for three components of ground motion, including consideration of large displacement effects.

The results show that the DBE response of the building is mainly linear elastic. Only four beam-to-column connections yield, and remain comfortably below ultimate rotational capacities. The east-west displacements are small, 0.33 in. maximum at the roof. The maximum north-south displacement is over 7 in. at the roof. The north-south displacement at the second floor level is 3 in. maximum.

The main conclusions of the 234-5Z Building DBE analysis and evaluation follow.

- The building, as is, could resist DBE motions without collapse.
- Separation and some seismic pounding are expected between the second floor slab and the stairwells; shear cracks could develop in the stairwell walls. The integrity of the building and the use of the stairwells for egress will not be threatened.
- The north-south concrete walls along column lines 4 and 8, need to be isolated from the lateral load path such that the columns do not attract seismic shear forces that may exceed their capacity.

A further assumption is made that the building separates along Column 12 (the building joint) due to presumed differential motion between the east half and west half. In addition, the side panels were assumed to tear, buckle, or pull out of the girders at the attachments. This damage is slight on walls perpendicular to the earthquake direction and on walls nearer to the ground. The damage is more pronounced in walls parallel to the earthquake and at upper levels. Recently a test was performed on panels in which a bounding condition of the seismic loads was applied. The panels suffered only minor damage around some of the fasteners, therefore it is assumed in this analysis that the panels remain intact.

234-5Z Building Panel Response. The results of tests that were performed on sheet metal wall panels fabricated to be approximately the same as the 234-5Z Building existing wall panels are described in (Giller 1989b). The tests simulate the wall panel reactions to seismic displacements.

The series of panel drift tests (applies a displacement which changes a rectangular panel into a parallelogram) were designed to evaluate diaphragm shear strength of the wall panel due to building drift during a seismic event. The test results showed the panel section to be very rigid in diaphragm action. The effect on the panel after being subjected to 160% of the expected drift from a seismic load was elongation of some bolts holes by about 1/4 in. These tests qualify the building panels to remain attached to the building during a design basis seismic event.

291-Z Stack Response. Previous preliminary and conservative seismic evaluation of the 291-Z Building and stack indicated that the building was structurally adequate to resist the lateral forces due to the postulated DBE loading, but the stack showed overstress (URS 1980). The seismic demand of the stack was calculated by the linear elastic response spectrum procedure, assuming a fixed base.

In the present study, (URS 1988a) the demand on the stack was calculated using an equivalent stick model. The soil half space surrounding the structure was modeled by frequency-independent springs to account for soil- structure interaction (SSI) effects. The stack responses were calculated using the time history modal superposition procedure with the free-field time histories conservatively applied at the embedded basemat level. The calculated demand was then compared with the capacity of the stack. The stack's capacity to resist horizontal and vertical DBE loading was rigorously calculated on the basis of nonlinear behavior of concrete and reinforcement bars. The nonlinearities considered were concrete cracking, parabolic compression behavior of concrete with crushing and ultimate strain specification, and elastic-plastic behavior of reinforcing bars. The capacity for reinforcement bar yielding initiation and the

ultimate capacity were calculated for each section of the stack. The results of this study show that the stack has enough ultimate capacity to resist the postulated DBE loading with ductile behavior.

This study rigorously and conservatively evaluated the capacity of the 291-Z stack to resist the postulated DBE with a zero period acceleration (ZPA) of 0.25 g. Alternative calculations were also performed to show the conservatism of the present evaluation. The conclusions of this study may be summarized as follows.

1. The dynamic analysis and evaluation of the Hanford Site 291-Z stack demonstrates that the stack reinforcing has enough ductile capacity to resist the DBE loading without collapse.

2. The steel reinforcement in the lower section of the stack is expected to yield, but the calculated steel strain is much less than the failure capacity of steel.

3. The maximum horizontal and vertical displacements at the top of the stack have been shown to be less than 8 in. and 0.2 in., respectively.

4. The maximum horizontal acceleration at the top of the stack has been calculated to be less than 0.8 g.

236-Z Building Response. Seismic analyses and evaluations were performed for the 236-Z Building to determine whether it can resist the 0.25-g DBE. Three-dimensional, lumped-mass beam models of the building were developed. Seismic forces and moments for these models were computed by using the modal superposition response spectrum method of dynamic seismic analysis. The overall seismic forces and moments were distributed to the individual walls and diaphragms and evaluated against their calculated code-allowable capacities. The evaluation indicated that the 236-Z Building will meet the code requirement to resist the DBE motions postulated for the site. Specific conclusions for the key structural members are as follows.

1. **Roof**--The metal roof deck has a maximum demand/capacity ratio of 0.94, indicating that it meets the code requirement.

2. **Concrete Floor Slabs**--All the slabs meet the code acceptance criteria.

3. **North-South Walls**--All the reinforced concrete walls oriented in the north-south direction have demand/capacity ratios of less than 0.62 for shear and overturning moments. All the north-south walls meet the code requirement.

4. **East-West Walls**--All east-west walls, except one, have acceptable demand/capacity ratios of less than 1.0 for shear and overturning moment. East-west wall 4 has a ratio of 1.23 for overturning. However, this is a minor wall, and the loads from this wall can be carried by the adjacent east-west wall 3, which has more than adequate capacity to carry the additional overturning force.

5. **Concrete Block Wall**--The concrete block wall (4-in. and 8-in.-thick) at the south cell wall does not meet the acceptance criteria since it has a demand/capacity ratio greater than 1.0. This ratio is not based on

inspection since inspection results were not available. It is to be emphasized that this is not a load-carrying wall, and its performance will not affect the structural behavior of the building. The entire area of the concrete block wall has been covered with welded steel plates which overlap into the poured concrete wall. The plates were installed on the exterior side with anchor bolts and sealed all around to preclude a leak path.

2736-Z Storage Complex Response. The 2736-Z storage complex is comprised of three buildings: 2736-Z, 2736-ZA, and 2736-ZB. Building 2736-Z is connected to 2736-ZA via a short (i.e., approx. 5 ft) ventilation duct.

Building 2736-Z. The 2736-Z Building storage vault is a single-story, reinforced concrete structure with four individual vault rooms. Within each room Pu is stored in shipping containers, or in storage cans placed on racks or in concrete storage cubicles. This building was seismically qualified at the time of its construction in the 1970-1971 time frame in the *Seismic and Tornado Analysis of Buildings 224-T and 2736-Z*, Vitro-R-161 (Lien and Vollent 1972). The method used by Lien and Vollent (1972) was reaffirmed in 1991 by a study that independently verified the building as a rigid structure and the appropriateness of the modeling method used at the time of construction. The structure was reanalyzed in 1994 (Giller 1994a) for normal operating and natural phenomenon loads. Equivalent static methods (versus dynamic methods) were used as recommended by *Design and Evaluation Guidelines for Department of Energy Facilities Subject to Natural Phenomena Hazards*, UCRL-15910 (Kennedy et al. 1990) for simple regular structures that have uniform mass and stiffness distributions. All structural members of the 2736-Z building were found to have positive margins of safety with respect to the material design strengths.

Additional seismic considerations in the mid-1970's provided container integrity assurance through shaker table testing of the pedestal storage configuration, and the establishment of Operating Specifications for storage that provide controls on container contents and packaging materials. The seismic qualification of storage cubicals, pedestals and racks were reanalyzed in 1994 (Ocoma 1994). It was found that the precast concrete cubicals and the pedestals were adequate to withstand DBE loads as were the two different types of metal storage racks in vault 2 used for the storage of 7-in cans. However, it was found that the anchor bolt loads of the storage racks in vault 2 used for the storage of lard cans exceeded allowable load capacities. Consequently, modifications have been made to the facility to assure the cans remain on the storage racks in the event of a DBE. Specifically, bracing has been installed to prevent the racks from falling over and seismically qualified retaining devices (chains) are installed to prevent cans from falling off shelves.

Building 2736-ZA. The 2736-ZA Building was designed in 1976 to provide a stand alone two-stage HEPA filtered exhaust system for the Pu storage vault. This system replaced the original means of exhausting the vaults through one-stage HEPA filters via the 234-5 Building ventilation system. This one-story precast concrete building and its essential equipment were built to the Hanford Standard Design Criteria SDC 4.1, which specified a maximum horizontal ground acceleration of 0.25 g at zero period. The exhaust fans, filters, and diesel generator are mounted on seismic snubbers and were analyzed to be resistant to the design basis earthquake by the supplier using dynamic response analysis techniques.
The building was reanalyzed in 1994 (Giller 1994b) using an equivalent static

analysis method. All structural members of the building were found to have positive margins of safety with respect to the material design strengths.

Analyses of the storage vault exhaust system were also performed in 1994 (Ocoma 1994). The specific elements analyzed were: the exhaust stack, exhaust fan and HEPA filter assembly, diesel generator, and the exhaust interface duct assembly connecting Buildings 2736-Z and 2736-ZA. The diesel generator has since been removed and replaced with an intertie to the Building 2721-Z diesel generators. The exhaust stack, exhaust fan/motor assembly, and HEPA filter assembly were found to be adequate to withstand DBE seismic loading. Due to differential motions between Buildings 2736-Z and 2736-ZA of up to 0.216-in. in-line displacement and 0.17 in. lateral displacement, shear tearing failure of a light gage sheet metal portion of the interface duct assembly could occur leading to very small cracks. The duct, however, will remain in place and provide an acceptable flowpath after the DBE. Based on the above information, it was concluded in *Seismic Analysis of Safety Class 3 Equipment in 2736-Z Complex*, WHC-SD-CP-SA-026 Ocoma (1994) that the function and operability of the exhaust system was reasonably provided for, although by no means assured, following a DBE. However, an evaluation of the potential for a release of Pu through the cracks in the duct is shown in Section 9.2.4.6.3.6.E.

Building 2736-ZB--The 2736-ZB Building was designed in 1980 to provide support functions for the 2736-Z Pu storage vaults. These support functions include shipping/receiving functions, a nondestructive Pu assay laboratory, and a glovebox for repackaging cans of Pu to support the long term storage mission of the vault. The project design criteria required conformance to the Hanford Standard Design Criteria SDC 4.1 for the structure and the ventilation system because it acknowledged that Pu might be dispersed within the facility during a seismic event from failure of containment provided by the repackaging glovebox. The structure was analyzed using a rigid response method at 0.25 g. The stresses under static loadings were found to be low and within acceptable code limitations with adequate margins to be qualified. The approach used to qualify the mechanical equipment, such as the ventilation supply and exhaust systems, was to procure a frame mounted assembly that would be mounted on snubbers attached to embedments in the floor and seismically isolated from other ducts using flexible connections. The equipment assemblies were modeled and dynamically analyzed by the vendor, and shown to have acceptably low loads. The filter housing assemblies used in the ventilation equipment package are commercially available shaker-test qualified equipment.

Building 2736-ZB was reanalyzed in 1994 (Weiner 1994) using an equivalent static analysis method. All structural members of the building were found to have positive margins of safety with respect to the material design strengths. The repackaging glovebox was also analyzed in 1994 (Ocoma 1994). It was found that the glovebox support frame and anchorage was adequate to withstand DBE loadings, i.e, that the anchor loads and the stresses in the support frame members, connections between the support frame and the glovebox, and the filter housing support were less than the allowable values.

291-Z Building Response (URS 1980). Preliminary evaluation of the 291-Z Building for the postulated earthquake ground motion was based on the assumption that the soil surrounding the structure does not provide any lateral support to the building. This assumption leads to simplified and generally conservative results, but it does not consider the interaction between the soil

and structure (called SSI). In order to study SSI during an earthquake, the computer program FLUSH, which employs a finite-element analysis technique that takes into account the variation of ground motions and soil characteristics with depth, was used. The FLUSH code has the following analytical capabilities:

- It considers the variation of soil characteristics with depth
- It considers nonlinear and energy-absorbing characteristics of soil
- It considers variation of ground motions with depth
- It considers the three-dimensional nature of SSI
- It can consider the effects of adjacent structures on each other, although this aspect was not utilized in the present analysis.

The building was analyzed for ground motions only in the east-west direction, as this direction was judged to be more critical that the north- south. Also, the analysis was carried out only for the DBE motions, since it was expected that as a result of preliminary evaluation, the building would qualify for DBE loads.

The results of the analysis indicate that bending moments predominate. Shear forces are well within the ultimate shear capacity of the section. Axial forces are less the 4% of the ultimate axial capacity. For this reason, interaction between the axial forces and bending moments was found to be insignificant. Although it is difficult to accurately assess the capacity of chord reinforcement against lateral loads from the results of the FLUSH analysis, based on preliminary results, local yielding of chord reinforcement at the first floor level due to the DBE lateral loads is expected. However, overall structural integrity will be maintained due to redistribution of forces and moments to the adjoining walls, which are able to accommodate these forces. In other words, the results of confirmatory seismic analysis of the building for the DBE loads indicate that, except for the chord reinforcement in the first floor slab, the computed forces and moments are well within the ultimate section capacities. The chord reinforcement at first floor slab level would yield, leading to minor cracking of concrete; however, overall structural integrity would be maintained due to the ability of the walls to sustain the lateral loads through redistribution of forces.

242-Z Building Response. The building was evaluated in accordance with the requirements of HPS SDC 4.1, Revision 10, and DOE Order 6430.1A. The load combinations in this study included dead load, earthquake loads, and specified equipment live loads, not concurrent with snow or ashfall loads as justified by UBC 1994 and WHC 1991a, respectively. The study included preparation of a three-dimensional computer model in order to perform a dynamic modal analysis from which member stresses are computed. The evaluation showed that one base plate anchor is marginal but the others have ample strength and therefore in the "as-is" (cleaned out and no operations occurring inside) condition the building will survive.

232-Z Building Response. The building was evaluated in accordance with the requirements of HPS SDC 4.1, Revision 12, and DOE Order 6430.1A. Based on this evaluation, it is concluded that the building will withstand a 0.09-g seismic event but is not qualified for a DBE of 0.20-g. Consequently, subsequent seismic

scenario evaluations in this section of the SAR consider the effects of both seismic events on this structure.

9.2.4.2 Seismic Accident Scenarios. A large earthquake is assumed to strike PFP. The size of the earthquake is assumed to be 0.20-g. The 0.20-g is the design basis/DBE for Hanford based on WHC 1991a and is the event for which the facility analyses were performed (see also Marusich 1988a, pp. 4-33, 4-34). In addition, a 0.09-g seismic event was considered since the 232-Z Building may not withstand a larger seismic event and releases may occur with events greater than 0.09-g.

The earthquake affects the facility and the facility internals such as internal structures, gloveboxes, piping, ventilation ducts, pumps, motors, valves, control system logic and equipment, electrical power, and filters. The damage will be described on a room-by-room basis with the description centering on those events that could result in the dispersal of plutonium or toxic materials (including inert gases). This is not the only damage that could occur in an earthquake, but it is the only damage of interest for the FSAR. Toppling of gloveboxes is considered later for criticality implications. The potential for seismic-induced glovebox fires is also considered later. The following describes what events may occur as a result of the earthquake, and what the "worst case" events are. The consequences of this are found in Section 9.2.4.6. The facilities considered were:

- 234-5Z
- 236-Z
- 241-Z
- 242-Z
- 232-Z
- 291-Z
- 2736-Z, ZA, and ZB
- Outside tanks around 234-5Z and 236-Z.

Several gloveboxes and hoods were specifically excluded from analysis because they are inactive. Several conveyors were also specifically excluded because they are normally empty. The conveyors and inactive gloveboxes and hoods are identified in Table 9-25. The column entitled "maximum plutonium allowed per CPS" contains the values in place at the time of the analysis.

The inactive gloveboxes and hoods were not included in this analysis because the residual quantity of Pu material in them is small in comparison to the dispersible Pu inventories assumed for the active gloveboxes and hoods. Piping and vessels in inactive gloveboxes have been drained and flushed and the gloveboxes swept, vacuumed or slurped to remove the majority of accumulated Pu material, to minimize direct dose exposure to workers. The residual Pu inventories in inactive hoods have been similarly minimized. The residual material in inactive gloveboxes and hoods is electrostatically or chemically adhered to surfaces or is contained in crevices or the internals of equipment where it is much less susceptible to resuspension than bulk material in open containers in active gloveboxes or hoods. NDA results verify that residual Pu in inactive gloveboxes and hoods are small in comparison to the dispersible inventory limits assumed to be subject to release in active gloveboxes and hoods. For example, the best estimate of the residual inventory in Glovebox HC-10, based on NDA results, is 31 g, compared to the CPS limit of the adjacent active Glovebox HC-11 of 30,000 g. All active gloveboxes are assumed in this accident analysis

to contain their CPS inventory limit at the time of the seismic event, whether or not the gloveboxes are currently in use for storage or processing of material. This results in very conservative dose estimates for the active gloveboxes that more than offsets the potential material releases neglected for the inactive gloveboxes.

Conveyor gloveboxes are used for interglovebox material transfers. As stated above, conveyor gloveboxes are normally empty. Because active gloveboxes are assumed to be at their CPS Limits, it is logically consistent to exclude the conveyors from analysis (i.e., if material is in a conveyor, then at least one, and more likely two gloveboxes would have to contain less than the CPS limit).

In addition to the assumptions described previously, the Seismic Event Accident Analysis is based on the following:

- There is no processing in rooms 153, 145, and 149 of 234-5Z (previous SARs have discussed operations other than temporary storage)
- The AL only contains nominally one pound propane bottles limited to a total of six in 234-5Z, with no more than two simultaneously located in a single room.
- The inventories of plutonium present are assumed equal to the CPS limits as shown in Table 9-25, except as modified by Table 9-26. Table 9-26 presents administrative limits for select areas (e.g., the Standards Laboratory) or gloveboxes that are more restrictive (i.e., smaller) than the CPS limits. These administrative limits were derived specifically for the purposes of risk acceptance.
- Chemical storage is as described herein (molarity and concentration)
- There are no operations in the PPSL other than what is currently being performed (See Section 9.2.4.2.1.I.). Consideration of the PPSL Laboratory Prototype Calciner releases resulting from a seismic event are summarized in Section 9.2.4.9 and the details are shown in the Laboratory Prototype Calciner addendum to this FSAR. The calciner releases are not included in the total facility releases since the calciner is not currently authorized for operation.
- That $KMnO_4$ and glycerine are kept in separate rooms and that iodine and NH_4OH are kept in separate rooms.
- No plutonium metal production will take place.
- The E-3 and E-4 HEPA filters are not seismically qualified and are assumed to fall from the filter frames.

The scenarios are developed by reviewing the glovebox operations, design and support systems (air, chemicals, ventilation, etc.) used. The failures which could result in the dispersal of plutonium are listed. Qualitative arguments are used to narrow the list to the one or two "worst case" events. Section 9.2.4.6 discusses the worst event for the bulk of the facility. From the analysis it should be clear that this event does result in the largest dispersal of plutonium within that glovebox. Some attempt has been made to consider glovebox

interactions (i.e. an accident in one glovebox may make the accident in the other glovebox more or less severe), but it was almost always found that the worst case accidents were independent.

9.2.4.2.1 Accident Scenarios, 234-5Z Building.

9.2.4.2.1A Accident Scenario, 234-5Z Rooms 100 Through 130--These are offices, locker rooms, or rooms no longer in existence. No releases are postulated for these areas.

9.2.4.2.1B Accident Scenario, 234-5Z Rooms 131 Through 157, PFPAL--Laboratory analysis is performed in rooms 131 through 157 on samples received from PFP Operations or others. The samples are in the form of powder and solution. Measurements include fissile material content, impurities, isotopic content, SpG, sinterability, LOI for oxide powders, and particle size. The total dispersible Pu inventory in the PFPAL, PPSL, and standards lab is controlled to 12,450 g of which no more than 5,250 g is > 10% ^{240}Pu (see Table 9-26). Note that the sum of the local inventories allowed by criticality prevention specifications would be several times this amount. Some of the gloveboxes contain argon so that there could be an argon release to the room and through the laboratory. There are fire suppression systems in the laboratory so that an earthquake could result in a release of water to the laboratory. In addition, the following gloveboxes have had sources of energy in the past sufficient to disperse material to a greater extent than simple spilling.

- **Room 139**--Glovebox 5: storage of plutonium samples.
- **Room 143**--Hood 3 and glovebox 4: $C_2H_2O_4$ added to solution.
- **Room 144**--Hoods 7 and 8: storage of concentrated plutonium solution, and Hood 4: dissolve samples.
- **Room 145**--Sintering furnace.
- **Room 146**--Discussions with operations show H-1, -2, -3, and 4-146 are inactive. For H-5, which is still active, CPS-L-114-00020 (WHC 1991b) allows 2,500 g of dry Pu with no liquid present in the box or 1,000 g of dry Pu if up to 1 liter of liquid is in the box.
- **Room 149**--Dissolving plutonium compounds.
- **Room 152**--Glovebox 552: waste concentrator, caustic scrubber (Inactive).
- **Room 153**--Contains compressed air and nitrogen bottles, hydrogen generation system and piping, compressed air, liquid nitrogen and 150 to 250 g Pu per hood.

Due to changes in the laboratory operation, there is no processing in room 153 (no hydrogen generator, etc.), no sintering in room 145, nor is there any dissolving in room 149. The operation in room 143 is a manual laboratory operation (i.e., operator pours oxalic crystals, purges, then filters using bottles and beakers). The storage in room 144 is in polyjars inside tubes with taped-on tops. The storage in room 139 is in small vials about 5 or 10 mL. The

racks are metal and resemble test tube holders so that the vial is supported on the bottom by a metal plate and at mid-height by another metal plate.

Therefore the earthquake will be assumed to possibly result in:

- Containers in hoods "falling" out of the hood and onto the floor
- Containers in the gloveboxes falling over
- The shelves in glovebox 5 of room 139 falling, with subsequent dispersal into the room through the clear panels which are assumed to fall out (or shatter)
- Loss of argon into rooms
- Failure of the glass concentrator tank and pressurization of glovebox 552 (inactive) in room 152 due to a failure in the steam line
- Oxygen-aided fire in room 136 (arc from Quantimeter and oxygen release)
- One-pound propane bottle falls onto the floor and ignites (room 144).

9.2.4.2.1C Accident Scenario, 234-5Z Rooms 158 Through 165, 167, and 168--Shops or offices. No release postulated.

9.2.4.2.1D Accident Scenario, 234-5Z Room 166--Room 166 contains the plutonium solution storage gloveboxes HC-4 and HC-6, a hood (designated the "south" hood), and an encased plutonium solution transfer line. Neither glovebox is presently in use. Glovebox HC-4 contains six glass tanks, each containing up to 22 L of solution (water, nitric acid and plutonium nitrate). The criticality specification allows a total glovebox Pu inventory of 52.8 kg. Criticality is discussed in Section 9.2.4.2.11. Glovebox HC-4 is seismic qualified. Other events considered but judged not to be the most severe case are as follows:

- Failure of the tanks or piping (there is a criticality drain in the tank which does not appear to be able to be failed such that it will plug; however, criticality will be addressed later)
- Failure of the encased transfer line (the tanks have more volume than a transfer line does and will impact the floor from about the same height)
- Failure of the concentrated HNO_3 line (the room is locked and normally is not occupied--a more severe case would be a failure of the line somewhere else).

9.2.4.2.1E Accident Scenario, 234-5Z Rooms 169 and 170--Gloveboxes HA-40F and HC-46F are not in operation and contain no measurable plutonium inventory, so there is no contribution from these gloveboxes.

9.2.4.2.1F Accident Scenario, 234-5Z Room 171--Airlock.

9.2.4.2.1G Accident Scenario, 234-5Z Rooms 172 and 173-- Rooms 172 and 173 have floor storage of PR cans which will remain intact during a drop or fire.

9.2.4.2.1H Accident Scenario, 234-5Z Rooms 174 and 175--Rooms 174 and 175 are storage vaults containing cabinet (room 174) or pedestal (room 175) storage. Analysis shows that the pedestals will not fail, the anchors to the wall and floor will not fail, and the container will not come out of the holder (Vollert 1987a, 1987b). Ventilation is needed in these storage areas. Loss of ventilation could result in container pressurization due to energy buildup.

9.2.4.2.1I Accident Scenario, 234-5Z Rooms 179 through 189-- Rooms 179 through 189 comprise the PPSL. The gloveboxes in the rooms are used to support bench scale (mostly wet) chemical procedures to support process development. Examples of these procedures are dissolution, reclamation of plutonium from scrap, extraction, and small scale plutonium work such as using the scanning electron microscope (SEM), etc. The PPSL along with the analytical and standards labs have an administrative limit of 12,450 g dispersible Pu total of which no more than 5,250 g can be >10% ^{240}Pu. The gloveboxes and hoods in the PPSL are not seismically qualified. It will be assumed that the powders or solution spill onto the floor.

Consideration of releases resulting from a seismic event impacting the Laboratory Prototype Calciner are summarized in Section 9.2.4.9 and the details are presented in the Laboratory Prototype Calciner addendum to this FSAR. The laboratory calciner is not currently authorized for operation. Therefore, the releases are not included in the total facility release resulting from a seismic event.

9.2.4.2.1J Accident Scenario, 234-5Z Room 190--Room 190 contains pedestal storage. See Section 9.2.4.2.1H.

9.2.4.2.1K Accident Scenario, 234-5Z Rooms 192-A, 192-B, and 192-C-- Rooms 192-B and 192-C contain pedestal storage of plutonium compounds, and as such are similar to room 175. (See Section 9.2.4.2.1H.) Room 192-A has floor storage of Fast Flux Test Facility (FFTF) fuel pins and bundles in shipping containers which will not be ruptured during the seismic event.

9.2.4.2.1L Accident Scenario, 234-5Z Rooms 191, 192-D Through 221-B-- Offices, shops, etc.

9.2.4.2.1M Accident Scenario, 234-5Z Rooms 221-C, 221-D, and 221-E-- Rooms 221-C, 221-D, and 221-E are the Radiochemical Standards Laboratory. The Radiochemical Standards Laboratory contains NDA equipment, balances, blenders, etc. for the making up of standards. The plutonium is in liquid or oxide form, but is normally doubly contained, except for that being used. Dispersal is similar to that in rooms 131 through 157.

9.2.4.2.1N Accident Scenario, 234-5Z Rooms 222, 223, 224, and 226--Except for room 224, no radioactive materials are present in these rooms. Storage of special containers (PR cans, L-10s, etc.) is allowed in room 224. The multiple-confinement features of these containers preclude release of the contained fissile materials.

9.2.4.2.1O Accident Scenario, 234-5Z Room 225--Room 225 is a storage vault. Fixed array storage in cubicles is allowed for laboratory standards samples. Seismic evaluation of the vault (Vollert 1987b) recommended installation of struts between the vault east and west walls and attached to the top of all shelve units

to ensure seismic resistance of the shelve storage units (cubicles). Inspection of the vault (Letter 1AK00-00-005, R. A. Giller to R. E. Gregory and M. D. Talbot, 2/22/2000) indicates the recommended struts were installed. The shelve cubicles are equipped with locking doors. The locking cubicle doors prevent material containers from falling from cubicles and the struts ensure the shelve units do not tip together at their tops as a result of a seismic event. Ventilation is needed in these stroage areas. Loss of ventilation could result in container pressurization due to overheating. This is discussed further in Section 9.2.4.6.3.1I.

9.2.4.2.1P Accident Scenario, 234-5Z Room 227--Plutonium solutions from PRF are pumped into the tanks in HC-227S. Plutonium solutions are also drawn from PR cans using equipment in HC-227T, which also pumps the solution to HC-227S tanks. The worst case event in this room is the failure of the discharge line of the pump used for recirculation of the solution near the top of the tank, coupled with a failure of the glovebox panels and creating a fountain-like situation. Other failures considered were line break, tank failure, and trolley falling onto a PR can in HC-227T. The trolley will likely not tip the PR can over as the trolley is small. Since the PR can is used in shipping, it must be able to withstand impact loads so that if tipped there should be no spill. If there is a spill, the amount of solution made airborne is much smaller than the case where the discharge leg of the pump fails. A similar case can be made for the line break and tank failure. Criticality will be discussed later in Section 9.2.4.2.11.

9.2.4.2.1Q Accident Scenario, 234-5Z Room 228-A--Room 228-A is one of the three rooms which house the RMC Line. It contains gloveboxes HC-7, HC-9B, HC-10, HC-11, and conveyor HC-1. Each glovebox will be considered separately.

Accident Scenario, 234-5Z Room 228-A HC-7. Glovebox HC-7 contains equipment to chemically adjust plutonium-HNO_3 solutions [convert any (VI) or (III) to (IV) and achieve the proper HNO_3 balance and molarity], and adjust the offgas and filtrate from the processes in HC-9B. Failures that were considered were:

- The HNO_3 transfer line break
- The H_2O_2 line failure
- Failure of tanks in the glovebox
- The $KMnO_4$ line failure inside or outside the glovebox
- A larger and more rapid addition of H_2O_2 to the Pre-Reduction Tank (PRT), as compared to the flowsheet (pressurization of the tank)
- Discharge leg failure on the pump that transfers the solution out of the Transfer Head Tank (THT) to HC-9B (either coupled with encasement failure or glovebox panel failure--could also be coupled with failure in the valve between the PRT and the THT, resulting in additional solution dispersed).

The worst case radiological events will be either the fast addition of H_2O_2 to the PRT [H_2O_2 reacts with PuO_2 $(NO_3)_2$] to liberate oxygen which could pressurize the tank] or the failure of the discharge line on the pump. Both will be investigated. The worst case toxicological release is considered to be the

reaction between $KMnO_4$ and H_2O_2. The reaction liberates some oxygen but not enough to pressurize the room; however, the failure of the peroxide line may result in a toxic material release.

Accident Scenario, 234-5Z Room 228-A HC-9B. Glovebox HC-9B contains the chemical reactor, the screw calciners, and the offgas equipment (condenser, vacuum receiving tank, etc). In the reactor, plutonium HNO_3 was reacted with $C_2H_2O_4$ to make plutonium oxalate. In the screw calciners, the plutonium oxalate was converted to PuO_2. Failures that were considered are:

- Failure of the transfer line to the chemical reactor
- A 90-lbf/in^2 air line fails inside the glovebox
- Calciner screw stops but heat addition continues
- Buildup on the vacuum filter
- Oxalic acid flood in glovebox if the valves upstream of the spray nozzles above the vacuum drum filter (VDF) fail open
- Buildup of PuO_2 in the glovebox if the line to the second-stage calciner fails closed or the line clogs
- Release of calciner offgases into the glovebox [rather than the condensate receiver tank (CRT)]
- Failure of 90-lbf/in^2 air (PRV) coupled with the Hopper Feed Control (BANJO) valve failure results in dispersed PuO_2.

To determine the worst case events, many arguments were considered.

Seismically induced criticality is incredible in this glovebox. A criticality may only be possible if many batches of plutonium oxalate or PuO_2, remain in this glovebox without notice. Even then, it is necessary that other containers not part of the actual process be brought in close proximity to the process and therefore there are no other containers in the vicinity to result in a critical mass. The assumption made for the seismic event is normal processing is occurring just before the earthquake.

Cessation of the rotation of the calciner screw results in hot oxide. Glovebox floods are no real concern because flooding is not an efficient dispersal mechanism. The room drains are safe with respect to criticality. Failure of the 90-lbf/in^2 air in the glovebox will not cause any damage as the panel will just pop out, or the gloves pop off, or the sphincter covers fly off because the lines are of small diameter and there are many flow paths out of the glovebox. The worst radiological case is a failure such that unregulated 90-lbf/in^2 air flows into the calciner coupled with a failure of the BANJO valve or calciner discharge line, resulting in a spread of plutonium powder (or both). Both will be investigated.

Accident Scenario, 234-5Z Room 228-A HC-10. Glovebox HC-10 was historically used to weigh powder pans of PuF_4. The glovebox is currently inactive. No release is postulated for this glovebox.

Accident Scenario, 234-5Z Room 228-A HC-11. Plutonium storage glovebox HC-11 has 12 storage locations, with a CPS limit of one 1.7-L powder pan or one 0.5-L slip-lid can per location. Each container is limited to 2.5 kg Pu, as dry PuO_2 powder.

The potential for a seismically induced criticality for the possible accumulation of fissile material in glovebox HC-11 is evaluated in Section 9.2.4.2.11.B, under "Accident Scenarios-Criticality." In view of the multiple error conditions or other pre-existing contingencies required, a criticality caused by seismic effects is judged not credible for this glovebox.

The glovebox remains standing so the only dispersal mechanism is if the powder pans move out the side that connects with glovebox HC-1; and if the panels on glovebox HC-1 fall off, some of these pans may fall to the floor.

9.2.4.2.1R Accident Scenario, 234-5Z Room 228-B--Room 228-B contains gloveboxes HC-12S, HC-15A, B, C, and HC-16CC, all of which are inactive. Glovebox HC-13MD is used as a seal-in/seal-out location for materials entering or leaving the thermal stabilization process. There is a CPS limited 2500 g plutonium and the glovebox is not seismically qualified. The 2500 g are assumed to be available for release.

9.2.4.2.1S Accident Scenario, 234-5Z, Room 228-C--Room 228-C contains gloveboxes HC-17DC, HC-17P, HC-17SBB, HC-18BS, and HC-18M. Gloveboxes HC-17-SBB, HC-17DC, and HC-17P are inactive.

Accident Scenario, 234-5Z Room 228-C HC-18BS. Glovebox HC-18BS contains 20 locations for slag storage of PuO_2 in 0.5-liter slip-lid cans or 1.7-liter powder pans. Storage of metal buttons was also allowed, up to 50 kg total, as a carry-over from previous operations. However, as containerized compound powders, the critically specifications permit a maximum of only 20 kg Pu total in the glovebox. The conveyer is not seismically qualified but it is considered extremely unlikely that a seismic event would generate sufficient vertical force for a can to jump out of the storage location. Even if a can were to fall to the floor and rupture, also an unlikely event, the glovebox is seismically qualified and so the release would be insignificant.

Accident Scenario, 234-5Z Room 228-C HC-18M. Sieving, grinding, sampling, packaging, weighing and bagging out of thermal stabilization product material is performed in this glovebox. The glovebox has a total Pu inventory limit of 10,000 g. This material is subject to release in a seismic event due to potential failure of the glovebox.

9.2.4.2.1T Not Used

9.2.4.2.1U Accident Scenario, 234-5Z Rooms 230-A and 230-B--Room 230-A contains glovebox HC-21C; room 230-B contains glovebox HC-21A. The contents are assumed to exit the gloveboxes and fall to the floor.

9.2.4.2.1V Accident Scenario, 234-5Z Room 230-C--Room 230-C contains glovebox HC-60, which is inactive. Room 230-C also contains glovebox HC-230C-2, which is used for plutonium-bearing solution stabilization, and conveyor glovebox HC-3.

The Magnesium Hydroxide Precipitation Process gloveboxes, HC-230C-3 and HC-230C-4, are located in this room. The effect of a seismic event on these gloveboxes is discussed in Section 9.2.4.10.

Accident Scenario, 234-5Z Room 230C, Gloveboxes HC-230C-2 and HC-3. Glovebox HC-230C-2 was added to the RMC Line after the analyses originally developed for this section were completed. The potential release mechanisms associated with the radiological inventory in glovebox HC-230C-2 are developed separately in Section 9.2.9.4. Conveyor glovebox HC-3 only contains PuO_2 powder in slip lid cans on a very short-term basis--just long enough to transfer the powder to glovebox HC-18M for packaging. No release is postulated from conveyor glovebox HC-3 in the seismic event as it is unlikely to contain any radiological material at the time of the event.

9.2.4.2.1W Accident Scenario, 234-5Z Room 232--Room 232 contains glovebox HA-46, which is inactive.

9.2.4.2.1X Accident Scenario, 234-5Z Room 235-A-3--Room 235-A-3 houses the oxide section of the old RMA Line, which is inactive. It is assumed that all of the gloveboxes in this room will topple because they are last on the list to be strengthened (as the line is cleaned out and inactive). The old RMA line is inactive. The gloveboxes were cleaned out in preparation of deactivation and decommissioning activities. As with the 242-Z Building discussed in Section 9.2.4.2.7, the residual material in the old RMA line is expected to be contained within process equipment and to be tightly adhered to surfaces. The releases from the gloveboxes in this room would be small in comparison to the releases from active areas of the plant and are not included in the dose consequences analysis for the seismic event.

9.2.4.2.1Y Accident Scenario, 234-5Z Rooms 235-A1 and 235-A2--Rooms 235-A1 and 235-A2 house gloveboxes which are inactive.

9.2.4.2.1Z Accident Scenario, 234-5Z Room 235-B--These contiguous rooms constitute a single area and contain gloveboxes HA-19, HA-20MB, HA-21I, HA-22B, HA-23S, conveyor HA-28, 235-B-2, 235-B-3, and part of conveyor HC-4. Only gloveboxes HA-21I, HA-22B, HA-23S, HC-4, and HA-28 are active. Glovebox HA-20MB may be used for future processing and is included in the accident scenarios. Conveyor HA-28 and HC-4 are normally empty.

Accident Scenario, 234-5Z Room 235-B HA-19--HA-19 is assumed to contain up to 2,500 g PuO_2 for conservative analysis purposes.

Accident Scenario, 234-5Z Room 235-B HA-20MB. Glovebox HA-20MB is used for cementation of low-level radioactive waste. The material is subject to disperal in the glovebox.

Accident Scenario, 234-5Z Room 235-B HA-21I. Glovebox HA-21I is used for reactive material stabilization. The material is subject to dispersal in the glovebox.

Accident Scenario, 234-5Z Room 235-B HA-22B. Glovebox HA-22B may be used for seal-in or seal-out of material stored in Glovebox HA-23S, or to stage materials destined for processing or just processed in glovebox HA-21I. The

Pu inventory limit for the glovebox is 2,500 g. Glovebox HA-22B is seismically qualified.

Accident Scenario, 234-5Z Room 235-B HA-23S. Glovebox HA-23S is used to store scrap. The material is stored in polyjars placed in storage carousels. Criticality considerations are discussed later in this section. Dispersal within the glovebox is also possible.

The Bagless Transfer System glovebox, HA-53BTS, is also located in this room. The release from this glovebox as a result of the seismic event is discussed in Section 9.2.4.11.

9.2.4.2.1AA Accident Scenario, 234-5Z Room 235-C--Room 235-C houses gloveboxes 235-B-2, 235-B-3, and 235-B-4.

9.2.4.2.1BB Accident Scenario, 234-5Z Duct Level--The 234-5Z duct level contains E-3 and E-4 ducts, filterboxes, chemical addition piping, and gas piping. Forces from the earthquake can result in piping failures with subsequent liquid or gas release, suspension of radioactive material within the duct and filterbox, or potential failure of the supply ducts. The E-4 ducts do not fall to the floor as a result of the earthquake, according to the latest structural calculations. It is also assumed that the seismically qualified filter boxes remain standing. The case of the filterboxes falling is in the *B Plant Preliminary Accident Analysis*, WHC-SD-WM-TI-385 (Marusich 1989) and 9.2.4.6.3.1W. The plenum downstream of the filter rooms also contains some radioactive material which could either be suspended within the intact duct or suspended in the duct level when the duct fails. Process vacuum lines around the plant contain about 4.3 kg plutonium total. This material is not dispersible as it is tightly (and possibly chemically) adhered to the vacuum lines (Schilling 1989).

9.2.4.2.1CC Accident Scenario, 234-5Z Second Floor--The second floor (third level) contains offices, chemical makeup tanks, and the filter rooms. The seismic forces could result in filter failures, loss of filter integrity, or chemical solution release (see Section 9.2.4.6.3.1.X.b). It will be assumed that the room filters fail in such a manner that they provide no filtering ability.

9.2.4.2.1DD Accident Scenario, 234-5Z Pipe Tunnels--The tunnels beneath the building house the drain lines which take waste solutions from the first floor and direct them to the waste tanks in 241-Z. Seismic forces may result in drainpipe damage. The transfers in these pipes are small, about 200 L, and have low Pu concentrations. This scenario is assumed to be bounded by failure of the 241-Z tanks analyzed in Section 9.2.4.6.3.8.

9.2.4.2.2 Accident Scenario, 236-Z PRF. The PRF processes are no longer operational. The seismic accident analysis for the PRF assumes the facility is fully operational, the accident analysis will be updated to reflect the current shutdown condition of the facility in a future revision to this FSAR. Assuming a fully operational PRF results in conservative seismic release estimates for the PRF that adequately represent or bound releases that could occur from failed piping or tanks during cleanup of the facility.

The accident scenarios postulated for the 236-Z facility are listed below. The assumptions are the same as were used in 234-5Z. Additional assumptions are as follows.

- The seismic forces result in random valve actuation, interlock failures, etc. The worst case combination will be considered here.
- The seismic-force-induced piping or duct failures are assumed to occur if the consequence of having intact piping or ducts is less severe.

- The facility gloveboxes are in operation and running smoothly. This is assumed because the probability of off-normal conditions coupled with the earthquake is considered incredible.

As a result, the approach used to determine hazardous conditions brought on by seismic forces is an investigation of release mechanisms due to abnormal processing (e.g., operation of a column without one of the inlet streams).

9.2.4.2.2A Accident Scenario, 236-Z Solvent Extraction--The solvent extraction portion of the PRF included the canyon, the east and west gloveboxes, the third floor instrument gallery, and the fourth, fifth, and sixth floor extensions of the CA and CC column glovebox. The chemical addition system in the east and west gloveboxes is also included.

Criticality considerations were built into the design. This analysis considered the above as well as other events. Table 9-27 provides a listing of the events considered.

9.2.4.2.2B Accident Scenario, 236-Z MT--Gloveboxes MT-1, MT-5 and MT-6 were the only gloveboxes with hazards that could be seismically induced. Glovebox MT-1 (inactive) was used for inspection (scrap burning is no longer done); MT-3 (inactive) was used for electrolytic dissolution; MT-4 (inactive) was used for the distillation of polystyrene cubes but is not operational; MT-5 (inactive) was used for dissolution; and MT-6 (inactive) was used for centrifuging the PRF solutions as well as storing dissolved solutions. The hazards postulated are as follows:

- Fire in MT-5 (9.2.4.2.12.A)

- Seismic initiated criticality in MT-5 (9.2.4.2.11.M)

9.2.4.2.2C Accident Scenario, 236-Z S&C--S&C is no longer in operation.

9.2.4.2.2D Accident Scenario, 236-Z Remainder of PRF Facility--Seismically induced hazards for the remainder of the PRF are:

- Tank or line break in chemical preparation area

- Chemical reactions due to the mixing of two or more solutions in chemical preparation

- Crane derails over tanks in canyon.

- Seismic-induced criticality in West Gallery glovebox (9.2.4.6.3.2.A.a)

9.2.4.2.3 Accident Scenario, Product Handling at 234-5Z and 236-Z. The product handling aspects of 234-5Z and 236-Z are, for the most part, immune to seismic forces. Spills of powders or solutions could occur if the earthquake occurred at the time of filling of the PR cans, for example. Usually the powders and solutions not in the process are in either gloveboxes, hoods (in the labs), or in storage rooms. If these materials are stable (as compared to reactive), they are packed in sealed containers and stored. If they are reactive they are placed in vented containers and stored in gloveboxes or, if the containers are PR cans, in storage rooms (the vent has a filter in the vent path). The seismic forces cannot result in a release of stabilized material as the packing or storage will preclude damage, given that the facility is not damaged. That is, PR cans stored on the floor will not tip over, and double-packed containers will not fail if they fall out of the storage location. This determination is based on tests in which slip-lid cans filled with 400 to 600 g of damp sand or basalt cuttings that were dropped from heights from 4 to 14 ft without any loss of material or can damage (Reichmuth 1988).

Releases can occur due to reactions, such as scrap fire in room 170 of 234-5Z or the release of plutonium solutions. Fire is considered in Section 9.2.4.2.12. The releases due to the breaking open of bulged drums or dropping of a PR can on the dock cannot be seismically induced and are not considered credible.

9.2.4.2.4 Accident Scenario, Vaults. There is no release of plutonium from the vaults because of the following considerations. There are vaults in 234-5Z that contain pedestal storage, a vault that contains shelf cubicle storage, and vaults that contain floor storage. The vault structures are not damaged by seismic forces (Marusich 1988b) and the containers do not fall out of the pedestals (Vollert 1987a, 1987b). Recommended upgrades to vault 225 shelf cubicle storage (Vollert 1987b) were performed. The shelf cubicle storage units remain upright during the seismic event and locked cubicles prevent containers from falling to the floor. The PR cans will not tip over. Loss of ventilation results in a slow heatup of containers, which could result in pressurization; but by the ideal gas law, a rise in temperature of 200 °F only results in a pressure increase to 19.8 lbf/in^2 (absolute). The can is able to withstand this [Szempruch (1984) containers can withstand up to 100 lbf/in^2]. In the unlikely event that a can fails, the second container, being much larger, will see a much smaller pressure increase. Note that the ventilation will only be off a short period of time (maybe weeks) compared to the time it takes to bulge a container. See Chapters 5.0 and 8.0 for further discussion concerning container features for the various vaults in 234-5Z.

9.2.4.2.5 Accident Scenario, Other (234-5Z and 236-Z). A walk through the 234-5Z and 236-Z Buildings revealed other potential hazards. These are:

- The HNO_3 storage tank failure
- Failure of the drain lines between 241-Z and 234-5Z

- Failure of a high pressure nitrogen tank (south side near the west corner of 234-5Z)

- Internal floods resulting from fire line failures

Note that the HNO_3 storage tank has been drained and it is not in service. An analysis of the impacts of a HNO_3 spill has been retained as it represents, from a historical perspective, the bounding chemical hazard (see Section 9.2.4.6.3.5.D).

9.2.4.2.6 Accident Scenario, 2736-Z Complex. The 2736-Z complex consists of 2736-ZA, -B, and -Z. Potential hazards are:

- Argon release due to an argon pipe failure to displace air in a room
- Flooding due to a failure in the fire system
- Container heatup due to ventilation failure
- Criticality (see Section 9.2.4.2.11).

In addition to the above hazards, a plutonium-release in 2376-Z due to the seismically-induced failure of a storage container is postulated. As discussed in Section 9.2.4.1.1, Building 2736-Z is seismically-qualified as are the storage racks contained therein. Therein, for this release to occur the seismic event must be coupled with a human error such that a storage container falls from the rack.

9.2.4.2.7 Accident Scenario, 242-Z. This facility was discussed in Marusich (1988a). The conclusion drawn was that the particles of plutonium left after cleanout of these gloveboxes are tightly adhered to the surfaces. The oxide powder left is hygroscopic and, as a result, has increased in size and diameter. Therefore, the portion of respirable particles is less than in-process powders and, as shown in Marusich (1989), the release fraction for contamination of glovebox walls is small.

The *242-Z Seismic Analysis*, WHC-SD-CP-DA-020 (Giller 1989a) indicates that the 242-Z facility will survive the DBE seismic forces. Although the gloveboxes may collapse, there is no additional dispersive force (building collapse).

Haas (1990) concludes that the plutonium in 242-Z was originally present in the form of residues or sludges associated with wet processes. The estimated holdup is 330 g, but formal Nuclear Materials Accounting records show no plutonium in 242-Z. Therefore, the holdup is dispersed. Two-thirds of the holdup is estimated to be in 9 tanks (20-30 g per tank) and one third on floors and hoods (Haas 1990). It is also believed that the holdup estimate is a factor of 8-10 high based on the fact that all the solution was transferred to the PRF and the columns were drained and the rashing rings disposed (Haas 1990). For purposes of accident analysis 110 g are assumed to be on walls and in the hoods. The quantity in the tanks will not be dispersed.

9.2.4.2.8 Accident Scenario, 232-Z. The 232-Z Building has been cleaned out but still contains some residual contamination. The facility is no longer in use. The structure has been analyzed to see if it will survive the seismic forces. Based on the analysis, it is concluded that the structure will

survive a 0.09-g seismic event but is not qualified for a 0.20-g event. Therefore, releases may be expected to occur for seismic events greater than 0.09-g. Consequently, for both the 0.09-g and 0.20-g events, it is conservatively assumed that the building will collapse and that some of the contamination will become airborne (see Marusich 1988a for assumptions for contaminated gloveboxes).

9.2.4.2.9 Accident Scenario, 291-Z. The 291-Z structure has contamination in it. The structure can survive the earthquake (URS 1980), but the seismic forces might dislodge some of the contamination.

9.2.4.2.10 Accident Scenario, Building 241-Z. The 241-Z structure contains waste tanks in cells covered with coverblocks. Constructed above the cells is a pre-engineered steel structure to provide weather protection and support for monorail crane hoist (see Section 5.2.4). It is assumed that the weather enclosure will withstand a UBC, no analyses have been performed. Therefore, this analysis assumes the structure will fail given an earthquake at or above 0.09 g horizontal with a frequency of 2×10^{-3}/yr. The coverblocks have been restrained so that they do not fall into the tanks. No analyses have been performed to determine if the coverblocks will remain intact if the crane, crane support structure or the building support structure collapse and strike the coverblocks. If the coverblocks fail due to the collapse of the steel structure or the crane falls there is a potential for a release to the atmosphere and soil column (see Section 9.2.4.6.3.8).

9.2.4.2.11 Accident Scenarios-Criticality. Areas in which a seismically induced criticality is conceivable are those that already contain a critical mass which is separated into several subcritical masses during operation. This condition comes as a result of the assumption of normal processing (no double batching) and no pre-existing failures (operator brings another container close by). Critical masses are taken from the figures in the Criticality Handbook (Carter et al. 1969):

- A 24-kg Pu powder sphere (unreflected, 3% ^{240}Pu, density is 2 g/cm^3, Figure III. A.9 (97)-4). Note that the value is about the same for density up to 10 g/cm^3
- A 11-kg Pu powder sphere (fully reflected, 3% ^{240}Pu, density is 2 g/cm^3, Figure III.A.9(97)-4)
- A 17-kg Pu powder sphere (reflected by 1 in. of water, 3% ^{240}Pu, density is 2 g/cm^3, Figure III.A.9(97)-4.

Note that Figure III.A.9(100)-5 shows, that if the powder is dry the values are about a factor of 20 higher.

- A 9.5-kg Pu metal sphere (unreflected, 3% ^{240}Pu, Figure III.A.9(97)-4, density is 19.6 g/cm^3)
- A 5-kg Pu metal sphere (fully reflected, 3% ^{240}Pu, Figure III.A.9(97)-4, density is 19.69 (g/cm^3)
- A 2-kg to 10-kg Pu solution (function of concentration, molarity of solution, reflection, and depth).

Examples for a plutonium (3% ^{240}Pu) nitrate solution are:

- Critical slab, full reflected requires an aerial concentration of 350 to 450 g/ft^2 and a 12 in. deep pool (p. III.A.8.100-1)
- Infinite cylinder, fully reflected 7- to 8-in.-diameter cylinder with 150 g/L or 9- to 10.5 in.-diameter cylinder with 30 g/L (p. III.A.4.97-1).

There are a relatively small number of gloveboxes in which a critical mass or concentration of Pu is conceivable. The locations where there are potential quantities of materials in excess of a critically safe mass (if all the material in the form allowed in the glovebox were to somehow be gathered into the optimum configuration and reflected) are:

- Vaults in 234-5Z and 2736-ZB
- HC-11
- HC-18BS
- HA-23S
- HC-4
- HC-227S
- 2736-Z
- HC-21A
- HC-21C
- HA-21I
- HC-18M
- Glovebox 5 in room 139
- HC-7
- HC-6 (inactive)
- Glovebox 522 in room 152
- MT-5 (inactive)
- West glovebox PRF
- HC-9B in room 228A
- MT-6 in 236-Z (inactive)
- Glovebox HC-230C-2 in room 230C

The above identified locations are analyzed in the following subsections. Criticality considerations for the Magnesium Hydroxide Precipitation Process gloveboxes, HC-230C-3 and HC-230C-4, are discussed in the related addendum (Carson 2000) to this FSAR. Criticality considerations for the Bagless Transfer System glovebox, HA-53BTS, are discussed in the related calculation notes (FH 2000).

9.2.4.2.11.A Accident Scenario-Criticality, Vaults (see also Sections 9.2.4.2.1H, 9.2.4.2.1L, and 9.2.4.2.11.F)--The criticality considerations in the design of the vaults have been discussed previously. Shelf storage cubicles will not tip together and containers will not fall from the cubicles; the storage pedestals will not fail and the containers will not pop out of the pedestals. Even if a water line broke, the spacing is such that a criticality is not possible. None of the vaults in 234-5Z have water lines in them. Only the 2736-Z room 2 has a water system, and this room has shelf storage (containers cannot float to the top of the room even if it is conservatively assumed that the room fills with water). Building 2736-ZB, rooms 638, 641, and 642 contain shipping containers (similar to a 55-gal drum), and they

contain a wet pipe sprinkler system. Shipping limit requirements and spacing will preclude a criticality even if the water line fails. Therefore, there are no seismically induced criticalities in the vaults.

9.2.4.2.11.B Accident Scenario-Criticality, HC-11--Glovebox HC-11 could contain 12 powder pans, each containing 2,500 g PuO_2. The total quantity of powder, if placed into a sphere, is not critical; but if wetted and moderated, it is. The total quantity of PuO_2 cannot be dispersed into a spherical shape (or be thick enough to be a critical slab) because of the following.

- The powder pans are relatively large with respect to all the glovebox dimensions (i.e., when all 12 pans are in the box, there is little room left as each pan chamber is about one-fourth of the glovebox diameter and about one-half of the available height).
- The pans are not filled to the top.
- The structure that supports the pan conveyor is made of three layers of thick channel or angle iron welded into a squat structure that almost fills the glovebox. The conveyor structure may bounce around but will not collapse (Ocoma 1990a). Collapse on one side only is needed to get the powder to "flow" down to one end (or corner).
- Glovebox HC-11 is completely open on one end to HC-1 and HC-11 floor is about 6 in. above HC-1 floor. Glovebox HC-1 has a criticality drain on the far end. Any powder that is wetted will tend to follow the stream, but since the powder is heavier than water, it will deposit along the way. It would require many very specific failures for the assumed water "supply" to the glovebox to wash the necessary amount of powder out of the powder pan (like washing and out of a bucket) to result in a criticality as the only water is a fire main near the glovebox.
- The assumed water supply is the fire protection piping in 228-A. If this pipe fails as a result of the earthquake, the stream of water will likely be directed downward or along the axis of the pipe. The pipe failure would have to be a split in the pipe in the exact location as the glovebox. That is, a split about 3 ft wide or less would have to occur in line with HC-11 and nowhere else. There is no stress intensification factor at this location (no anchor, elbow, etc.).
- The top glovebox panel would not fail completely. The top panel will likely crack or drop into the box, neither of which allows the assumed water supply to sluice out all the powder.

As a result, a criticality in HC-11 is incredible.

9.2.4.2.11.C Accident Scenario-Criticality, HC-18BS--RMC Line area Glovebox HC-18BS is used to receive boats of dry plutonium bearing materials from the thermal stabilization process. Canned plutonium bearing materials are also expected to be stored in the glovebox, as well as multiple boats containing plutonium and/or uranium in metal or oxide forms. The CPS allows for 20 containers each containing 2500 g Pu, or 50,000 g total in the

glovebox. HC-18BS is a "dry" glovebox where no internal solution lines are present. Except for a maximum of 50 ml of lubricants, no free liquids are allowed in the glovebox. The CPS also establishes specific spacing, H/Pu, container volume, and unit mass limits where appropriate.

The glovebox is seismically qualified. The structure supporting the glovebox does not collapse as a result of a DBE. HC-18BS is constructed in a similar manner to HC-11, in that the conveyor that holds the powder in slip lid cans or powder cans is supported by three levels of thick angle iron and "C" channel so that it will not collapse. The containers are supported by a metal cup-like holder that is surrounded by a thick, large-diameter ring. Furnace boat holders are used to support and restrain boats that are placed onto a pedestal position. The material containers are separated on the conveyor by pins about 5/8 in. long. The CSER credits the conveyor pedestal design with limiting the number of containers that may fall to the glovebox floor as a result of a DBE. The CSER identifies there are two sprinklers of the non-seismically qualified room fire suppression system above the glovebox. During a DBE, the top panels of the glovebox may be breached and water entry into the damaged glovebox is likely. Full flooding of the glovebox is avoided either by the failure of attached non-seismically conveyor gloveboxes HC-1 and HC-2, or the function of the glovebox HC-1 and HC-5 criticality drains. The CSER documents that under DBE conditions with fire suppression water entering the glovebox, four dislodged containers on the glovebox floor directly below another similar container on the conveyor would not result in unacceptable material interaction k effective.

Therefore, as a single contingency, a seismically induced criticality in Glovebox HC-18BS is not credible. Additional violations of CPS limits combined with a DBE would have to occur simultaneously before a criticality is possible.

9.2.4.2.11.D Accident Scenario-Criticality, HA-23S--A seismically induced criticality will not occur in glovebox HA-23S. In this case the conveyors are on four levels within the glovebox. However, the conveyors are supported by (i.e., welded to) the side walls or the floor. The support is angle iron with thick channel spanning each half of the elliptical conveyor. The containers are slip-lid containers which are vented. The containers sit in a bucket whose sides are at least half as long as the cylinder. The basket is positioned in the ring which is positioned on the conveyor using metal rods (3/4 in.). The radioactive material does not fill the container. There is no water near the glovebox, and the glovebox is mostly metal. Because of the above, there is no reasonable mechanism to pile enough containers together to get a critical mass.

In addition, the Criticality Safety Evaluation Report (CSER-91-007) for this glovebox shows that if all of the material presently stored (0.5-L polyjars with 1000 g maximum) fell to the floor, the areal density of plutonium (grams per square foot) is not high enough to result in a criticality. Jumbled containers would actually be confined to their original level.

9.2.4.2.11.E Accident Scenario-Criticality, HC-4 and HC-227S--The following data is summarized from various Criticality Safety Analysis Reports (CSAR) covering HC-4 and HC-227S (Doto 1989).

Glovebox	Glovebox floor area	Minimum Critical Solution Depth (cm)	Solution volume at critical depth (L)	Total tank volume (L)
HC-4	25,300 cm^2	9.65	244	142
HC-227S	22,326 cm^2	9.65	215	190

Criticality would require additional solution or water over that contained in the tanks. This would require a plugged criticality drain and the addition of liquid from an external source.

The actual depth required for criticality depends on the amount of plutonium on the floor. If sufficient plutonium is not available, criticality cannot be achieved at any depth. According to the Criticality Handbook (Carter et al. 1969), Figure III.A.8.95-2, an infinite slab of plutonium nitrate (5 wt% 240) would have a minimum critical areal density of 270 to 400 g Pu/ft^2 depending on reflection conditions and the amount of excess nitrate ion. This would correspond to a minimum somewhere between 6.5 and 10.9 kg Pu on the floor of these gloveboxes.

Based on the above, criticality due to solution on the floor would require the following steps.

1. Have an adequate amount of plutonium in the glovebox (greater than 6.5 kg). Adequate amounts exist periodically in HC-227 and HC-4.

2. Plug the criticality drain. (A pre-existing failure.)

3. Leak the plutonium solution to the floor.

4. Add enough other liquid from an external source to achieve a critical depth. This would require breaching the upper part of the box to allow the entry of liquid (e.g., water from a fire main) while the lower part remains sound to contain the liquid. This is more than 22 L in glovebox HC-227S and greater than 116 L in HC-4.

In HC-227S, there is a chemical addition tank that has a motor-operated valve on the downstream leg. It is assumed that the earthquake causes opening of the valve, the draining of this tank into the glovebox, and the breaking of the storage tanks. It is further assumed that the criticality drain remained plugged. These failures do not result in a criticality in HC-227S because the tank only contains 3 L.

A similar situation to HC-227S is HC-4, but the valve on the downstream side of the tank is a manual valve and thus will not fail open. In addition, far more additional solution is needed for this glovebox to go critical (about a hundred liters as compared to tens of liters). The chemical addition tank does not have sufficient volume to result in a criticality. Processes associated with HC-4 are currently inactive.

Therefore, there are no seismically induced criticalities in gloveboxes HC-227S or HC-4 since their support structures are seismically qualified so that toppling or tipping does not occur.

9.2.4.2.11.F Accident Scenario-Criticality, Criticality in 2736-Z or 2736-ZB Due to Flooding--The containers and storage in 2736-Z and -ZB cannot go critical assuming water or water spray addition as the quantities in storage are limited by criticality prevention specifications to be safely subcritical under these conditions (see Breaking of a Fire Main in an Area with Room Storage of Fissile Material (Altschuler 1989a).

Room storage is currently allowed in the presence of fire mains. The question arises as to the effect on criticality safety should the main break, flood the room, and cause the storage containers to float off the floor.

This accident condition requires that the rooms be sufficiently water-tight and that the flow from the broken main is not shut off in a timely fashion.

It is assumed that arrays consisting of more than one layer are spread out into a one-layer array unless restricted by the size of the room. This will tend to lower the surface density (the amount of fissile material per unit area of floor) and thus the reactivity.

Should the fire main fail and flood the room, the array will now be reflected by water on all sides instead of concrete walls and floor. The water between the containers will add a reflecting moderator. When sufficiently thick (i.e., the containers drift about 6 in. apart) the containers will be neutronically isolated from each other.

Presumably any containers that fill with water, either because of leaks or an open outer container, will sink to the floor of the room. An accident in which fissile solution can leak into the water requires a preexisting failure which is not considered in this report.

For the case where the fissile material stored is highly moderated, the actual surface density is less than 100 g Pu/ft^2. The minimum surface density required for criticality is 240 g Pu/ft^2. The exception to this is for solution containers (i.e., PR cans, L-10s, etc.). These are limited to 10 L which is well within the limits of surface density in liter per square foot for fissile solution.

Amounts up to 4,500 g Pu stored as slightly moderated material (H/Pu<20) in birdcages will be safely subcritical. The water surrounding the water-tight containers will be sufficient to isolate the fissile units from each other. The minimum critical mass for full water reflection is a 5.4 kg alpha metal sphere (Carter et al. 1969, pages III.A-2). The actual critical mass required will be larger since the fissile density may be lower, the shape is less ideal than a sphere, and the container walls will absorb neutrons.

For slightly moderated material stored in L-10s or L-3s, the only reactivity effect would be caused by the moderation and reflection of water between the barrels. The 6- to 8-in. air gap between the water and fissile material will appreciably reduce this effect. From the geometry, the

probability of a neutron reflected by the water striking fissile material is at least as low as one-third and more likely less than a tenth. Monte Carlo calculations have been made using the MONK code and the UKAEA cross-section library. These modeled an infinite array of DOT-6Ms with two 2.5-kg Pu metal buttons one atop the other on the bottom of the container. For conservative results, no ^{240}Pu or structural material was used. The DOT-6M was smaller than L-10s or L-3s and would have a higher reactivity and thus be a more conservative case. Results for K_{eff} were 0.8787 $\pm$0.0081 (MSA247), 0.9866 $\pm$0.0081 (MSA248), and 0.8798 $\pm$0.0075 (MSA251) for the array in air on a concrete floor, water added between the containers which are still on the concrete floor, and floating with water between and underneath the containers, respectively.

For slightly moderated material in lard cans, the actual surfaces density is 1,600 g Pu/ft^2 or 14.5 L/ft^2. For 55-gal drums, these values are 476 g/ft^2 and 4.3 L/ft^2. Floating should reduce these values by a factor of four (to 400 g Pu/ft^2 or 3.63 L/ft^2 and 119 g Pu/ft^2 or 1.1 L/ft^2, respectively) as the four layers spread out to form a layer only one storage container thick. These latter values for a one-layer array are acceptably low. These will only be achieved after the water has surrounded the lower layer(s) sufficiently to provide enough buoyancy to float a container. A Monte Carlo calculation of a floating infinite array of large cans stacked four layers high has a k_{eff} of 0.9356 $\pm$0.0077 (MSA250). The 400 g Pu/lard can is distributed as a 1-cm-thick layer on the surface of the stack so as to give the maximum reactivity effect due to moderation when the water is present. The conservative assumptions for the DOT-6Ms have been also made for this case.

From the preceding discussion, the breakage of a fire main in the presence of a room storage array will not cause a criticality even in the unlikely event that flooding occurs. There also is no potential for criticality due to pedestal failure as the pedestals can withstand seismic loads (see Section 9.2.4.2.1H).

9.2.4.2.11.G Accident Scenario-Criticality, HC-21A and HC-21C--RMC Line area gloveboxes HC-21A and HC-21C are used for stabilization of miscellaneous scrap plutonium bearing materials. Glovebox HC-21A is used for material preparation activities and contains a can opener, sieve, electronic scale and a mortar and pestle for crushing material if necessary. Cans of feed materials are opened in this glovebox, inspected, weighed, and placed in furnace boats for transfer to muffle furnaces. Glovebox HC-21C contains two muffle furnaces where stabilization takes place. The CPS's for the gloveboxes allow for processing of various forms of plutonium materials. Each material form, (i.e., oxides, metals, or sludges) has a specific criticality safety limit set. Both are "dry" gloveboxes where no internal solution lines are present. Except for a maximum of 50 ml of lubricants, no free liquids are allowed in either glovebox. The CPS's in effect as of May 2000 allow for 7100 g Pu oxide and compounds, 2500 g Pu sludges, or 4800 g Pu metal, metal corrosion products, oxidized metal, and product quality oxides in Glovebox HC-21A. Glovebox HC-21C is allowed 5000 g Pu oxide and compounds, 2500 g Pu sludges, or 4800 g Pu metal, metal corrosion products, oxidized metal, and product quality oxides. Each limit set has specific spacing, H/Pu, container volume, and unit mass limits where required by material type.

Neither glovebox is seismically qualified due to their supports not being anchored to the floor. During a DBE, the structures supporting the gloveboxes are assumed to collapse, allowing all fissile material to collect in one corner of the glovebox. It is assumed that a DBE sufficient to collapse the glovebox support will also damage the glovebox itself and the room fire suppression system. Under these conditions, fire suppression water may enter the glovebox and saturate and surround the fissile material accumulated in the glovebox corner. Each criticality safety limit set has been established to ensure that material interaction k effective remains acceptable under this DBE scenario.

Therefore, as a single contingency effect, a seismically induced criticality in gloveboxes HC-21A and HC-21C is not credible. Additional violations of CPS limits combined with a DBE would have to occur simultaneously before a criticality is possible.

9.2.4.2.11.H Accident Scenario--Criticality, Glovebox HA-21I--RMA Line area Glovebox HA-21I is used for stabilization of miscellaneous scrap plutonium bearing materials. The glovebox contains three muffle furnaces where stabilization takes place after material is transferred from Glovebox HC-21A. The CPS for the glovebox allows for processing of plutonium in the form of oxides and metals (processing of sludge in HA-21I is prohibited due to process limitations). HA-21I is a "dry" glovebox where no internal solution lines are present. Except for a maximum of 50 ml of lubricants, no free liquids are allowed in the glovebox. The CPS and CSER in effect as of May 2000 allows for 8000 g of Pu oxides and other compounds. Additional limits have been established for Pu metal, metal corrosion products, oxidized metal, and product quality oxides. Each limit set has specific spacing, H/Pu, container volume, and unit mass limits where required by material type.

The glovebox is not seismically qualified due to its supports not being anchored to the floor. During a DBE, the structure supporting the glovebox is assumed to collapse, allowing all fissile material to collect in one corner of the glovebox. It is assumed that a DBE sufficient to collapse the glovebox support will also damage the glovebox and the room fire suppression system. Under these conditions, fire suppression water may enter the glovebox and saturate and surround the fissile material accumulated in the glovebox corner. Each criticality safety limit set has been established to ensure that material interaction k effective remains acceptable under this DBE scenario.

Therefore, as a single contingency effect, a seismically induced criticality in glovebox HA-21I is not credible. Additional violations of CPS limits combined with a DBE would have to occur simultaneously before a criticality is possible.

9.2.4.2.11.I Accident Scenario-Criticality, Glovebox 5 in Room 139: Glovebox 5 in Room 139 of the PFP Engineering Laboratory provides storage for dry plutonium metallic or compound samples in what is called a Carousel, a semi-fixed array upon a motor-operated multiple rack assembly. The storage elevator resembles a "ferris wheel" with 50 removable trays mounted on chains which pass over sprocket pulleys near the top and bottom of the glovebox. Each tray has 42 fixed positions to hold sample bottles. The sample bottles each hold 25 to 35 ml of material. The CPS limits any sample bottle to 50 grams maximum Pu, but also limits each tray to 840 Pu grams maximum and the

total carousel to 20,160 grams Pu. Another 840 grams is allowed in the glovebox but off the elevator in a container not exceeding 2 liters volume.

Glovebox 5 is not seismically qualified, due to lack of anchorage and need of some structural welds. It is uncertain how the trays of samples might respond under seismic motions, but it is plausible for a sizeable fraction of the sample bottles to get piled up and for some of these being shattered open. The effective volume-averaged density of the contained material, by the maximum allowed per bottle, is at most 2 g Pu/cm^3, meaning that the bottles are essentially 80% void space. For a more full tray the clustered bottle density average for the Pu is only 0.8 g/cm^3, and about 0.4 g/cm^3 for a full carousel inventory of clustered bottles. As dry material at this low density with such large void fractions, mixed with glass, the minimum critical mass for Pu is certainly over 50 kg.

The seismic impacts as a single contingency cannot therefore produce a criticality with the Room 5 glovebox loadings. The potential for water entry into the intact array is not a problem, and it is doubtful (because of the high bottle void contents) that a pileup of bottles plus flooding would cause criticality.

9.2.4.2.11.J Accident Scenario-Criticality, HC-7--Processes associated with Glovebox HC-7 are currently inactive. It has Pu nitrate solution tanks for feeding the Pu oxalate production process in HC-9B and also tanks for receiving the filtrate drawn from drum filtering of the oxalate to a damp cake. The 16.5-L, 6 inch diameter glass PRT and THT can both be loaded with 450 g/L Pu-nitrate solution, the CPS limit (actual flow sheet values would be on the order of 200 g/L). The filtrate-kill, -catch and -storage tanks, of up to 33 liters each, normally contain no plutonium. Occasionally, a faulted drum filter may pass Pu oxalate through to the Filtrate Kill Tank (FKT), settling as "solids" to the bottom and into the U-shaped pipe connection to the Filtrate Catch Tank (FCT). The Pu concentration in the oxalate solids could be up to 600 g/L.

Glovebox HC-7 is 98-inches long by 36-inches wide by 118-inches tall and sits on a grout pad with the bottom of the box 2 inches above the floor of Room 228A in 234-5Z. Table 9-25 states this glovebox is qualified against seismically induced structural failure. Its frame has been anchored to the floor. The criticality drain for HC-7 is a 2.5-inch hole at the bottom of the north panel, with a soft-plastic tube/steel roller bar arrangement on the room floor outside. The bottom of the drain hole is 2.188 inches above the floor of the glovebox. Mesh-steel cages protect the drain apparatus both inside and outside of the glovebox.

Glovebox HC-7 has a number of liquid-bearing input pipelines, besides the lines for vacuum transfer of Pu nitrate solution from HC-227S. There are four lines for accessing makeup chemical supply tanks, for H_2O_2, $KMnO_4$ and two strengths of nitric acid. There is also an internal fire-suppression sprinkler fed by two 2.5-gallon water canisters above the glovebox.

The 14.85-kg total of Pu in the tanks allowed by the CPS combined with a limit of 3 kg for that in containers gives nearly 18 kg of Pu (with a minimum of 5% ^{240}Pu). The CPS also permits 1/2 inch of solids or solution on the glovebox floor, which conceivably could be 600 g Pu/L oxalate, with a total of

17 kg of Pu, or even higher density-nitrate sludge. However, such heavy floor solids accumulations would never be permitted from ALARA considerations and because the CPS requires cleanup of spills before continuing operations. The more likely floor residue might be 7 or 8 kg, maximum, which would represent a batch of oxalate which had drained out of the FKT after a drum-filter breach. Thus, the maximum total Pu in glovebox HC-7 is 25 to 26 kg.

As common-cause faults induced by seismic stresses, one could postulate dumping of one or two of the Pu nitrate solution feed tanks, activation of the internal sprinkler (5 gals. maximum), and/or leaks from one or two of the chemical makeup lines. These are conservative assumptions considering the seismic qualification, and the chemical feed lines are more likely to sever outside the glovebox.

Tilting of the glovebox is precluded by the new anchoring. Addition of exterior-source water, as from window breaking in conjunction with activation of room overhead sprinklers, is considered a secondary contingency of low likelihood. Blocking of the criticality drain also is considered a secondary contingency, either pre-existing or from the low likelihood of something falling on the drain box. (Actually, the first seismic effect would be rolling off the steel bar which seals the drain bag during normal conditions).

Criticality thus would involve a solution slab, if sufficiently deep, on a level floor. With up to 26 kg of Pu available, the potential areal density (1061 g/ft^2), is about three times the minimum for criticality. However, calculations for HC-7 reported in the CSER for the adoption of the 5-gallon internal fire sprinkler system (WHC 1990), show that, with 26 kg of Pu (5% 240) in a uniform nitrate solution, the depth would have to exceed 3.4 inches before losing the required margin of subcriticality (bias-adjusted k-value not more than 0.95). The volume of all the tanks and cans in HC-7 plus the 5 gallons of sprinkler water is insufficient to provide the 197 liters for this slab thickness.

Flooding to 3.4 inches deep would require a constant-flow liquid input sufficient to yield a 1.2-inch head over the bottom of the criticality drain hole. According to the flow/head correlations for 2- and 3-inch ports graphed in *Criticality Drain Performance*, RFP-2222 (Lehmkuhl 1974), a 1.2-inch head requires a flow rate of 5.5 gpm. None of the chemical lines with full supply tanks would discharge at more than 3.2 gpm, and the most from two of these lines combined is 5.3 gpm.

Therefore, a criticality in Glovebox HC-7 as a result of plausible common-cause faults, as a single contingency, incurred during an earthquake is not credible. With the drain blocked, as a second contingency, criticality could ensue with any of the chemical lines discharging, given at least 7 kg of Pu in solution. (This conservatively neglects the neutron poisoning effects from nitrogen if it is nitric acid discharging). An exterior-flooding scenario (room sprinkler water into broken windows) might also insert water at up to 4 gpm.

9.2.4.2.11.K Accident Scenario-Criticality, HC-6--Glovebox HC-6 in Room 166 of Building 234-5Z contains two long, 6-in. diameter steel tanks, with the round-end sections protruding out of the glovebox. In the past these tanks were used for storage of a Pu nitrate solution, but, being no longer in

service, the connections thereto have been blanked off. The glovebox is currently inactive. The analysis that follows assesses the potential for a criticality to occur in the glovebox based on past operations where plutonium nitrate solutions were transferred from the 236-Z Building through piping that traversed the glovebox.

Glovebox HC-6 is 67-inches long by 27-inches wide and sits on the room floor, with the glovebox floor sloping slightly down toward the criticality drain end (the east panel). There are actually two drains, the lowest of which is piped to two 60-liter, geometrically favorable overflow tanks in the floor of the room. (These floor tanks could accommodate dumping of the glovebox tanks). The total glovebox holdup with flooding to the bottom of the room drain would be 190 liters.

As for RMC operations, the solution in transfer through HC-6 or in samples may have Pu concentrations of up to 450 g/L. The specifications also allow two 0.5-L cleanup containers and eight sample bottles. Up to 0.5 inches of solution or solids is allowed on the floor, but with required cleanup procedures the amount of residual plutonium to be left on the glovebox floor is not significant. With the plausibility of nitrate-sludge-filled cans in the glovebox, the total inventory might typically be on the order of 1 to 2 kg Pu.

One prospect for criticality in HC-6 involves the potential for pipeline or valve leakage flooding the floor of the glovebox with Pu nitrate solution. However, such leaks would break the vacuum transfer force and quickly terminate flow, and the source tanks could not provide enough solution to flood to the height of the room's floor drain anyway.

Glovebox HC-6 is not anchored to the floor, so there is the possibility for tilting or toppling during a seismic event. Extensive tilting would more likely sever the plutonium solution piping outside of the glovebox, to spill directly to the room floor. The seismic scenario might also postulate the shattering of glovebox windows with an additional contingency of water entry from activation of the room fire sprinkler. In this case the worst orientation would be tilting 45 degrees on the south edge. To be critical as a 90-degree trough, there would have to be at least 2,500 g of Pu available in solution. Given the multiplicity and severity of fault or error conditions required, a criticality in Glovebox HC-6 is not credible.

9.2.4.2.11.L Accident Scenario-Criticality, Glovebox 522 in Room 152-- Glovebox 522 in the PFPAL was previously used to concentrate waste laboratory plutonium solutions. However, its concentrator vessel has been isolated and will not be used pending a major redesign and resolution of safety issues. Also the glovebox will not be used to transfer waste fluids from the PFPAL to the PRF.

The 8-ft by 22-inch by 6.5-ft glovebox is along the north wall of Room 152. Adjacent to its eastern end is Hood 521, a standard, open faced fume hood which was used for vacuum transfers of waste solutions into Glovebox 522. The base of Glovebox 522 is supported three inches off the room floor by a frame table with leveling bolts on circular pads. This frame is not anchored to the floor and is not seismically qualified.

There are eight fixed, 6-inch diameter pyrex tanks and one 3-inch diameter scrubber in Glovebox 522. The concentrator and its associated condenser, scrubber, and distillate storage tanks are out of service with their connections blanked off. For the waste liquid transfers, the only vessels expected to contain fissile solution were the Aqueous Storage (A), Organic Storage (O), Miscellaneous Storage (M), and Load-Out (L) tanks. The rounded-bottom, 16-L storage tanks are just one inch off the floor, and the 10-L loadout tank and the vacuum trap are near the top of the glovebox.

All solution load-ins and load-outs were achieved via vacuum transfer, and liquid lines (water and chemical makeup) to the glovebox have been blanked off. An oil-pool type criticality drain at the bottom of the south panel services the glovebox, operability inspections are subject to OSR requirements.

The current criticality specifications for Glovebox 522 allow Pu solution concentrations of up to 450 g/L, which is higher than previous waste liquid transfers. For the total glovebox there is a limit of 3,400 g of Pu. No containers, other than a 1-inch-deep catch pan, are permitted. Thus, the configuration for a possible criticality would have to be a solution on the floor of the glovebox. Dumping the contents of the three storage tanks (A, O and M) plus the load-out tank (for a total of 58 liters) would only flood the level floor to a depth of 1.7 inches, which is insufficient for criticality. With the allowed 3,400 g of Pu spread out on the level glovebox floor, the areal density would be 232 g Pu/ft^2, which is below the minimum critical slab thickness even if fully reflected.

A criticality in Glovebox 522, therefore, would require extra error conditions in addition to dumping of tank contents to the floor. For an upright box there would have to be more than 3,400 g of Pu available (on the order of at least 5,000 g) plus extra flooding by liquid from outside of the glovebox. A seismic event might activate an overhead fire sprinkler and also break windows to provide water entrance. However, the combined probabilities of the DBE, the box being overloaded, the sprinkler tripping and spray entering the box make this not credible.

Tilting of the glovebox due to seismic-induced faults, however, could lower the fissile amount needed for criticality by providing a non-slab pool shape. One extreme scenario, probably prevented by pipe and ductwork attached at the top, would be the glovebox toppling forward: in this event, the worst position would be at 45 degrees so that an 8-ft-long, 90°, solution-filled trough is created. For a 90° trough with the bottom edge horizontal on the concrete floor, it would take about 4,000 g of Pu for criticality (~500 g/ft x 8'). The more likely fault would be sheared leveling bolts so that the front edge or one corner of the glovebox drops three inches.

Specific calculations of plausible tilting configurations with glovebox 522 have not been performed. Until such an analysis is carried out, it is appropriate to conservatively limit the fissile inventory for unanchored gloveboxes such as 522 to not more than 2,000 g. This is based upon calculations for an optimally oriented corner pool, with the side and bottom edges all at the same angle to the horizon, forming an equilateral pool surface. The minimum critical mass for such corner pools, with nominal reflection on the pool surface and concrete below, is 2,100 g of Pu (as PuO_2-

water and 3% minimum ^{240}Pu). The minimum occurs at a concentration of about 32 g/L Pu, so that a liquid volume of nearly 65 liters is needed.

With the limit on total fissile inventory reduced to 2,000 g, a criticality in glovebox 522 of Room 152 becomes a multiple contingency event, requiring errors like overloading, tanks dumping, entry of extra liquid from outside, and/or drastic reorientation of the glovebox by seismic stresses. The combined probabilities for these errors concurrently gives an incredible scenario.

9.2.4.2.11.M Accident Scenario-Criticality, Glovebox MT-5--Glovebox MT-5 in the MT facility (room 41 of the 236-Z Building) was used for dissolving and leaching of plutonium bearing scrap in pot dissolvers. The dissolution and leaching process is currently inactive and not authorized for operations or interim storage of Pu material. The following analysis determines the inventory limit necessary to preclude a criticality if the glovebox is reactivated.

Glovebox MT-5 has six, 32-inch long by 36-inch wide sections. Each of five dissolver sections has a hotplate, 4-liter dissolver beaker and a reflux condenser. The east end section has two chemical makeup tanks, a 6-liter ANN addition tank and an 8-liter "B" Acid addition tank. This tank end section, where the conveyor box is attached, is also used for can storage. 1-liter and 0.5-liter containers are allowed as cans, polyjars, beakers, etc. A steel framework supports the glovebox 31-inches off the room floor, with bolts ($\frac{3}{4}$-in. diam.) spacing the frame 3-inches from the box and also from the floor anchors. The anchors are secured to the concrete room floor with $\frac{5}{8}$-in. bolts.

The criticality drain for MT-5 is on the floor about five inches from the east end of the glovebox, and about midway from front to back. It is a 3-inch diameter pipe extending 2 inches above the floor and going down nearly to the room floor to feed a 1.5-inch diameter horizontal header, which also drains MT-4 and MT-6. Water cooling for the reflux condensers was provided by the PRF Closed Loop Cooling System (Hess, 1993a). A total of 364 liters (96 gallons) of water was available from the cooling circuit, and the flow rate into MT-5 limited to 5 gpm by a flow restrictor on the cooling line input to the glovebox.

The CPS for MT-5 currently limits the glovebox contents as follows;

- Per dissolver station: 4,000 g Pu, maximum; two containers, maximum
- Per dissolver pot: 2,000 g Pu, maximum
- Tank section : 6 containers, maximum
- Limits on containers: 1,500 g in 0.5 L units; 800 g in 1.0 L units

In normal operations, however, the glovebox contents have been typically 400 g Pu loads in dissolvers and 2,000 grams total in other various containers.

The *PFP Safety Systems and Components Seismic Evaluation - Phase II*, WHC-SD-CP-SA-007, (Ocoma 1990b) determined that MT-5 is not seismically qualified due to weakness in its anchoring to the room floor, where bending/yielding could give vertical displacements of up to 2.3 inches. This seismic study examined the stress response of the MT-5 support features as a

stand alone glovebox. As such, it is not determined if motions by the other MT gloveboxes, interconnected with the conveyor glovebox, might further stress the MT-5 support structure. Also, toppling of gloveboxes MT-4 and MT-6 (which are not anchored and not analyzed) could impact MT-5.

Studies of the vulnerability of Glovebox MT-5 to a seismically induced criticality are reported in CSER 93-003 (Hess, 1993b). The hazard depends on how much plutonium is available, the extent of glovebox floor tilting, and the volume of liquid leaked to the floor. The basic accident scenario is the following;

1. The event dumps the Pu-nitrate solution from all of the five 4-liter dissolvers. Open containers in all the sections are also spilled.

2. Enough of the lower framework bolts are bent or sheared to disconnect the box from the frame, but with its east end staying upheld by the conveyor box. The west end of the glovebox then angles downward away from the drain, with a drop ranging from a few inches to all the way to the floor.

3. The seismic stresses may also dump the ANN and acid tanks, adding 14 liters of fluid. The extra acid dissolves the solids from spilled cans.

4. A break of the condenser cooling device and/or the internal cooling circuit lines might also be caused by the seismic stresses.

However, the chance for discharging such cooling water into MT-5 decreases as the box becomes more tilted (becoming more likely to break loose outside). The same conditions would apply to the ANN and acid supply lines. In addition, the makeup chemical lines would seldom be pressurized (only during the occasional pumped load-in transfers). The postulated entrance of room overhead fire sprinkler water into the glovebox would depend not only on the chance for activation in Room 41, but also the probability of the event cracking large holes in the upper windows (which are wire-safety-glass) without creating drainage openings below. Also, the fire water main may rupture elsewhere. Thus, the entry of sprinkler water into MT-5 has to be considered an unlikely, extra contingency.

The CSER 93-003 studies (Hess, 1993b) modeled MT-5 tilted lengthwise and back-to-front to various degrees, and the subcritical margins were calculated using the Monte-Carlo codes MONK5 and MONK6A. The severest scenario studied had the front west corner of the glovebox dropped 31 inches to the concrete floor, tilting the box in two directions, the front edge of the box angling upward at 9.2° and the west face of the box tilted 45°, forming a trough-wedge shaped pool. The following table summarizes the details and results of the corner drop calculations most pertinent to the evaluation.

MONK CALCULATION RESULTS FOR GLOVEBOX MT-5 WITH CORNER DROPPED TO FLOOR

Set #	Case #	Solution Wedge Details[a]			Total Pu, g	MONK5 Results	
		Maximum Depth, inches[b]	Volume, L	Density of Pu, g/L		k_{eff}	Std. Dev.
1	MT5D08	8.32	20.0	300.0	6,000	0.8202	0.0049
2	MT5D01	9.93	34.0	88.24	3,000	0.9385	0.0052
3	MT5D07	11.29	50.0	30.00	1,500	0.8986	0.0049
	MT5D04	12.43	66.7	30.00	2,000	0.9616	0.0051

[a] Glovebox bottom edge angling 9.2° from floor, west face rotated 45°.
[b] From dropped corner to surface of pool. Concrete reflector below corner.

The first two case results in the table are for liquid volumes limited, respectively, to the 20 L available from the dissolvers, and to the 34 L of the dissolvers plus tank contents. It is seen that the prospect for spillage of the ANN and acid liquids reduces the allowed available Pu to 3,000 g. For the last two cases in the table, it is assumed that extra water is spilled to the floor, either closed loop cooling water or liquids from outside the glovebox. The Pu concentration is optimized at 30 g/L (for minimizing the critical mass), and the pool depth and volume varied. The k-effective of 0.96 for a 67 L solution pool with 2 kg Pu (case MT5D04) is a few percent over the normal acceptably-subcritical criterion. However, the configuration represented goes far beyond a simple one contingency event (the earthquake with dissolvers dumped). The full corner drop is much less likely than the small vertical displacements found by the stand-alone seismic-response study, and the discharge of extra water into MT-5 is not a for-certain occurrence.

Overall, the study results indicate that a 2,000 g limit on the total Pu inventory in glovebox MT-5 is adequate to provide assurance against any conceivable scenario for earthquake-caused criticality with glovebox MT-5 not seismically qualified. A higher limit, on the order of 10 kg, could readily be justified if additional seismic analyses for the coupled, interconnected MT gloveboxes show no support failures which tilt the glovebox to an extent that pools more than 7 inches deep could form.

Glovebox MT-5 is currently designated inactive (see Table 9-25). Based on NDA results the glovebox is estimated to contain $\leq$350 g of residual plutonium. A criticality in Glovebox MT-5 is thus not credible.

9.2.4.2.11.N Accident Scenario-Criticality, West Glovebox, PRF-- On the walls of the PRF canyon (or cell) are several bank-tanks for various process plutonium solutions, with allowed concentrations of up to 450 g Pu/L. Leakage from these tanks within the cell is not a direct criticality hazard, because spreading of the solution over the expansive floor area will give a solution depth below the minimum needed for criticality.

However, control of the process tank flows is accomplished with piping through the cell walls into the cell-access gloveboxes on two floors to the east and west of the cell. These access gloveboxes contain some smaller tanks, piping and various control valves. Leakage from these equipment items could conceivably result in a solution criticality on the first floor of the access gloveboxes, with smaller areas for spreading. Liquid spills (if significant) in the second-floor access gloveboxes and from the 4th, 5th and 6th-floor column gloveboxes could also be involved, which all drain through various pipe chases

and gaps down to the first floor could also be involved. There are also closed-loop cooling water lines that, if leaking, could contribute to liquid accumulations on the first floor.

On the first floor, the 63-ft-long east and west access boxes are 30 inches above the room floor, except for the two 32-in.-long, north-end sections (designated WW/WZ and EW/EZ) where the bottom of the box is only 7.5 in. off of the room floor. In these lower sections are the criticality drains, 2.5-in.-dia pipes going horizontally out of the north-end panels into the process cell. The bottom of each drain hole is 1.75 in. above its glovebox floor. The wire-mesh cage protecting the drain hole on the inside of the glovebox extends 4.2 in. from the wall and is 5.5 in. tall by approximately 10 in. wide. The 1/2 in. square mesh grid of 16-gauge steel wires allows easy flow without chance of clogging by debris. At the back of both the east and west north-end regions, at approximately 2 in. off of the floor, there are also older, 1-in.-dia drainholes going directly into the cell.

Liquid discharges into other than the north-end glovebox sections would first have to fill the associated 64-in.-long by 23-in.-wide floor "trays", or catch basins formed by the 2.5-in.-high weirs between every two sections, before spilling over into the drain section. Each tray can hold approximately 60 liters at a depth of 2.5 in., which is less than the minimum critical slab thickness for any plausible solution or sludge concentration. A floor solution criticality is thus precluded in most sections of the four cell-access gloveboxes, except for the lowered-floor drain sections on the first floor.

The four cell access gloveboxes are assessed as seismically qualified (see Table 9-25). They will incur no structural damage during a DBE. This is attributed to being well anchored to the thick concrete cell walls and to the floor. Thus no significant tilting would be expected as a result of a DBE, nor is it likely that the criticality drain pipes could be crimped. Also, inside the glovebox it is unlikely that falling objects would damage the guard screen on the criticality drain entrance to a degree which would impede the action of the drain.

It is postulated that a source of plutonium for a criticality on the floor results from seismic stress-induced failures on some of the process lines or tanks within the gloveboxes. In the east-access glovebox, there is a closed-loop cooling water line in Section ET, the product from the filtrate concentrator in Section ER, closed-loop cooling water lines in Section ES, and so on. On the west side, the product concentrator tank is at Section WS, the CRT in Sections WT, WV, and WS, along with other liquid lines. It is assumed that only one-third of the floor catch basins (trays) need to be filled before they overflow into the drain section, based on the abundance of liquid lines and concentrated plutonium solutions in this third of the glovebox. Pages 2-22 through 2-26 of *Plutonium Reclamation Facility Engineering Technical Reference*, WHC-SD-CP-TI-122, (Kronvall 1988) show that there are easily 200 liters that could drain into the glovebox if the tank process lines therein broke.

In either of the north-end drain sections, a pool of plutonium solution or slurry deep enough for criticality could result, from blocking of the criticality drain or by a leak overflow rate in excess of the flow capacity of the drain. A slow discharge yielding a pool up to the bottom of the drain (1.75 in.) would certainly be safe. The minimum critical slab thickness, for Pu

(3% of ^{240}Pu) nitrate solution with nominal reflection, would be 4.4 in. (per Carter et al. 1969), graph III.A.5.97-2. This is over the top of the drain hole and would require approximately 14 kg of Pu in 106 liters of liquid.

Thus, for just the plausible liquid-line discharges from common-cause, seismic-stress equipment faults considered as a single contingency, a DBE-induced criticality is not credible unless flow through the criticality drain is blocked or severely impeded. Such impediment of the drain action would have to be considered an extra contingency of low probability, either a pre-existing blockage, or the result of some abnormal occurrence that provides metal, plastic or cloth panels covering all faces of the drain screen structure. A plausible scenario for incurring such coverage is not evident.

If the drain was effectively blocked, criticality would require as little as 3.2 kg of Pu in a solution pool of 9-in. depth, requiring 217 liters of liquid at 14.6 g Pu/L (Carter et al. 1969), graph III.A.8.97-2. A critical pool depth might also result because the total overflow rate into the drain section is excessive (more than 15 gpm). Such excessive flow rates are not likely, considering that it requires multiple line faults, that the spreading of the liquids into the other section trays reduces the flow, and that massive ruptures are more likely to occur within the cell.

By whichever mode criticality occurs, if it were to occur, the dose would be bounded by that determined in Section 9.2.3.

9.2.4.2.11.0 Accident Scenario-Criticality, HC-9B--Glovebox HC-9B houses equipment for the previous RMC Line process of converting plutonium in nitrate solution into plutonium fluoride powder, with intermediate stages as damp oxalate and as oxide powder. The glovebox has three levels, the highest of which contains the reactor-precipitator and vacuum drum filter (VDF) for generation of plutonium oxalate, and a calciner which reduces the oxalate to Pu-oxide powder.

As fluoride production no longer takes place, the fluorinator, in the middle level of the glovebox could be used as a second-stage calciner, operating up to 500 °C. The plutonium oxide powder churned out by the top level calciner drops directly down through a floor opening into the second-stage calciner, the output of which is collected in 1.7-liter powder pans or 0.5-liter slip-lid cans or polyjars in the middle level.

The bottom level of HC-9B contains a tank to collect condensate from the calciner off-gas system, a tank for temporary storage of the filtrate to be sent to glovebox HC-7, a tank to collect overflow from the vacuum drum filter, and two pumps to handle transfers from the latter two cited tanks. Except for upset situations, the lower section tanks and pumps would not contain significant amounts of plutonium. Storage of plutonium oxide in as many as four 1.5-liter containers is allowed in the lower level.

Sources of liquids into the glovebox are in the upper level. Feeding the reactor-precipitator are the Pu-nitrate solution line from HC-7, the oxalic acid line and a distilled water line. The process feed rate is only 6 liters/hour, and a leaking input line would have a maximum of only 16 liters of fluids available. There is also a wash solution line for the VDF. The divider floors between the upper/middle and middle/lower levels have central drain holes with

cover screens, so that there is effectively no holdup of liquids if such are spilled in the upper and middle sections. On the bottom level there is a screened criticality drain pipe going out very nearly at the floor level of the glovebox, which sits on the floor. With no liquid holdup in the upper two levels, and with the low criticality drain arrangement in the bottom section, a solution criticality in glovebox HC-9B is not plausible.

Glovebox HC-9B was determined to be seismically qualified, meaning that structure or equipment damage would not occur as the result of a DBE (Ocoma, 1990b); thus, the glovebox stays upright and the equipment supports and pipelines do not fail. In such events, the reactor vessel and the calciner operating in the continuous feed mode will remain geometrically favorable, as qualified by the criticality safety analysis supporting the CPS. In addition, the material entrained within the reactor and calciner would be dumped out by the shaking.

Seismic motions, however, could tumble containers of plutonium compounds and/or accumulations of material allowed beneath equipment or on the section floors. Considering the small diameter of floor drains, it is not plausible for much of the material to move between levels. In the upper level, all of the loose or canned materials should be hydrated plutonium oxalate, as a result of spills going from the drum filter to the calciner inlet. Since fluorination no longer is done in the middle level, there is less need to use the recycle inlet hopper at the end of the upper-level calciner. Thus, containers of oxide powder are not routinely expected in the top level.

The criticality safety specifications allow 1.6 kg Pu as oxalate under the drum filter, four full, 1.5-liter containers, and 1/2-inch of material on the top floor. As a matter of SNM accountability and ALARA considerations, the floor accumulation would not be over 1 kg of Pu. The calciner inlet chute is also allowed a maximum of 1 kg of oxalate. Assuming all material as hydrated Pu-oxalate cake, at 600 g Pu/L, gives a maximum of 7200 g Pu available in the upper level, of which perhaps 1,800 would be in closed cans.

The criterion for a dry material in a glovebox allows 12 kg of Pu before it is considered vulnerable to a seismic-induced criticality. The "dry" stipulation allows for slight moderation, with an H/Pu ratio less than 15. At stoichiometric conditions, hydrated Pu-oxalate has an H/Pu ratio of 12, and if compacted to 600 g/L of Pu, would have a void fraction of 54%. Verification that 12 kg of Pu-oxalate would be safe is documented in CSER 88-006 (Hess, 1990), which determined that a conical pile so loaded would not approach the subcritical limit until the free water content exceeds 35% by volume. For the assumed retention of fluid line integrity, there would be no source for the extra moderation. However, even if such was available, the near saturation of the oxalate would not allow a self-supporting cone, but provide an easily flowing slurry which flattens and/or drains to the lower level. With a maximum of 7.2 kg of Pu as oxalate available exterior to the calciner, there is no chance for criticality in the top level of glovebox HC-9B.

For the lower levels, the amount of plutonium available, as oxide and perhaps some oxalate, is even less and the consequent risk for criticality lower still.

9.2.4.2.11.P Accident Scenario-Criticality, MT-6--Glovebox 6 in the Miscellaneous Treatment facility (room 41 of the 236-Z Building) contains equipment to vacuum transfer process solutions and to centrifuge solids from such solutions. The solutions were received from the MT-5 pot dissolvers discussed previously in Section 9.2.4.2.11.L, and also from operations in the process cell. Four of six 32-inch long by 36-inch wide sections of the glovebox were utilized; the middle two sections with centrifuges, and the two tank sections to the east. Viewed from the south, the box is stepped shaped. The two tank sections on the right rest on the room floor, while the other four sections are supported 31 inches above the floor by a table frame. No floor anchors are provided, but the east face of the glovebox is bolted to the MT conveyor box.

Inside, near the back of the tank sections are four 6-inch diameter tanks, co-axial vertical tanks C-3 and C-5, and tanks C-2 and C-6 on another vertical axis 32 inches away. The receiver tanks C-2 and C-3 are each 30-in high Pyrex vessels which loaded with the transferred Pu-nitrate solution and possibly solid precipitate. Reagents could also be added to C-2 and C-3 to precipitate impurities, which were then removed by running the solutions through Centrifuge C in the central glovebox section.

Toward the front are the vacuum pump and associated trap tank C-1. The pump was cooled by water recirculated through a 30-inch tall heat-exchanger tank C-4, in which the heat was transferred to a cooling coil fed by the PFP Closed Loop Cooling System discussed in the section about MT-5.

In the central two glovebox sections are four, levelable, 1-ft square centrifuge platforms, about 7 inches above the section floor. Only three centrifuges are inplace, the 'C' unit in the northeast quadrant for the C-2, C-3 output, and the B1 and B2 units on the south side.

The criticality drain for Glovebox MT-6 sits right on the concrete floor of Room 41. The drain is a 1.5-inch diameter pipe coming out of the end panel and centered at about 1.6 inches above the bottom of the box. This drain feeds 5 ft of 1.5-inch pipe (with two 90° bends) running horizontally over to the 1.5-inch lateral header for the MT drain system. With this arrangement, a flow restrictor device was required on the Closed Loop Water inlet to limit flow to 5 gpm and limit the flooding depth in the double end section to 3.2 inches in case of a cooling water line break.

A previous CPS for MT-6 provided limits on the fissile contents of the receiver tanks, centrifuge bowls, and "unit masses" (an assemblage of containers with up to 2.7 liters of total volume). Spacings of 10 inches were required between these various fissile accumulations, bowls and tanks. It had been shown in CSER-88-006, *Solid Limits for Receiver Tanks in Glovebox MT-6*, (Hess 1990) that 5 kg of Pu could be allowed in each of tanks C-2 and C-3 without concern for how much settled solids were present. Previously, before consideration of the impact of seismically-induced faults, the number of subcritical masses was limited to two, and each to no more than 3,000 g Pu.

Glovebox MT-6 was not included in the Ocoma study of glovebox seismic responses and is deemed not seismically qualified because of its lack of floor anchoring. Thus, it is plausible that MT-6 could topple. Another aspect with

the possibility of the box moving is the potential for crimping the long, lateral criticality drain header.

Considering that up to 46 liters of Pu solution plus water could be present in tanks C-2, C-3 and C-4 within the glovebox, and subject to dumping in the seismic event, a criticality can be precluded only by limiting the total fissile inventory in the tanks plus the solids available in open containers. Tilting due to seismic stresses will give a more reactive pool geometry than a uniform thickness floor slab. It could be argued, because of the tank section sitting right on the room floor, that MT-6 is less likely to incur the edge-drop configuration considered for MT-5. However, tilting 45° in one direction could yield a 6-ft long, troughlike pool, for which a minimum linear critical concentration of 500 g/ft would mean only allowing 3 kg total Pu.

Glovebox MT-6 is currently designated as inactive and contains $\leq$700 g of residual plutonium. There is no plausible critical pool geometry which could be formed by seismically-induced displacements given the rectangular box structure and the lack of significant reflector formation.

9.2.4.2.11.Q Accident Scenario-Criticality, HC-230C-2--Glovebox HC-230C-2 will contain greater than a critical mass of Pu when activated (the glovebox is currently inactive). The vessels in the glovebox are sized and separated in a manner that precludes criticalities during normal operation. Fissile inventory in the glovebox vessels and in open containers on the glovebox floor is administratively controlled. The glovebox is qualified for the DBE and will not topple or collapse. Should vessels rupture inside the glovebox during the DBE and spill to the floor of the glovebox, a criticality drain is provided to prevent the accumulation of a critical geometry of moderated solution within the glovebox. The criticality drain protects against a criticality in the event fire water infiltrates into the glovebox following the DBE. A DBE-induced criticality in glovebox HC-230C-2 is not considered to be credible.

9.2.4.2.11.R Accident Scenario-Criticality, HC-18M--RMC Line area glovebox HC-18M is used as part of the stabilization process for product sieving, grinding, sampling, weighing, and seal-out (or transfer to another glovebox for seal-out). The glovebox contains electronic scales, mortar and pestle, and a sieve shaker. Stabilized plutonium bearing material is transferred to this glovebox where it is prepared for packaging and sampled. The CPS for the glovebox allows for preparing, sampling, and packaging dry plutonium compounds. Glovebox HC-18M is a "dry" glovebox where no solution lines are present. Except for a maximum of 20 ml of lubricants that must be capped when not being used, no free liquids are allowed in the glovebox. The CPS in effect as of May 2000 allows for 10000 g of dry plutonium compounds. The CPS also establishes specific spacing, H/Pu, container volume, and unit mass limits. The CPS recognizes that approximately one-fourth of a metal plutonium item may unintentionally be introduced into the glovebox and requires that it be promptly removed if introduced.

The glovebox is not seismically qualified due to its supports not being anchored to the floor. During a DBE, the structure supporting the glovebox is assumed to collapse, allowing the material containers to freely tumble to one end, spilling and accumulating their contents into a single volume. The CSER for the glovebox analyzes a central sphere of dense fissile material with up to two spherical shells around it. The spheres are assumed to be surrounded by one

inch of water reflection. The CPS limits have been established to ensure that material interaction k effective remains acceptable under this DBE scenario. The CSER recognizes the presence of a non-seismically qualified fire suppression system and the potential for glovebox window breakage. However, the evaluation also determines that the probability of fire suppression water entering the glovebox and not leaking back out would be small. This small probability, in combination with the small probability that sufficient fissile material assembles into a compact enough configuration was judged to be too low to be considered credible.

Therefore, as a single contingency effect, a seismically induced criticality in Glovebox HC-18M is not credible. Additional violations of CPS limits, and unlikely configurations caused by a DBE, would have to occur simultaneously before a DBE induced criticality is possible.

9.2.4.2.11.S Accident Scenario-Criticality, Conclusion--There are no criticalities possible as a result of seismic loads alone. If there are preexisting criticality drain failures, a criticality is possible only in the west gallery glovebox. Given the presence of a criticality safety program and the arguments in Section 9.2.4.2.11.N, the likelihood of a criticality during a seismic event is much less than the likelihood of the seismic event. Even if a criticality did occur, the onsite and offsite doses are only 5% of the total doses and, therefore, insignificant to those individuals far from the facility. For these reasons, the criticality doses are not included in the doses determined for the seismic event.

9.2.4.2.12 Accident Scenarios-Fire. Fires are conceivable as a result of scrap processing, spontaneous ignition, electrical shorts, flammable liquids, or contact of combustibles with hot equipment (Marusich 1988a). Each will be discussed.

9.2.4.2.12.A Accident Scenario-Fire, Scrap Processing. In order to get a seismically related process upset fire, ignitable process solutions are required to contact a heat source. Ignitable process solutions are organic or nitrated organic solutions. Solutions like this and heat sources (hot plates) existed in glovebox MT-5. Glovebox MT-5 is no longer used for scrap processing, and large quantities of organic are not present. There are no ignitable process solutions present to contact heat sources in the PFP.

9.2.4.2.12.B Accident Scenario-Fire, Spontaneous Ignition. Spontaneous ignition at the time of the seismic event is not considered credible as it requires spontaneous ignition of trash or rags at the same time as the seismic event. In addition, the seismic event will not cause spontaneous ignition of the trash.

9.2.4.2.12.C Accident Scenario-Fire, Electrical Shorts. Fires due to electrical shorts may start in areas of high fire loading during the initial building vibrations prior to internal failure, assuming that the electrical power remains intact. As discussed in *Correction for MT-5 Hotplate Power in Design Basis and Small Earthquakes* (Weiner 1992), the probability that electrical power remains on is greater than 10^{-1}/event.

The fires that are assumed to be started in high-fire-loading areas such as the changeroom or offices are not near any gloveboxes. The air draw caused by

these fires should not disturb any material on the floor because the velocity across the rubble is small. Fires could possibly be started in the area of the gloveboxes due to shorts and arcs in the high current lines going to the scrap stabilization furnaces in Gloveboxes HC-21C and HA-21I. Electrical shorts are very unlikely to start a fire in a glovebox. This is because the electrical short must occur in the very near vicinity of combustible material and must remain energized for a time sufficient to cause ignition. The high energy and long duration shorts necessary to ignite glovebox panels will likely cause the breaker to trip, thereby removing the short. Typically combustible material is stored well away from electrical sources as part of proper housekeeping. Excessive glovebox motion (such as toppling) could cause combustible material to come in contact with sources of electricity. However these same motions will likely cause the wires to fail or short elsewhere.

9.2.4.2.12.D Accident Scenario-Fire, Flammable Liquids. Flammable liquids are only present in PFP facilities in small quantities stored in specially designed flammable material storage cabinets away from the processing areas. These may be damaged during the seismic event but the lack of ignition source, the presence of debris all around, and the solution present (water may also be present) could result in only small local fires, if any.

9.2.4.2.12.E Accident Scenario-Fire, Contact with Hot Equipment or Hot Material. The calciners in Glovebox HC-9B are inactive, as are the induction furnaces in Gloveboxes HC-15A, -15B, and -15C. No fire threat from contact of hot equipment with combustibles or glovebox panels exists in these gloveboxes. Section 9.2.10.5 addresses the potential for a seismic induced fire in Gloveboxes HC-21C and HA-21I, which contains muffle furnaces that may be operating at 1000°C at the time of an earthquake.

Gloveboxes HC-15A, -15B, and -15C contain inactive induction furnaces, so no fire threat exists. The gloveboxes have been analyzed and found to remain upright during a seismic event. Therefore, there is no seismically induced fire for gloveboxes HC-15A, -15B, and -15C as a direct result of the DBE.

9.2.4.2.12.F Accident Scenario-Fire, Fire Due to Seismic Event The preceding sections provide discussions of the potential seismically induced fire ignition sources. From these discussions it can be seen that a seismically induced fire in the RMC/RMA Line is most likely caused by contact of hot equipment (muffle furnace) with combustibles or with the glovebox panels (viewing windows) in Gloveboxes HC-21C and HA-21I.

The fire scenario due to a seismic event assumes that fires start in glovebox HC-21C and HA-21I.

The fire is presumed to start in Gloveboxes HA-21I and HC-21C due to the presence of hot furnaces and the assumed interaction with the panels. It is noted that the furnaces are insulated by firebrick held in place by a metal case. The door is counter-weighted so it takes some force to open it. The vacuum exhaust piping and filter are also insulated except for small portions.

Ignition of the plastic panels requires the following:

- A furnace must be at a temperature above the ignition temperature of the plastic panels

- The seismic event causes a furnace to move and come in contact with a panel

- An area of the furnace that is above the ignition point of the plastic panel comes in contact with it and remains long enough to ignite the panel.

The above sequence can only reasonably occur if the seismic event results in glovebox motions strong enough to knock off the insulation of the offgas line, knock off the metal case and fire brick or if the seismic event results in a hot furnace boat being forced out of a furnace and coming into contact with a panel. Seismic motions this strong probably result in glovebox toppling. Certainly, spilling the hot boat from the furnace which then comes into contact with a plastic panel requires the glovebox to topple. The furnaces are free to move within the glovebox (that is, they are not fixed to the glovebox floor). Since an analysis of furnace motions as a result of the earthquake has not been performed, it is conservatively assumed that a hot surface of a furnace comes in contact with a plastic panel in Glovebox HC-21C and in Glovebox HA-21I.

Contact of a hot surface of a furnace with a panel can have a number of differing outcomes. The most benign outcome is that a small portion of the panel melts, but is not ignited so that a fire does not propagate over the remainder of the plastic panel. Alternatively, the panel could ignite and the fire could propagate through the panel. The resulting energy release could cause ignition of other plastic panels both in the glovebox initially burning and other gloveboxes near the burning glovebox. Section 7.4.3 of the FHA (Mckinnis 1998) states that a glovebox having PMMA panels can be ignited by a burning glovebox having PMMA panels if the separation is less than 10 ft.

In the most severe case, the entire RMC and RMA Lines could be involved in the fire as discussed in Section 9.2.2A. This case requires that a number of conditions relative to fire propagation from glovebox-to-glovebox as well as room-to-room be satisfied. It is judged that a seismically initiated fire of this magnitude is very unlikely due to the number of unqualified process gloveboxes and conveyor gloveboxes, the mix of PMMA and polycarbonate panels, which are much harder to ignite than PMMA, the large distances between gloveboxes in some areas, the presence of doors between rooms that are maintained closed for ventilation control, and the potential for some portion of the fire protection system to partially or fully perform its function especailly with respect to the Halon systems for the seismically qualified gloveboxes.

As a result, it is judged that a reasonably conservative, seismically-induced fire scenario starts in Gloveboxes HC-21C and HA-21I. The fire in Glovebox HC-21C is assumed to burn all of the panels. The fire is then judged to propagate to Glovebox HC-21A via the conveyor. It is judged that the fire does not propagate into Room 230-C which houses the Magnesium Hydroxide Precipitation Process gloveboxes, HC-230C-3 and HC-230C-4. The wall and door between the rooms are 1-hour fire barriers and do not burn. The door is assumed to be closed. The conveyor glovebox, HC-2, from Room 230-B (Glovebox HC-21A) runs into Room 230-C. The fire in Room 230-B will not propagate into Room 230-C via the conveyor because of the closed airlock in the conveyor just downstream of Glovebox HC-21A. In addition, the fire initiated in Glovebox HA-21I cannot propagate to the precipitation process gloveboxes from conveyor HC-4 because the fire door on the ventilation inlet to the Magnesium Hydroxide Precipitation

Process glovebox, HC-230C-3, will close, thereby preventing the fire from entering the glovebox.

The fire in Glovebox HC-21C is judged not to propagate to the remainder of the RMC Line (toward Glovebox HC-18BS) due to the presence of a 1-hr fire barrier between Room 230-A and Room 228-C (assuming the doors between these two rooms are closed), due to the long length of unqualified conveyor between Glovebox HC-21C and Glovebox 18-M and due to the other reasons discussed previously regarding the mix of PMMA and polycarbonate panels and glovebox fire protection features.

The fire initiated in Glovebox HA-21I can propagate to Glovebox HA-20MB due to radiant heating. Section 7.4.3 of the FHA states that a glovebox having PMMA panels could be ignited by a burning glovebox if that glovebox were less than 10 ft away. Glovebox HA-20MB is 4.5 ft from Glovebox HA-21I. Similarly, Glovebox HA-19 could be ignited by Glovebox HA-20MB, and Glovebox HA-22B could be ignited by Glovebox HA-21I.

Propagation of the fire to Glovebox HA-23S is not likely. First, the glovebox is more than 10 ft away from Glovebox HA-21I so that it will not ignite due to radiant heating. Second, the water walls (iron tanks that when full provide a 1 ft water shield around the glovebox) also prevent ignition heating of the panels when the walls are in place. The walls are typically in place, so credit is taken for the walls. Third, even if the fire could propagate toward Glovebox HA-23S via the conveyor, it would be very unlikely that it would propagate into the glovebox itself. The glovebox walls containing the flammable panels are separated from the conveyor by about 4 ft. In this area are the sweep mechanisms that take containers from the conveyor and place them on the lift assembly that raises or lowers the container to the appropriate level within the glovebox. Fourth, the plastic panels of the glovebox are perpendicular to those of the conveyor. Therefore, the view factor (used in radiant heat transfer calculations to account for geometry) is much less for this geometry than it is if the panels were parallel. If a panel can ignite another panel when they are parallel and less than 10 ft away, a distance of 4 ft with perpendicular panels is likely to be insufficient to cause ignition.

Based on the above discussion, the postulated fire in Glovebox HA-21I is assumed to propagate to Gloveboxes HA-20MB, HA-19 and HA-22B but not to Glovebox HA-23S.

Because of the above reasons, it is judged that the seismically initiated fire does not involve the entire RMC/RMA Line but only portions of it. This is characteristic of PFP fires which have the potential to release plutonium out of the facility; if they occur at all, they are small and do not propagate through the process lines.

Based on the above discussions, the seismic induced fire is assumed to involve the following groups of gloveboxes:

- Gloveboxes HA-19, HA-20MB, HA-22B and HA-21I. This group is ignited by the furnaces in Glovebox HA-21I.
- Gloveboxes HC-21C and HC-21A. Glovebox HC-21A is ignited by the furnace initiated fire in Glovebox HC-21C.

The seismically induced glovebox fire as described above involves the following gloveboxes (The releases are determined using the data and methods described in Section 9.2.2A.):

HC-21C 0.30 g (unprotected oxide - ARF * RF = 6×10^{-5}; inventory = 5000 g)

HC-21A 0.43 g (unprotected oxide - ARF * RF = 6×10^{-5}; inventory = 7100 g)

HA-21I 0.48 g (unprotected oxide - ARF * RF = 6×10^{-5}; inventory = 8000 g)

HA-20MB 0.06 g (protected oxide - ARF * RF = 6×10^{-6}; inventory = 10000 g)

HA-19 1.00 g (polycubes - ARF * RF= 4×10^{-4}; inventory = 2500 g)

HA-22B 0.02 g (protected oxide - ARF * RF = 6×10^{-6}; inventory = 2500 g)

The total release into the facility is therefore 2.29 g of oxide. This release must be added to the seismic release due to glovebox toppling as the fire could spread as described above even if the gloveboxes topple.

The release into the rooms will be transported through the 291-Z-1 Stack due to ventilation exhaust airflow (if the exhaust system is running) or, in cases where there is no exhaust flow, to other portions of the 234-5Z Building due to fire-induced air currents and flow out the penetrations in the room walls and paths around doors due to room pressurization.

In the situation where the ventilation exhaust system operates, the fire induced release out of the room is assumed to be transported out of the facility through the 291-Z-1 Stack in the same manner and to the same extent as the plutonium release due to glovebox toppling. In the case where the exhaust system does not operate, it is assumed that half (about 1.15 g) of the suspended plutonium remains within the rooms and half is transported out of the room due to room pressurization and fire-induced air currents. This assumption is considered to be reasonable because there is no large open flow path out of the rooms. Flow is out relatively narrow openings in the doors and other penetrations. Under these conditions, there is additional time for the suspended aerosol to be deposited on surfaces due to impact, settling and thermal gradients over that in the exhaust system operating case. The half of the release that is transported into the other portions of the facility outside the RMC/RMA Line areas is removed in the same manner and to the same extent as the release of the other material in the case where the ventilation exhaust system is not operating.

9.2.4.2.13 Accident Scenario-Separation of Walls and Floor in 234-5Z. The *Seismic (SSE) Evaluation for the 243-5Z Building at the Hanford Site*, (URS 1987) identified a need to separate the vertical walls in column line 4 and column line 8 to preclude damage to the facility. Without this separation the following occurs (north-south earthquake).

The relatively massive second floor slab is excited by seismic forces and moves. The force generated by the slab acceleration is transferred to the column (bearing load) and to the floor beam (by friction). The movement of the

column and floor beam creates loads in the vertical concrete walls in Column 4 (between Columns A through E) and Column 8 (between Columns C and D). If the vertical walls were weak (like plaster board), they would crumble and the east side of 234-5Z would move just like the west side and the stresses would be within limits. The walls are strong, so the load is transferred to the column base plate. Since there are few base plates to carry the load, they become overstressed. The failure mode without the separation is: failure of the base plate and spalling of the vertical wall (with possible gross failure).

The equipment that would be impacted by the failure of the wall is the inactive HF scrubber, a few empty rooms, and some piping in the duct level. There is no significant dispersal of plutonium into the facility as a result of the failures.

9.2.4.3 Mitigation. The PFP has been reviewed for seismic resistance many times. At each review, many modifications have been made which assist in mitigating the consequences of accidents that could occur. These modifications also assist in preventing or reducing the likelihood of these accidents. A short list of modifications that were made based on previous analyses are:

- Automatic shutdown of building ventilation supply fans
- Removal of propane piped gas substituted by use of small bottles. [See Section 9.2.1F - Flammable Gas Explosion]
- Removal of methane gas
- Removal of hydrogen fluoride gas
- Modifications as necessary to show that certain gloveboxes, ducts from the gloveboxes to the first testable filter bank, and filterboxes holding this filter bank remain upright.

9.2.4.4 Recovery. The recovery from a seismic event will involve facilities other than PFP and may involve personal injury as well as radioactive and toxic material release. The injured personnel (if any) would be removed from the facility soon after the event. Since they could be contaminated, special medical facilities will need to be used. After (or during) the removal of the personnel, the processes will be stabilized (probably by disconnecting the electricity since electrical power is not needed for safety over the short term). There will likely be work proceeding next to provide for confinement and to assess damage. Confinement will be important if glovebox panels have failed or if an explosion occurred. Next, cleanup of the inside can proceed as well as identification and stabilization of sources outside. All of these actions will be planned and the potential releases calculated, accepted, and coordinated with other facilities.

9.2.4.5 Probability. The probability of the DBE (the one to be used in design per the DOE Order 6430.1A, *General Design Criteria*,) is 2×10^{-4} yr^{-1} per Kennedy et al. (1990). The *Natural Phenomena Hazards Modeling Project: Seismic Hazards Models for DOE Sites*, URCL 52582 (Coats and Murray 1984) present additional data (and is referenced for the DBE in Kennedy et al. [1990]) that show that the probability of a 0.2-g earthquake is 10^{-4} yr^{-1} and a 0.25-g at 4×10^{-5} yr^{-1}

(extrapolated). These are all best estimate values. Table 9-29 presents the standard deviations to these estimates.

The determination of the probability of the release is very complicated because it involves the determination of the probability of failure of the individual components. It is further complicated by the fact that to get the release calculated, the failure must be exactly as indicated.

The values of the individual component failures range from very nearly 1.0 (e.g., a very poorly restrained glovebox or an electrical transformer) to as low as 10^{-3}. The earthquake probability ranges from 10^{-3} to 10^{-4}. The value of 10^{-3} was argued in *Details Concerning Development Use and Impact of the Quantity of Material in the E-4 Ducts*, EDT 100843 (Marusich 1988b) to be the probability of the smallest earthquake that could result in damage.

Because of the difficulty of properly assigning a probability to the earthquake and individual component failures, the difficulty of combining them, and the perception that if a component is not specifically qualified to withstand seismic forces, it must be considered to fail with a probability of 1.0, the annual probability of the release calculated in Section 9.2.4.6 is taken to be 10^{-4} for the 0.20-g seismic event. For the 0.09-g seismic event, the annual probability is taken to be 2×10^{-3} based on the same references discussed above.

9.2.4.6 Seismic Accident Analysis.

9.2.4.6.1 Accident Analysis Assumptions. The accident analysis was performed assuming that the failures that were described in Sections 9.2.4.1 and 9.2.4.2 occur with the earthquake.

As stated in Section 9.2.4.2, the inventories of plutonium present are assumed equal to the CPS limits as shown in Table 9-25, except as modified by Table 9-26. Table 9-26 presents administrative limits for select areas or glove boxes that are more restrictive than the CPS limits. Facilities, processes, and locations are analyzed as defined in Section 9.2.4.2.

9.2.4.6.2 Accident Analysis, Methods and Models. Most of the methods and models are the same as those used in Marusich (1988a). Some extensions of the models have been developed and are used where necessary. The extension is described where it is used. Generally, most of the release fraction data come from experiments or empirical data with a small additional amount coming from "first principles." The scenario developed will be compared to the various experiments or empirical fits. The one that matches closest to the scenario is used for the release fraction.

An element common to the majority of the scenarios presented in Section 9.2.4.2 is the spilling of plutonium powders or solutions associated with gloveboxes or hoods. To simplify the analysis, four cases have been examined and the associated release fraction determined.

Case 1--Involves a seismically qualified glovebox. Containers of Pu can tip over because of vibratory motion, but the vibratory motion is insufficient to force the container through the walls, windows, or floor of the glovebox. Therefore, there is no release outside the glovebox. There is negligible Pu

suspension within the glovebox because the resuspension factor, caused by tipping of the container, is very small. Powders could be suspended should a process air line fail; however, the filters at exhaust outlets will minimize the release into the ventilation ducts to an insignificant amount. Thus, it is assumed that seismically qualified gloveboxes do not contribute to the release.

Case 2--Involves a glovebox that is not seismically qualified and could tip over or open up as a result of an earthquake. The floors of most gloveboxes are about 1 m (3 ft) off the floor of the room; therefore, a fall from 1 m (3 ft) represents the typical glovebox accident. Previously, Rev. 0 of Marusich (1988a) used a fall from 3 m (10 ft) to account for the added energy caused by the impact of falling concrete from damaged floors overhead. This approach is now judged to be overly conservative because it has been subsequently determined that the concrete floor on the third level above these gloveboxes does not fail (URS 1987).

For this analysis, the release fraction is based on a 2-m (7-ft) fall. A 2-m fall is selected versus a 1-m fall as some of the energy associated with the toppling glovebox could be transferred to a container of Pu. This value is further justified in Appendix 9.A.

The experimental data found in Table B.3 of NUREG CR-2139, *Aerosols Generated by Free Fall Spills of Powders and Solutions in Static Air* (NRC 1981), demonstrates the maximum respirable release fraction for depleted uranium oxide (DUO). DUO is expected to behave similarly to Pu oxide. For a 1-m (3-ft) drop the respirable release fraction is 4×10^{-5}, and for a 3-m (10-ft) drop it is 5.9×10^{-4}. The values found in Table B.2 of NRC (1981) for a 10 g/L uranium solution are 1.6×10^{-5} for a 1-m (3-ft) drop and 8.3×10^{-5} for a 3-m (10-ft) drop. The release fraction for a 2-m drop is found by taking the square root of the product of the 1-m and 3-m data. Applying this approach, the respirable release fraction for a 2-m drop of powders is 1.5×10^{-4} and for solutions it is 3.6×10^{-5}.

Case 3--Involves a seismically qualified fume hood. The release fraction is based on the 1-m (3-ft) fall data because of the assumption that the vibratory motion can make the container "walk" over the lip of the hood and fall to the floor below.

Case 4--Involves a fume hood that is not seismically qualified. The situation is similar to Case 2, but the release fraction is based on a 1-m (3-ft) drop as the hoods weigh much less than the gloveboxes and, therefore, the additional energy imparted to the material is smaller.

9.2.4.6.3 Accident Analysis-Calculations. It is helpful if the accident scenario section (Section 9.2.4.2) pertaining to the room or glovebox of interest is reread prior to reading about the accident analysis for that room or glovebox.

9.2.4.6.3.1 Accident Analysis-Calculations, 234-5Z.

9.2.4.6.3.1.A Accident Analysis-Calculation, Analytical Laboratory, Plutonium Processing Support Laboratory, and Standards Laboratory--The Analytical Laboratory contains 26 gloveboxes (two of which are inactive) and 42 hoods. The Analytical Laboratory is contained in rooms 131 through 157. The

PPSL contains nine gloveboxes (two of which are inactive) and eight hoods (two of which are inactive). The PPSL is located in rooms 179 through 188. The Standards Laboratory contains ten combination glovebox/hoods and is located in Rooms 221-C, 221-D and 221-E. An administrative limit of 12.45 kg of dispersible plutonium (of which not more than 5.25 kg is >10% ^{240}Pu) has been established for all three labs. This material, as either a powder or solution, could be present in gloveboxes, hoods, or both.

For this analysis, it is assumed that all of the allowable inventory is present in gloveboxes that are not seismically qualified (e.g., gloveboxes 1 through 6 in room 139, gloveboxes in Room 179, Glovebox 3 in Room 221-C). This assumption is conservative in that the release fraction is larger for unqualified gloveboxes than for unqualified hoods. It is further assumed that all of the material present is a powder. This assumption is conservative in that the release fraction is larger for powders than for solutions. Lastly, it is assumed that the maximum allowable quantity of >10% ^{240}Pu is present. This assumption is conservative in that the dose conversion factor is larger for >10% ^{240}Pu than it is for <10% ^{240}Pu. Therefore, of the 12.45 kg limit of dispersible plutonium, the material is assumed to be in the following forms:

- 5,250 g as plutonium oxide with ^{240}Pu content greater than 10%
- 7,200 g as plutonium oxide with ^{240}Pu content less than 10%.

Applying the Case-2 (Section 9.2.4.6.2) release fraction, the release of respirable Pu into the three PFP laboratories is calculated as follows:

a) <10% ^{240}Pu fraction

$$7{,}200 \text{ g } (1.5 \times 10^{-4}) = 1.08 \text{ g}$$

b) >10% ^{240}Pu fraction

$$5{,}250 \text{ g } (1.5 \times 10^{-4}) = 0.79 \text{ g}$$

Of the 5,250 g of plutonium oxide with ^{240}Pu content greater than 10% in gloveboxes in the laboratories, 0.79 g is released into the facility based on applying the Case 2 release fraction of 1.5×10^{-4}. Also of the 7,200 g of plutonium oxide with ^{240}Pu content less than 10% in the gloveboxes in the laboratories, 1.08 g is released into the facility based on applying the Case 2 release fraction of 1.5×10^{-4}.

The accident analysis for the seismic event impacts on the PFP laboratories does not include seismically initiated releases due to the Laboratory Prototype Calciner in the PPSL since the calciner is not authorized for operation. The releases from the laboratories due to a seismic event and considering operation of the calciner are presented in Section 9.2.4.9 and in the Laboratory Prototype Calciner addendum to this FSAR. However, these releases are not included in the total facility releases from the seismic event evaluated in this analysis.

9.2.4.6.3.1.B Accident Analysis-Calculation, 234-5Z Room 145--See analysis presented in Section 9.2.4.6.3.1.A.

9.2.4.6.3.1.C Accident Analysis-Calculation, 234-5Z Room 139--See analysis presented in Section 9.2.4.6.3.1.A.

9.2.4.6.3.1.D Accident Analysis-Calculation, 234-5Z Room 152--The laboratory waste concentrator in room 152 is no longer used. If future use of the concentrator is required the section will be analyzed and incorporated.

9.2.4.6.3.1.E Accident Analysis-Calculation, 234-5Z Argon Release--Argon lines can fail as a result of the earthquake but there are only consequences for the facility worker.

9.2.4.6.3.1.F Accident Analysis-Calculation, 234-5Z Room 144--In room 144, electric heat is used to heat a sample disk to red hot.

9.2.4.6.3.1.G Analysis-Calculation, 234-5Z Room 136--The Quantimeter was a mixture of argon and oxygen in a steel enclosure to support a small arc near a tiny cup of plutonium oxide (looks like an all-metal automobile fuse). The arc vaporizes the impurities in the powder which are analyzed. The argon flowrate is 10 to 60 times the oxygen flowrate. An oxygen aided fire is not possible as the flow is primarily argon and the plutonium available for release is very small.

9.2.4.6.3.1.H Accident Analysis-Calculation, 234-5Z Room 166--Room 166 contains gloveboxes HC-4 and HC-6 and the South Hood. Glovebox HC-6 is inactive and is not considered further.

Glovebox HC-4--A previous analysis of glovebox HC-4 calculated a significant release from glovebox HC-4 based on the assumption that the front glovebox panel came out because the glovebox was not seismically qualified. The motive force for the release was a recirculation pump assumed to be operating at the time the seismic event occurred. The glovebox has been modified such that it remains standing and the panels remain in place. Although failures could occur such that the recirculation pump sprays Pu solution, there is no release outside of the glovebox per Case 1.

South Hood--The South Hood has a CPS limit of 400 g of Pu. There are no restrictions on isotopic composition; thus, it is conservatively assumed that the entire 400 g is >10% ^{240}Pu.

The respirable release fraction for solutions applied to hoods (either Case 3 or 4) is 1.6×10^{-5}. The release into Room 166 is calculated as follows:

$$400g\ (1.6x10^{-5}) = 0.01g$$

9.2.4.6.3.1.I Accident Analysis-Calculation, 234-5Z Rooms 174, 175, 190 and 225--Rooms 175, and 190, contain pedestal storage, room 174 contains cabinet shelf storage, and room 225 contains cubicle shelf storage, and cubicle storage (room 174). The criticality specifications generally allow 2,500 g (H/Pu<2) of plutonium in each storage location. Exceptions to this are documented in

individual ciriticality prevention specifications (CPS's) and postings. Storage is in carbon steel containers. Loss of ventilation may result in overheated and thus pressurized containers. The following calculations show that the containers will not fail.

The analysis first starts with a determination of the heat rate due to decay. Using the heat rate, the temperature across the container is determined. The heat rate is put into the room and the wall temperature is determined over time. The container temperature is then determined from the wall temperature.

The heat rate for each container is:

$$\text{Heat rate} = (2{,}500\ \text{g})(0.67\ \text{Ci/g})\left(3.7\text{x}10^{10}\ \frac{\text{dis}}{\text{s-Ci}}\right)\left(5.5\ \frac{\text{MeV}}{\text{dis}}\right)\left(\frac{10^6\ \text{eV}}{\text{MeV}}\right)$$

$$= 3.4\text{x}10^{20}\ \text{eV/s}$$

where: 2,500 g = Amount of plutonium in a container
0.67 Ci/g = Activity (Marusich 1988a, p. A-3).

The power is:

$$3.4\text{x}10^{20}\ \frac{\text{eV}}{\text{s}}\left(1.6\text{x}10^{-12}\ \frac{\text{erg}}{\text{eV}}\right)\left(10^{-7}\ \frac{\text{W-s}}{\text{erg}}\right) = 54.4\ \text{W}$$

Note that this value is much higher than the facility figure of 5-10 W based on 6% ^{240}Pu. The value of 54.4 W differs from 5-10 W because ^{241}Pu, which comprises about 90% of the total Curies, is not an alpha emitter. However, the value will continue to be used because there is some material in the storage rooms that does not have 90% of the total curies as ^{241}Pu. Some packages are as high as 25 W.

$$54.4\ \text{W}\left[\frac{3.4\ \text{Btu}}{\text{h-W}}\right] = 185\ \frac{\text{Btu}}{\text{h}}$$

To find the temperature in the container, the room and plutonium container are modelled like a nuclear reactor fuel element (cylinder with distributed source). The containers are separated by 4 in. of air if measured between one side of the pedestal and the other and 1 to 2 ft in between pedestals. Using the *Principles of Nuclear Engineering*, p. 662 (Glasstone 1955) the temperature distribution through the container is:

$$T - T_c = \frac{Q}{4k}(a^2 - r^2)$$

where: T = Temperature within the container, °F
T_c = Temperature at edge of container, °F
Q = Volumetric heat rate, Btu/h-ft^3
k = Thermal conductivity, Btu/h-ft^2 °F
a = Radius of container, ft
r = Radius within container, ft.

therefore,

$$V = \frac{\pi}{4}\left[\frac{2 \text{ in}}{12 \text{ in/ft}}\right]^2 \frac{6 \text{ in}}{12 \text{ in/ft}} = 0.011 \text{ ft}^3$$

$$Q = 185 \frac{\text{Btu}}{\text{h}}\left[\frac{1}{V}\right] = 1.68 \times 10^4 \frac{\text{Btu}}{\text{h-ft}^3}$$

$$k = 0.023 \text{ cal/s-°C-cm}$$

$$= 5.56 \frac{\text{Btu}}{\text{h-ft-°F}}$$

$$a = \frac{2 \text{ in}}{12 \text{ in/ft}} = 0.16 \text{ ft.}$$

$$T - T_c = \frac{1.68 \times 10^4 \frac{\text{Btu}}{\text{h-ft}^3}}{4(5.56)\frac{\text{Btu}}{\text{h-ft-°F}}}(0.16 \text{ ft})^2 = 19 \text{ °F, if } r = 0$$

When r = 0, T = centerline temperature.

So the temperature distribution through the powder is essentially uniform. The temperature in the container must now be determined. Heat is transferred through the container by conduction, through the air by radiation and into the concrete wall or cubicle by conduction. The temperature difference between the container outer surface and the room wall assuming radiation heat transfer (free convection heat transfer is small compared to the radiation heat transfer) is (Parker et al. 1974):

$$q = (0.1718 \times 10^{-8})\, A\, F_{12}\, (T_c^4 - T_w^4) + hA\,(T_c - T_w)$$

where: q = Heat rate of the container, Btu/h
A = Surface area of the container, ft^2 = π(dia.)(height) =

$\pi(4 \text{ in.})(6 \text{ in.})/144 \text{ in}^2/\text{ft}^2 = 0.52 \text{ ft}^2$
h = Heat transfer coefficient = $0.22 (T_c - T_w)^{0.33}$ for natural circulation
T_c = Outside surface temperature, °R (°R = °F + 460)
T_w = Wall temperature, °R
F_{12} = Fraction of radiation exchanged between surfaces 1 and 2 (between the surface and the wall).

The wall temperature under conditions of constant heat rate from the container assuming an infinitely thick wall is:

$$T_w = \frac{2q}{K_w A}\left[\frac{at}{\pi}\right]^{0.5}$$ (Jakob 1957, p. 258)

where: T_w = Wall temperature, °F
t = Time, h
q = Heat rate of the container, Btu/h = 185 Btu/h
A = Area of the wall irradiated by the container and is chosen to be the area over which the heat falls perpendicularly = 1 ft^2
k_w = Thermal conductivity of the wall, Btu/h-ft-°F = 0.79 Btu/h-ft-°F (Parker et al. 1974)
a = Thermal diffusivity = k_w/pC_p = 0.021 ft^2/h (Parker et al. 1974)
p = Density of the wall, lb/ft^3
C_p = Specific heat of wall, Btu/lb-°F.

Choose one container and use 36 h after loss of ventilation as representative of the time over which power is lost:

$$T_w = \frac{2\ (185)}{0.79\ (1)}\left[\frac{0.021\ (36)}{\pi}\right]^{0.5}$$

Solving yields

$$T_w = 229.8 \text{ °F}$$

Since the room is at 70 °F, the wall temperature will be 300 °F.

Now to determine T_c the equation for natural convection radiation must be solved. Assume $F_{12} = (1/0.429)$, which is from Marusich (1988a), p. A-9, a

similar case where containers of PuO_2 are stored in a concrete room in the Fuels and Material Examination Facility.

Solving:

$$185 = (0.1718 \times 10^{-8})(0.52\ ft^2)\ (1/0.429)\ \ [(T_c + 460)^4$$

$$- (300\ °F + 460)^4] = 0.22\ (T_c - 300\ °F)^{0.33}$$

$$x\ (0.52\ ft^2)\ (T_c - 300\ °F)$$

Solve by substitution:

T_c	Left-hand side (correct values of T_c gives 185)
350 °F	221
340 °F	173
330 °F	126

So the container wall temperature is about 343 °F at 36 h.

The internal pressure has then increased due to temperature rise. At a concrete temperature of 70 °F (about normal) the container temperature is found by solving the equation above using T_w = 70 °F. The container temperature under these assumptions is 180 °F. The initial pressure is 17.7 lbf/in^2 assuming initial air was 70 °F, and assuming the ideal gas law applies ($P_2/14.7$ = [460 + 180]/[460 + 70]) the internal pressure at 36 h increased to:

$$\frac{P_2}{17.7\ lb/in^2} = \frac{(460 + 343)}{(460 + 180)}$$

where: P_2 = 22.2 lbf/in^2.

The *Initial Concepts on Energetics and Mass Release During Non-nuclear Explosive Events in Fuel Cycle Facilities*, NUREG/CR-4593, p. 11 (Halverson 1986) gives an equation for stress covered by expansion as:

$$\sigma = \frac{PD}{2t}$$

where: σ = Ultimate tensile strength, lb/in^2 = 65,000 for carbon steel
P = Burst pressure, lbf/in^2
D = Diameter, in. = 4 in.

t = Thickness, 0.009 in. (Szempruch 1984).

$$65{,}000 \text{ lb/in}^2 = \frac{P \text{ (4 in.)}}{2 \text{ (0.009 in.)}}$$

$$P = 292 \text{ lbf/in}^2.$$

Since the pressure in the container is 22 lbf/in^2 it will not fail due to pressure. *The Effectiveness of Corrective Actions Taken to Preclude Events Involving Tin Cans and Plutonium*, RHO-HS-SA-59P (Szempruch 1984) also points out on p. 23 that containers can hold up to 100 lbf/in^2 and do not bulge until 40 lbf/in^2 g. Note that more recent studies suggests bulging begins at approximately 15 psig and that containers may vent at the seam between 30 and 50 psig (Figure 9-37).

Historically, containers have failed due to alpha radiolysis of moisture or organics in the powder, phase change in the metal or oxidation of the metal (turns metal into powder with a significant volume increase) due to air in-leakage. The assumption in the seismic event is that the containers are good and they are filled with material which meets specifications; therefore, none of the above is assumed to occur with the earthquake (the probability of an earthquake big enough to shut off the ventilation coupled with the storage of "bad" containers is incredible).

9.2.4.6.3.1.J Accident Analysis-Calculation, 234-5Z Plutonium Processing Support Laboratory, Rooms 179 through 188--The release from the PPSL, other than from the Laboratory Prototype Calciner, is calculated along with the releases from the Analytical and Standards Laboratories in Section 9.2.4.6.3.1.A. The release from the PPSL from the Laboratory Prototype Calciner is discussed in Section 9.2.4.9 but are not included in the total facility releases due to a seismic event since the calciner is not authorized for operation.

9.2.4.6.3.1.K Accident Analysis-Calculation, Rooms 192-A, 192-B, and 192-C--Rooms 192-B and 192-C contain pedestal storage locations similar to those in rooms 174 and 175. Room 192-A contains floor storage of FFTF fuel pins and fuel elements in special shipping containers.

9.2.4.6.3.1.L Accident Analysis-Calculation, 234-5Z Standards Laboratory, Rooms 221-C, 221-D, and 221-E--The release from the Standards Laboratory is calculated along with the releases from the Plutonium Processing Support Laboratory and the Analytical Laboratory in Section 9.2.4.6.3.1.A.

9.2.4.6.3.1.M Accident Analysis-Calculation, 234-5Z Room 227--Room 227 contains Glovebox HC-227S and Hood HC-227T.

Glovebox HC-227S. Referring to Section 9.2.4.2.1P, the accident scenario for Glovebox HC-227S is a pressurized release of solution due to a recirculation pump discharge line failure.

The release fraction as a result of the rapid opening of a pressurized container into a test vessel 3 m tall and 3 m in diameter was determined in

Aerosols Generated by Releases of Pressurized Powders and Solutions in Static Air, PNL-4566 (Sutter 1983). The aerosol in the test vessel, which resulted from depressurization, and the aerosol that formed when liquid transported to the ceiling by the initial depressurization fell to the floor, was measured. The maximum respirable fraction is 10^{-5} for 100 cm^3 uranyl nitrate nonahydrate sources at 50 lbf/in^2 (gauge) (Sutter 1983, Table B-5). The discharge pressure of the HC-227S recirculation pump is 40 lbf/in^2 (gauge). Because room 227 is larger than the test vessel, the release fraction will be larger. The release fraction will also be larger because the material will be airborne for a greater period of time. To account for this, the release fraction for 250 lbf/in^2 (gauge)$_5$ (i.e., the next test pressure used by Sutter) is used: a value of 4×10^{-5}.

Assuming the entire 20,000 g allowable inventory is present, and applying a respirable release fraction of 4×10^{-5}, the release into room 227 from Glovebox HC-227S is calculated as follows:

$$20{,}000g\ (4x10^{-5}) = 0.8\ g$$

Hood HC-227T. Hood HC-227T is used for Pu nitrate load-in and load-out with a single solution container limited to a maximum of 4,500 g of Pu for the transfer. Vacuum is used to make the transfers. Most of the time the outer carrier lid is off. The inner solution container remains in the carrier although there are times that the inner container with solution is removed using a hoist. The height of the container during these activities is nominally 2 m. In a seismic event the worst possible release of Pu to the room would be caused by a drop of the inner container loaded to 4,500 g of Pu from a height of 2 m. The associated release fraction is 3.6×10^{-5} (per Case 2 for solutions). The release of plutonium into Room 227 from Hood HC-227T is shown by the following equation:

$$4500g\ (3.6x10^{-5}) = 0.16\ g$$

It should be noted that it would be unlikely for both Glovebox HC-227S and Hood HC-227T to be at maximum plutonium inventory limits. There must be room in an empty solution container in Hood HC-227T to receive the loadout material. However, for conservatism it is assumed that maximum inventories are present in both gloveboxes. Therefore, 0.96 g is the maximum release into Room 227 from any scenario involving Hood HC-227T and Glovebox HC-227S. This material is assumed to be > 10% ^{240}Pu as there are no restrictions on isotopic composition.

9.2.4.6.3.1.N Accident Analysis-Calculation, 234-5Z Room 228-A--Room 228-A contains gloveboxes HC-1, HC-2, HC-7, HC-9B, HC-10, and HC-11.

Conveyor glovebox HC-1 extends into rooms 228-A, B and C. Conveyor glovebox HC-2 extends into room 228-C and rooms 230-A and B. These conveyors are normally empty and thus are not considered further. Glovebox HC-10 is also not considered further because it is inactive.

Glovebox HC-7. Glovebox HC-7 is inactive except when used as a portion of the solution transfer system from HC-227S to 236-Z. The scenario is assumed to

be identical to that for HC-227S; i.e., a pressurized release of solution due to a recirculation pump discharge line failure. Using the preceding information for HC-227S, the release is 0.20 g. It is important to note that solution is present in HC-7 only during transfers from HC-227S. Accordingly, the release of 0.20 g can be assigned to either HC-227S or HC-7, but not both simultaneously.

Glovebox HC-9B. Glovebox HC-9B is seismically qualified; thus, there is no release outside of the glovebox per Case 1.

Glovebox HC-11. Glovebox HC-11 is seismically qualified; thus, there is no release outside of the glovebox per Case 1.

9.2.4.6.3.1.O Accident Analysis-Calculation, Room 228-B--Room 228-B contains gloveboxes HC-1, HC-12S, HC-13MD, HC-15A, HC-15B, HC-15C, and HC-16CC all of which are inactive, except HC-1 and HC-13MD. Conveyor glovebox HC-1 is normally empty. Glovebox HC-13MD is used for seal-in or/and seal-out of plutonium bearing materials to or from the thermal stabilization process. The glovebox is not seismically qualified. Maximum plutonium allowed in glovebox HC-13MD is 2,500 g. The material is assumed to be PuO_2. Applying a release fraction of 1.5×10^{-4} as established in release case 2 (Section 9.2.4.6.2), the release to Room 228-B is 0.38 g.

9.2.4.6.3.1.P Accident Analysis-Calculation, 234-5Z Room 228-C--Room 228-C contains gloveboxes HC-17-SBB, HC-17DC, HC-17P, HC-18BS, HC-18M, and conveyor gloveboxes HC-1, HC-2, and HC-5. Gloveboxes HC-17-SBB, HC-17DC, and HC-17P are inactive. Conveyor gloveboxes HC-1, HC-2, and HC-5 are normally empty.

Glovebox HC-18BS--Glovebox HC-18BS is seismically qualified thus there is no release outside the glovebox per Case 1.

Glovebox HC-18M--Glovebox HC-18M is not seismically qualified. The CPS limit is 10,000 g. The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Applying a release fraction of 1.5×10^{-4} per Case 2, the release is calculated as follows:

$$10{,}000g\ (1.5x10^{-4}) = 1.50\ g$$

9.2.4.6.3.1.Q Accident Analysis-Calculation, 234-5Z Room 230-A--Room 230-A contains glovebox HC-21C. The glovebox has a CPS Limit of 5,000 g. The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Applying a release fraction of 1.5×10^{-4} per Case 2, the release is calculated as follows:

$$5000g\ (1.5x10^{-4}) = 0.75\ g$$

The above calculation accounts for the direct, mechanical release of Pu from Glovebox HC-21C. The thermal stabilization process in the glovebox poses potential fire and flammable gas hazards in the seismic event as well. These hazards are addressed in Sections 9.2.10.3 and 9.2.10.5. Section 9.2.10.3 concludes that a small flash fire may result from failure of the glovebox furnaces if PuO_2 containing plastic contaminant is being stabilized at the time

of the seismic event. The additional airborne release of Pu from the flash fire is shown to be insignificant compared to the mechanical release estimated above. The flash fire release is therefore ignored in this analysis.

Sections 9.2.10.5 and 9.2.4.2.12.F conclude that a fire may occur in Glovebox HC-21C as a result of a seismic event which results in hot furnace equipment contacting and igniting the glovebox Lexan™ panels. The additional Pu released from the glovebox in the fire is determined in Section 9.2.4.2.12.F.

9.2.4.6.3.1.R Accident Analysis-Calculation, 234-5Z Room 230-B--Room 230-B contains conveyor gloveboxes HC-2 and HC-3 and glovebox HC-21A. Glovebox HC-21A has a CPS limit of 7,100 g. The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Applying a release fraction of 1.5×10^{-4} per Case 2, the release is calculated as follows:

$$7{,}100\ g\ (1.5 \times 10^{-4}) = 1.07\ g$$

9.2.4.6.3.1.S Accident Analysis-Calculation, 234-5Z Room 230-C--Room 230-C contains glovebox HC-60 and conveyor gloveboxes HC-3 and HC-4. Glovebox HC-60 is inactive and conveyor gloveboxes HC-3 and HC-4 are normally empty.

Glovebox HC-230C-2 was added to the end of the RMC Line in room 230C after the analyses contained in this Section (9.2.4) were originally developed. The worst-case seismic release scenario for glovebox HC-230C-2 is described and analyzed separately in Section 9.2.9.4.

The Magnesium Hydroxide Precipitation Process gloveboxes, HC-230C-3 and HC-230C-4, are located in this room. The effect of a seismic event on these gloveboxes is discussed in Section 9.2.4.10.

9.2.4.6.3.1.T Accident Analysis-Calculation, 234-5Z Room 232--Room 232 contains glovebox HA-46. This glovebox is inactive.

9.2.4.6.3.1.U Accident Analysis-Calculation, 234-5Z Room 235-B--Room 235-B contains glovebox HA-19, HA-20MB, HA-21I, HA-22B, HA-23S, conveyor glovebox HA-28, and part of conveyor HC-4. Conveyors HA-28, and HC-4 are normally empty.

Glovebox HA-19--Glovebox HA-19 is not seismically qualified. It has a CPS limit of 2,500 g. The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Although the glovebox is not qualified, no release is postulated because the Pu present is in the form of polycubes.

Glovebox HA-20MB--Glovebox HA-20MB has been determined to be seismically qualified. Therefore, per case 1, there is no release.

Glovebox HA-21I--Glovebox HA-21I is not seismically qualified. It has a dispersible inventory limit of 8,000 g (Table 9-26). The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Applying a release fraction of 1.5×10^{-4} per Case 2, the release to room 235-B is shown in the following calculation:

$$8{,}000\ g\ (1.5 \times 10^{-4}) = 1.20\ g$$

The above calculation accounts for the direct, mechanical release of Pu from Glovebox HA-21I. The thermal stabilization process in the glovebox poses potential fire and flammable gas hazards in the seismic event as well. These hazards are discussed in Sections 9.2.10.3 and 9.2.10.5. Section 9.2.10.3 concludes that a seismically induced deflagration results in negligible release.

Sections 9.2.10.5 and 9.2.4.2.12.F conclude that a fire may occur in Glovebox HA-21I. The Pu released from the glovebox in the fire is determined in Section 9.2.4.2.12.F.

Glovebox HA-22B--Glovebox HA-22B is seismically qualified. Per Case 1, no release is postulated for this glovebox.

Glovebox HA-23S--Multilevel Glovebox HA-23S is used to store miscellaneous scrap material (e.g., sludge residues collected from PRF gloveboxes, floor sweepings from gloveboxes, samples and standards collected from the lab gloveboxes and hoods, process heel material, etc.). The scrap material is stored in polyjars, which are placed in storage carousels in the glovebox. The polyjars have screw-top lids with a small center hole to allow venting of radiolytically generated gases from the containers. There are eleven storage carousels located on each of four horizontal racetrack-shaped conveyors in the glovebox. The conveyors are spaced 34 in. apart, vertically. The conveyors are supported by floors constructed of 1/4 in. plate and 4 in. x 4 in. x 1/4 in. angle iron braces welded together. Half inch wire mesh fills in large openings in each floor located below the center of each racetrack conveyor.

Each carousel is designed to hold eight polyjars, giving a total of 352 storage positions for the 11 carousels on each of the four conveyors in the glovebox. Only one polyjar may be inserted or removed from the carousel at a time. This is achieved by aligning the desired storage position beneath a cutout in the top plate of the carousel. T-shaped holders in the bottom circular plate of the carousel and the top circular plate of the carousel secure the polyjars in the event the carousel is overturned (e.g., due to contact with glovebox glove during conveyor operation).

The CPS for Glovebox HA-23S limits the quantity of Pu in each carousel to 1000 g and limits the maximum Pu quantity in each container to 1000 g. The total CPS inventory for the glovebox is 44 kg. For the purposes of this analysis, all of the carousels are assumed to be loaded to their 1000 g limit, giving a glovebox inventory matching the CPS limit at the time of the seismic event.

Glovebox HA-23S is seismically qualified (see Table 9-25), meaning it is not expected to topple in the seismic event. However, it is unknown whether the conveyor supports will survive the seismic event. The carousels are not bolted or otherwise secured to the conveyor and may topple or shift from their positioning pins during the seismic event. This may cause carousels to slide into and impact each other. This problem would be exasperated if the conveyor/floor supports failed causing glovebox floors to drop. If the supports survive, it may still be possible for carousels to "hop" over the conveyor rails and fall through the floor openings (depending on the integrity of the wire mesh) or through the elevator area of the glovebox. Impacts or

falls involving carousels may cause individual polyjars to be ejected from the cutout position of the carousel. The carousel would be expected to contain the remaining polyjars due to its design.

Impact of unsecured carousels and ejected polyjars into glovebox equipment, and freefall drops of carousels and polyjars could cause failure of multiple polyjars. The polyjars may be especially susceptible to rupture due to radiation embrittlement during long term storage. Impact damage also imparts energy that can suspend respirable material into the glovebox air through the failed containers. Glovebox windows are assumed to fail due to equipment impacts allowing released material to enter Room 235B.

For the purposes of this analysis, all the material in the polyjars is assumed to be dispersible plutonium oxide powder at the time of the seismic event. As discussed above, much of the material stored in Glovebox HA-23S originates from sludges, process heels, or relatively large solids materials (metal alloys) that are much less dispersible than plutonium oxide. Assuming the inventory is all plutonium oxide ensures a conservative release estimate.

The release fraction used for plutonium oxide powders in containers in other gloveboxes in this seismic accident analysis is overly conservative for the material contained in the polyjars of Glovebox HA-23S. It is possible for the plutonium oxide material in Glovebox HA-21I analyzed above to be in open boats at the time of the seismic event, for instance. The material in Glovebox HA-23S is in closed polyjars (with very small vents). Although the polyjars are assumed to fail, the release fraction for the material in the container would be expected to be significantly less than that postulated for open containers in other gloveboxes.

To account for the material being in closed containers, the Case 2 release fraction of 1.5E-4 is adjusted downward by a factor of 2. The release to the glovebox air is calculated as follows:

$$44{,}000\ \text{g}\ (1.5\text{E-}4)(1/2) = 3.30\ \text{g}$$

This release estimate is judged to be conservative for the following reasons:

- The glovebox is assumed to be loaded to its CPS inventory limit. It normally contains considerably less than this amount.
- All the material is assumed to be dispersible plutonium oxide powder. The inventory typically in Glovebox HA-23S contains sludges, process heels, lab samples, metal alloys and other scrap materials that are much less dispersible than PuO_2.
- All containers (polyjars) are assumed to be impacted and damaged in the event. Based on the design of the carousels, conveyor supports and glovebox floors, only a fraction of the containers would be expected to be damaged.

Conveyor Glovebox HA-28--Conveyor glovebox HA-28 is not seismically qualified. The CPS limit is 2,500 g. The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Applying a release fraction of 1.5 x 10^{-4} per Case 2, a release of 0.38 g is calculated as follows:

$$2500g\ (1.5x10^{-4}) = 0.38\ g$$

The Bagless Transfer System glovebox, HA-53BTS, is also located in this room. The release from this glovebox as a result of the seismic event is found in Section 9.2.4.11.

9.2.4.6.3.1.V Accident Analysis-Calculation, 234-5Z Room 235-C--Room 235-C contains glovebox 235-B-2. Glovebox 235-B-2, with a CPS limit of 2,500 g, is not seismically qualified. The material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. Applying a release fraction of 1.5 x 10^{-4} per Case 2, a release of 0.38 g is calculated as follows:

$$2500g\ (1.5x10^{-4}) = 0.38\ g$$

9.2.4.6.3.1.W Accident Analysis-Calculation, 234-5Z Duct Level-- Releases from the duct level result from the presence of plutonium in the E-4 ventilation system ducting and filterboxes 7A and 9A.

E-4 Ducting--Based on NDA measurements, there are 6,000 g of Pu present in the E-4 ventilation system ducting. The *PFP Remediation Project Management Plan*, WHC-SD-CP-PMP-003, Figure 1 (Schilling 1989) shows schematically the location of contaminated E-4 ducts. Attachment II of Marusich (1988b) shows specifically the holdup in the E-4 ducts of the RMC Line.

To reduce the risk associated with Pu holdup in E-4 ducts, sections of ducting have been modified in accordance with Herzog (1991) to withstand seismic forces. The quantities of Pu involved are 1,800 g (in the FB-9B bypass duct) and 1,893 g (in two other duct sections near HC-9B and FB-9B). The quantity of material at risk is therefore 2,307 g. For the purposes of this analysis, the entire 2,307 g (6,000-1,800-1,893) is assumed to be present in the form of suspendable powders. This assumption is judged to be conservative based on plant experience indicating that a significant fraction of the material is tightly adhered to internal duct surfaces. Specifically, scraping of a segment of ducting removed only 4 out of 7 g present as measured by NDA. In addition recent ductwork remediation efforts have greatly reduced the amount of plutonium in the E-4 ventilation system.

A resuspension model is used to estimate the quantity of Pu released versus application of release fractions based on powder spills from either a 1- or 3-m height. A resuspension model is judged applicable given the anticipated seismically induced vibration of the ducts. NRC (1981) provides a list of resuspension factors. Sutter provides a resuspension factor from 0.01 m^{-1} to 0.04 m^{-1} for vigorous sweeping in an unventilated room. Because the energy imparted to the Pu from the seismic event is envisioned to be much less than from vigorous sweeping, the lower bound of the data (i.e., 0.01) is used. The release is calculated as follows:

$$\frac{\text{g suspended within duct volume}}{\text{volume}} = \frac{\text{0.01 g on surface}}{\text{surface area}}$$

$$\frac{G_v}{\frac{\pi}{4} d^2 L} = 0.01 \frac{G_s}{\pi d L}$$

where: G_v = g suspended in volume
G_s = g on the surface
d = duct diameter, m
L = duct length, m

Cancelling out the common terms gives:

$$G_v = 0.01 \ (G_s) \ \frac{d}{4}$$

Since the diameter of the ducts is 10 in., d is equal to 0.25 such that:

$$G_v = 0.01 \ (0.25) \ G_s = 0.0025 \ G_s$$

Given G_s is equal to 2,307 g, the quantity of Pu resuspended is 5.77 g. Of this mass, 20% or 1.15 g is respirable. Based on the operating history of the facility, the material is assumed to be <10% ^{240}Pu.

Filterboxes 7A and 9A--Filterboxes 7A and 9A are not seismically qualified. Based on NDA measurements, the inventory of Pu present is 26 g and 66 g respectively. Based on the operating history of the facility, this material is assumed to be <10% ^{240}Pu.

The release from the filter boxes is calculated using the model presented in Marusich (1988a), p. 4-43, in which structural failures are assumed to result in crushing of the filter boxes. Based on the difference observed from removal of the filter from filter box 9A, 85% of the Pu is assumed to be associated with the filter. Release from the filter is treated as in *Source Term and Radiation Dose Estimates for Postulated Damage to the 102 Building at the General Electric Vallecitos Nuclear Center*, PNL-2844 (Mishima et al. 1979b), with 10% of the of the Pu on the crushed filters made immediately available for suspension. Of these particles, 10% are assumed to be respirable (Wodrich 1984). The release associated with crushing of the filters is 0.78 g:

$$92\text{g} \ (0.85) \ (0.1) \ (0.1) = 0.78 \text{ g}$$

The amount of respirable Pu contributed by the filter boxes (versus the filters) is based on a concentration of 15 mg/m^3 assumed to be present following

shaking of the boxes by seismic forces. Given each filterbox has an approximate volume of 1.5 m^3, the release is 0.05 g:

$$2\,(1.5)\,(15 mg/m^3)\,(1x10^{-3} g/mg) = 0.05g$$

The total release associated with filter boxes 7A and 9A is therefore 0.83 g.

The calculations above are judged to be very conservative. This judgement is based on the fact that the model developed in Marusich (1988a) presumed severe structural failures resulting in collapse of the duct and second level floors. Revised structural analyses have shown the floors do not collapse. Thus, the filters are not crushed.

9.2.4.6.3.1.X Accident Analysis-Calculations, Second Floor (Third Level) 234-5Z.

9.2.4.6.3.1.X.a Filter Rooms--The E-3 and E-4 filter rooms are located on the second floor of 234-5Z. There are two E-4 filter rooms each containing 128 filters. There are seven E-3 filter rooms each containing 112 filters. Because the HEPA filter frames are not seismically qualified, it is assumed that all of the filters (a total of 1,040) fall to the floor. This assumption is judged to be conservative as the filters are bolted into the filter frame and it is unlikely that all 1,040 filters would be dislodged.

The amount of Pu present on the HEPA filters can be estimated from recent non-destructive assays performed following a HEPA filter change-out of one of the E-4 filter rooms, i.e., room 310 (Fazzari 1994). The removed filters had been in service for fourteen years, during seven of which major 234-5Z processes were operated. The measured Pu loading of 129 individual filters averaged 5.4×10^{-3} g. Based on this information, it is assumed that the E-4 filters contain a total of 2.76 g of Pu as shown by the following equation:

$$(256 \text{ filters}) \times (0.0054 \text{ g/filter}) \times (2) = 2.76 \text{ g}$$

where:

- 256 represents the total number of E-4 filters
- 0.0054 represents the average filter loading
- 2 represents a factor accounting for potential future increases in HEPA filter loading. Application of a factor of two is judged to be conservative as the room 310 data is believed to be representative of future filter loadings based on the 14-year service life of the filters.

The E-3 filters are assumed to contain a total of 4.23 g of Pu as shown by the following equation:

$$(784 \text{ filters}) \times (0.0054 \text{ g/filter}) = 4.23 \text{ g}$$

where:
- 784 represents the total number of E-3 filters
- 0.0054 represents the average filter loading.

The value of 0.0054 is applied as there is no current filter loading data for E-3 filters. Use of this value is judged to be conservative as the E-3 filter rooms draw the atmosphere of rooms while the E-4 filter rooms draw the atmosphere of gloveboxes. Therefore, the E-3 filters would logically contain less Pu as glovebox interiors would produce much more filter contamination. Accordingly, the factor of 2 is not applied to the E-3 calculation as it was to the above E-4 calculation.

The release from the filter rooms is calculated using the model presented in Marusich (1988a), page 4-43, in which structural failures are assumed to result in crushing of the filters. Ten percent of the material on the filters is assumed to be suspended of which 10% is assumed to be respirable. (Note that this is equivalent to the 0.01 respirable release fraction applied in the filter drop scenario, Section 9.1.5A). The release is therefore 0.07 g Pu:

$$(2.76g + 4.23g) \times (0.10) \times (0.10) = 0.07g$$

Based on the operating history of the facility, this material is assumed to be <10% ^{240}Pu.

Accident Analysis-Calculations, Downstream Plutonium--There is plutonium powder downstream of the final filters. Schilling (1989) states that, excluding the exhaust stack, the estimated plutonium accumulation in the section downstream of the final filters is 2 to 20 g. Of this, between 0.16 g and 1 g is contained in the sheet metal exhaust plenums inside the 234-5Z Building. This material is also "tightly held" (Schilling 1989). The earthquake forces will cause the ducting to vibrate vertically, horizontally, and there may even be torsional forces. These forces may result in the loosening of this material and possibly its resuspension.

The situation described above can be viewed as being similar to resuspension due to moving a dolly over a contaminated surface or walking over a contaminated surface. Resuspension factors (Curies per cubic meter above surface divided by Curies per square meter contaminated) for these cases are 2×10^{-4} m^{-1} (NRC 1981). The total E-4 and E-3 duct area is ≈13,000 ft^2 (Fulton 1989). The stack manifold volumes can be estimated using dimensions from Figures 9-24, 9-25, and 9-26. The E-3 volume is ≈510 m^3 and E-4 volume is ≈96 m^3.

From *Transmittal of Results on Plutonium Holdup Downstream of Final Filtration at the Plutonium finishing Plant*, Attachment 1 (Fulton 1989) the areal plutonium concentrations for the E-3 and E-4 duct surfaces can be calculated. Using the high side of the error bound for the amounts present and by lumping floor and nonfloor surfaces the areal concentrations are calculated as follows:

$$\text{E-3} \quad \frac{3 \times 10^{-1}\ \text{g}}{12{,}000\ \text{ft}^2} = 2.5 \times 10^{-5}\ \text{g/ft}^2\ (2.7 \times 10^{-4}\ \text{g/m}^2)$$

$$\text{E-4} \quad \frac{6 \times 10^{-1}}{1{,}300\ \text{ft}^2} = 4.6 \times 10^{-4}\ \text{g/ft}^2\ (5 \times 10^{-3}\ \text{g/m}^2)$$

The amount of plutonium suspended in each system is the product of the suspension factor, the areal concentration, and the volume.

$$\text{E-3} \quad 2 \times 10^{-4}/\text{m} \times 2.7 \times 10^{-4}\ \text{g/m}^2 \times 510\ \text{m}^3 = 2.8 \times 10^{-5}\ \text{g}$$

$$\text{E-4} \quad 2 \times 10^{-4}/\text{m} \times 5 \times 10^{-3}\ \text{g/m}^2 \times 96\ \text{m}^3 = 9.6 \times 10^{-5}\ \text{g}$$

Adding the amount for each duct system gives the total suspension.

$$2.8 \times 10^{-5}\ \text{g} + 9.6 \times 10^{-5}\ \text{g} = 1.2 \times 10^{-4}\ \text{g suspended}$$

Vibrating the duct is not an efficient way to disperse plutonium. The release from the duct surfaces is small compared to the other releases calculated in this section and is ignored.

9.2.4.6.3.1.X.b Chemical Storage Area--The chemicals stored in rooms 336, 337, and 338 are those needed for routine processes. Other chemicals that may be needed are purchased in small quantities to satisfy immediate needs. An active inventory of all chemicals used at the PFP is maintained per 40 CFR Part 355 (SARA).

Rooms 336 and 337 contain numerous chemical makeup and storage tanks previously used in support of RMA and RMC Line operations (see Chapter 5, Section 5.4.13). The majority of these tanks are empty. Currently, Tank C in room 336 is used for the storage of 57 wt% HNO_3. This tank has a volume of 600 L. Tanks G-1 and G-2, also in room 336, are used for the storage of dilute (1.8-2.2 M) HNO_3. These tanks each have a volume of 175 L. Room 336 may also be used for the storage of drums of KOH. Although HNO_3 and KOH can react violently, the concrete sumps around the storage tanks would effectively prohibit mixing given a seismic event. The onsite and offsite consequences of seismic-induced HNO_3 spill within room 336 are bounded by those presented in 9.2.4.6.3.5.D.

Room 338 is used for the storage of the dry chemicals. Chemicals include activated charcoal, portland cement, and sodium carbonate (see Table 9-30). The inadvertent mixing of these dry chemicals would not result in a hazardous reaction.

9.2.4.6.3.2 Accident Analysis-Calculations, 236-Z, PRF.

9.2.4.6.3.2.A Solvent Extraction.

9.2.4.6.3.2.A.a Accident Analysis-Calculations, 236-Z Criticality--An analysis of the potential for a criticality in 236-Z is contained in Section 9.2.4.2.11.N.

9.2.4.6.3.2.A.b Accident Analysis-Calculations, 236-Z, Solvent Extraction, Na_2CO_3 and HNO_3 Reaction--If the line carrying Na_2CO_3 to the CX column fails, and if the lines carrying HNO_3 fail and if these solutions mingle, the following reaction takes place:

$$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O + Heat$$

No reactive gases are released and the effects of the heat and gas can be easily accommodated in the gallery glovebox, the canyon (through holes between the gallery glovebox and the canyon), and the ventilation system/piping.

There is no large blowback from the CX column where Na_2CO_3 and HNO_3 are mixed in the process, because both streams are very dilute. Piping failures outside of the column can result in the mixing of higher concentration solutions.

9.2.4.6.3.2.A.c Accident Analysis-Calculations, 236-Z, Solvent Extraction, Pipe or Tank Failure in Canyon or Glovebox--A pipe or tank failure in the canyon would result in a resuspension of plutonium droplets as described in the 234-5Z analysis. The spill in the canyon was covered in Marusich (1988a), pp. 4-75 and -76, and was determined to be 0.40 g.

9.2.4.6.3.2.A.d Accident Analysis-Calculations, 236-Z, Solvent Extraction, Overflows of Solution to the 52 Tanks--Overflows of solution to the overflow tanks are of two kinds, mix of chemicals that react (like Na_2CO_3 and HNO_3) and those that do not react (water and organic). Any or all of the chemicals used in PRF-Solvent Extraction could be present in these tanks. If reactive mixtures are present, the release of gas and energy can again be accommodated by the glovebox, the canyon, and/or the glovebox ventilation piping. There are no mixtures that result in explosive gases or in flammable solutions.

9.2.4.6.3.2.A.e Accident Analysis-Calculations, 236-Z, Solvent Extraction, NaOH Reacting with HNO_3 (TK-17, -18)--The reaction of NaOH and HNO_3 results in the release of heat. Tank A-103 contains a 50% solution of NaOH. Tank A-105 contains a 57% mixture of HNO_3. Tank 17 is 234 L, and is a makeup tank for stream CAF (feed to the CA column). These are very concentrated solutions and have the potential to generate much heat. This heat would pressurize TK-17 (if the valves opened due to seismic forces or seismically induced failure). The chemical addition lines are connected to TK-17 via a funnel break, so that there is no backflow potential up into these lines (Drawing H-2-28021). Blowing the contents of TK-17 to the overflow, vent, or drain results in a flow to TK-52.4 or -52.3 (the overflow tanks, see

Drawing H-2-28032) which in turn overflows to the gallery glovebox (the place of the assumed criticality). If the tank ruptures, there is a release into the canyon that is of little consequence to those inside or outside the facility. While a reaction between two concentrated, reacting chemicals inside a tank is normally an excellent way to disperse the tank solution, it does not appear that any of the dispersed solution will get out of the glovebox.

Note that the funnel breaks are very important to the safety of the occupational worker in this case.

9.2.4.6.3.2.A.f Accident Analysis-Calculations, 236-Z, Solvent Extraction, Failure of the Air Pulser--The columns are pulsed by an air pulser in which air is alternately applied and vented on a 1-in. pulse leg connected to the bottom of the column and extending up to the sixth-floor glovebox. The pulsing is produced using a Hannifin valve, and the pulsed columns are vented. A failure in the Hannifin valve as a result of the earthquake could result in air being constantly applied. A simultaneous failure of the PRV could result in 90-lbf/in^2 air entering the column. Pressurization of the column would result in a mixture of air and solution out the vent (solution will flow to the drain), process solution generally flowing forward to the next step in the process (for those flows originally flowing away from the column), and flow in the reverse direction for those flows normally flowing to the column. Since the pulser pipe is only 1 in. in diameter, and it enters the column far from the source of air (friction along the path), and since there are numerous paths out, all of which are in the gallery glovebox, there is no release from the increased air pressure to a location outside the glovebox or canyon.

9.2.4.6.3.2.A.g Accident Analysis-Calculations, 236-Z, Solvent Extraction, Failure of the Lines in the Pipe Chase--There is a pipe chase in the fourth floor of the PRF, along side the CA and CC column glovebox. The chase has a plastic viewing window on it. Within this pipe chase is:

- The column air pulse legs
- The CCP stream
- The CA column intermediate scrub (CAIS) stream
- The CAX stream
- The CCDP stream
- The column aqueous waste (CAW) stream
- The CUX stream.

The CCDP, CCP, and CAIS streams contain moderately concentrated plutonium aqueous solutions. The CAW stream contains the waste products from the CA column. The CUX and CAX contains chemicals but no plutonium. The CAIS stream is pumped to the CA column using the CAIS Pump Tank contents and pump 36-MOP-B (Drawing H-2-28019). The CCP and the CCDP stream is forced out of the CC column by the action of the air pulser. There is not much force behind this flow unless the Hannifin valves fail. The result of this accident is a spray of plutonium solution from the CAIS stream should this line rupture and the pump remain running and the plastic panel pop out. The CCP and CCDP stream will overflow from the pipe chase if these lines fail and the feed pump continues to run and the panel pops off the pipe chase. It is important to note that the CCP leaves the CC column on the 6th floor and flows by gravity to the 5th floor where there is a stream splitter. When the proper Pu

concentration is reached, part of the flow is diverted via the stream splitter to the CCD tank. The CCDP and CCP both flow down from the 5th floor through the 4th floor pipe chase under a gravity head.

The spray release from the pipe chase is modeled the same as the spray release from glovebox HC-227S, i.e., a release fraction of 4×10^{-5} based on experiments documented in Sutter (1983) (see Section 9.2.4.6.3.1.M). The CCDP stream flows to the CAIS tank, which contains 57 L (Drawing H-2-28019). The CCP stream flows to TK 58 which holds 6 L. The CCP and CCDP streams contain 60 g/L Pu. The release is therefore:

$$(57 \text{ L} + 6 \text{ L}) \times (60 \text{ g/L}) \times (4 \times 10^{-5}) = 0.15 \text{ g Pu}$$

9.2.4.6.3.2.A.h Accident Analysis-Calculations, 236-Z, Solvent Extraction, Transfer Line Failure Outside of Column Glovebox--There is a transfer line that runs from the centrifuges in glovebox MT-6 to the fourth floor column glovebox. The line carries centrifuged CAW stream (Drawing H-2-28040). There are 230 L of CAW with one batch having 0.02 g/L of Pu in it. If a failure of the Hannifin valve occurs so that the column is flooded, and the flood goes out of the CAW line to the centrifuge and then to the surge tank, and the CAW pump continues to pump and the transfer line fails in the room with the CA/CC column pipe chase, then a mixture of organic and solution will come out of the opening. The release fraction will be the same as that for glovebox HC-227S. The CAF stream has a concentration of 4 g/L of Pu but there may be recycle from CCP. The analysis assumes the CA column contains plutonium at 2 g/L (half is CAF and half is non-plutonium solution). The CAF pump tanks contain 220 L each (Kronvall 1988). Assuming only one is in use, the release is:

$$220 \text{ L}(2 \text{ g/L})(4 \times 10^{-5}) = 0.02 \text{ g Pu}$$

The MT-6 glovebox has been declared inactive since the above analysis was originally performed. The release estimate is retained for conservatism, pending a future update to the entire seismic accident analysis.

9.2.4.6.3.2.A.i Accident Analysis-Calculations, 236-Z, Solvent Extraction, Failure of the Drain Lines--Beneath the east and west gallery gloveboxes are the drain lines. The drain lines carry condensate from condensers and from evaporators used in the process. A failure in a drain line will result in a puddle on the floor and not much else.

9.2.4.6.3.2.A.j Accident Analysis-Calculations, 236-Z, Solvent Extraction, Failure of Pipes Between the Second Floor Glovebox and the First Floor Glovebox--There are many lines that travel between the second-floor glovebox and the first-floor glovebox, through access ways in the second floor. Failure of this piping would result in a waterfall down the face of the first-floor glovebox. All of the concentrated plutonium solutions are in the first-floor glovebox, with the exception of the CCP and CAIS streams which were already involved in an accident on the fourth floor. The first-floor glovebox top is 10 ft above the top of the floor (Drawing H-2-29936). The

release fraction for solutions falling 3 m was given previously (room 166) as 2×10^{-5}. In order to get 0.1 g respirable, the amount of solution would need to be (assuming 1 g Pu/L)

$$("x" \text{ L})(1 \text{ g/L})(2 \times 10^{-5})(0.50) = 0.1 \text{ g}$$

where: "x" L = 10,000.

Since there is not this much plutonium solution, the release from the waterfall is negligible.

9.2.4.6.3.2.A.k Accident Analysis-Calculations, 236-Z, Solvent Extraction, Reaction of Hydroxylamine Nitrate with HNO_3--If the CCX flowrate increases, there is excessive carryover of hydroxylamine nitrate to the CAIS pump tank. The CCX flow rate can be increased by a speedup of pump 30-MOP-B (CCX pump tank pump). Low plutonium concentration could also result in carryover of hydroxylamine nitrate. Low plutonium concentration could occur if the CAP pump failed or if the tank became diluted (addition of cooling water as a result of a leak or poor CA column extraction, etc.). The solution in the CAIS tank is mixed with 12M HNO_3 to adjust molarity (WHC-CM-4-29, p 11). The CAIS tank holds 37 L. Assuming that 0.4M hydroxylamine nitrate (WHC-CM-4-29, p. 7) gets to the tank and reacts with 12M HNO_3, the reaction is (Kronvall 1988, pp. 3-37)

$$4NH_2OH + 2HNO_3 \rightarrow 3N_2O + 7H_2O$$

The flowsheet states that this reaction is exothermic and vigorous where the technical reference (Kronvall 1988) implies on pp. 3-37 that the solution must be heated first. The flowsheet will be used as the basis for this analysis. The CCX stream comes from tank A-109 and flows into TK-30, which holds 57 L. Assume that 56 L of hydroxylamine nitrate get to the CAIS tank, as well as 1 L of 12M HNO_3. Fifty-six liters of hydroxylamine nitrate equals 22.4 mol. This will react with 11.2 mol of HNO_3. The reaction will liberate 16.8 mol of N_2O and heat that could result in some steam production. If the cooling water also fails there will be additional heat. The CAIS pump tank contains a vent and an overflow. The chemicals enter the tank via a funnel break. There could be backflow to the CC column. This could be the driving force for the spray in the fourth floor instead of the pump. The conservatisms in that analysis would cover this situation as well. Note that this line does not travel between the first and second-floor gloveboxes.

9.2.4.6.3.2.A.l Accident Analysis-Calculations, 236-Z, Solvent Extraction, Pumping Process Solution Through the Cooling Water Lines--If a pump on one of the pump tanks (like TK-36 or TK-120 on Drawing H-2-28019) continues to run, and the solenoid valve between the tank and the column closes (flow controller system fails somewhere due to seismic forces), and the cooling jacket water flow ceases and depressurizes (line break, etc.) **and** the cooling water piping in the jacket fails, there is no backflow through the

cooling water system because the cooling water jacket surrounds (is outside of) the process pipe (Gibson 1989).

9.2.4.6.3.2.A.m Accident Analysis-Calculations, 236-Z, Solvent Extraction, Steam Line Break in Glovebox--A steam line could fail inside of the glovebox but there would be no consequence of this action since the gloveboxes are quite large. There are holes that connect the gloveboxes with the canyon and the gloveboxes contain a large-diameter ventilation line. Steam condensate would collect on the glovebox floor. In the case of a steam line failure on the second level or third level, the liquid would drain through various pipe chases and gaps to the first-floor gloveboxes.

9.2.4.6.3.2.A.n Accident Analysis-Calculations, 236-Z, Solvent Extraction, Gases Produced in Plutonium-HNO_3 Solutions. Tanks containing plutonium solutions are constantly evolving gas products, primarily hydrogen, as the result of radiolysis. These gas products are vented off from the process tanks through individual vent lines connected to the ventilation system. The ventilation system is operated at a negative pressure relative to the process tanks to maintain the venting. Loss of the ventilation would increase the hydrogen levels in both the process tanks and vent lines. Tank TK-45, examined in this section, contains significant quantities of concentrated plutonium nitrate solutions and is considered to be representative of a worst case situation. This tank is characteristic of the process receiver tanks (TK-45, TK-46 and TK-128) used to receive product solutions from the product concentrator (TK-43).

The starting conditions and assumptions used in this analysis are presented with a discussion of any conservatism associated with them.

- **Plutonium Concentration** -- A concentration of 450 g/L is the upper limit and is based on criticality considerations. The normal operating range is 100 to 400 g/L.

- **Batch Size** -- The operating procedures show a batch size of 40 liters of plutonium product stored in the tank.

- **Plutonium Isotopic Composition** -- The assumed isotopic composition of the plutonium mixture is given in Table 9-7. This composition is characteristic of plutonium with greater than 19% ^{240}Pu. Based on inventory record estimates, less than 6.2% of the plutonium presently being stored at PFP has this high of burnup (Crowe and Szempruch 1994).

- **Tank TK-45** -- Tank TK-45 consists of cylinders constructed of pipe with a diameter of 12.7 cm (5 in) and a height of 114 cm (45 in.). The overflow capacity of the tank is 57 L. A 40 L batch of plutonium solution leaves a head space volume of 17 L.

  Each of the four 5 in. cylinders comprising TK-45 has a vent line (1/2 in. diameter tubing, 0.065 in. wall), an overflow line (1/2 in. diameter tubing, 0.065 in. wall), a pump recirculation line (1/2 in. schedule 40 pipe) and a pump suction line (1 in. schedule 40) pipe. The cylinders and all the piping are made of 304L stainless steel.

The piping from tank TK-45 runs through the process cell wall into the adjacent west corridor, first floor glovebox. The glovebox contains the pump and valves associated with the operation of the tank. This glovebox is seismically qualified (see Table 9-25). From here, there are lines going to the second floor glovebox and beyond.

- **Ignition present** -- Postulating the presence of an ignition source while the ventilation system has been down for an extended period is conservative. A seismic event would result in a shut down of the processes and evacuation of Zone 3. Time would be required for hydrogen to reach flammable concentrations and then an ignition source would have to be introduced or created.

  The most likely source of ignition of the hydrogen in the head space would be a deflagration or explosion somewhere else in the vent system that propagates back through the vent lines to the process tanks. At each tee connection in the vent system, the flame front might be able to propagate down the side line but not as a detonation, only as a burn. A distance of at least 10 pipe diameters would be required to re-establish the detonation conditions. The 3 in. long entrance lines from the 1/2 in. vent line into the 5 in. cylinders do not provide sufficient distance for this to occur. In addition, the critical tube diameter for hydrogen is 7.5 in. for propagation from a tube into a large open space (Camp et al. 1983). Since the vent line is only 1/2 in. in diameter, the vent tube could not initiate a detonation in the head space. Therefore, even if a detonation were to occur the in 1 in. vent header, it would not ignite a detonation in the process tank. The gas in the process tank might be ignited and burn but it does not detonate.

- **Hydrogen generation Rate** -- Henrie and Flesher (1986) provide hydrogen generation rates as a function of the specific gravity. For tank TK-45, the specific gravity for the 6M HNO^3 plutonium solutions with concentrations up to 450 g/L will be greater than 1.7 (Kronvall 1988). For a specific gravity of 1.7, the hydrogen generation rate, $G(H_2)$, is estimated to be 0.06 molecule/100 eV (Henrie and Flesher 1986). Using this value and the data from Table 9-7, the rate of hydrogen generation per gram of plutonium in solution can be calculated as follows:

$$1.557 \frac{Mev}{dis} \frac{Ci}{g\ Pu} \frac{3.7 \times 10^{10}\ dis}{Ci} \frac{2\ g\ H_2}{6.023 \times 10^{23}\ molecules} \frac{0.06\ molecules}{100\ ev}$$

$$= 1.15 \times 10^{-10} \frac{g\ H_2}{g\ Pu\ \text{sec}}$$

Hydrogen generated by radiolysis and released from the solution would collect in the head space volume. Over time, the hydrogen concentration in the head space would increase if the ventilation system was not functioning. Eventually, the lower flammability level would be reached. Since the tank contains no readily apparent ignition sources, the hydrogen concentration would continue to increase until the rate of diffusion of hydrogen out of the

tank matched the rate of hydrogen generation or until the ventilation is restarted. A batch of 40 liters with 450 g Pu/liter reaches a flammable level of 4% in about eight hours.

$$\frac{(4\%)\ (17\ \ell)}{\left(1.15 \times 10^{-10}\ \frac{g\ H_2}{g\ Pu\ sec}\right)\left(\frac{23.4\ \ell}{2\ g\ H_2}\right)\left(450\frac{g\ Pu}{\ell}\right)\ (40\ \ell)} = 7.8\ hours$$

It is postulated that the hydrogen in the vapor space of tank TK-45 is ignited from the vent system. If ignited, the hydrogen in the head space would burn, but due to the large expansion at the entrance and the short distance in the head space, a detonation would not be possible. The tank would pressurize from the hydrogen burn. The peak over pressure due to a hydrogen burn is expected to be eight times the original pressure for a stoichiometric mix (Camp et al. 1983). Halverson and Mishima (1986) give a relationship for the bursting strength of a vessel as a function of the diameter and wall thickness. For tank TK-45, constructed of 5 in. schedule 40, 304L stainless steel pipe with a wall thickness of 0.258 in., the calculated burst pressure is 7,600 lbf/in^2. Since this burst pressure is many times the peak pressure anticipated from the hydrogen burn, the tank will not burst.

The pressure in the tank would be relieved primarily by venting gas through the vent line and also by forcing liquid out the pump suction line at the bottom of the tank. For a release, the liquid must travel out of the tank, through the process cell wall into the first floor glovebox, through the pump, a remote-operated valve, and three manual valves, up to the second floor glovebox and then out of the glovebox. Even at this point, the transfer lines are encased so failure of two barriers would be required for a release.

Estimating the amount of liquid that flows out of the tank that could potentially be released requires calculating the length of time the head space is pressurized. Bird, Stewart and Lightfoot (1960) present a solution for the venting of a tank with expansion of an ideal gas through a frictionless, adiabatic orifice. The gas flow rate from a pressurized tank depends on the pressure at the exit opening. For lower tank pressures, the exit pressure is equal to the ambient pressure or vent line pressure. At higher tank pressures, the exit pressure is independent of the ambient pressure. The critical pressure ratio is defined in terms of gamma, γ, the ratio of specific heats. For a gamma equal to 1.4, the critical pressure is:

$$P_{crit} = \frac{P_{ambient}}{\left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}}} = \frac{14.6\ psia}{0.528} = 27.8\ psia = 191\ kPa$$

For pressures less than the critical pressure, the mass flow rate and discharge time to reach any specific mass fraction of the original gas are given by the following equations:

$$w = A_h\, C_d \sqrt{2\, P_1\, \rho_1 \left(\frac{\gamma}{\gamma - 1}\right) \left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{\gamma}} - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma + 1}{\gamma}}\right]} \qquad (2)$$

where: w = *instantaneous mass flow rate*

A_h = *area of orifice opening* = $\pi \dfrac{(\textit{vent diameter})^2}{4}$

C_d = *discharge coefficient* = 0.5

γ = *heat capacity ratio of vapor* = $\dfrac{C_p}{C_v}$ = 1.4

P_1 = *pressure inside the tank*

ρ_1 = *vapor density in tank*

P_2 = *pressure at vent line*

ρ_2 = *vapor density at vent line*

$= \rho_1 \left(\dfrac{P_2}{P_1}\right)^{\frac{1}{\gamma}}$; *for an adiabatic expansion of an ideal gas*

$$t = \frac{\dfrac{V}{A_h\, C_d}}{\sqrt{2\left(\dfrac{\gamma}{\gamma - 1}\right)\left(\dfrac{P_1}{\rho_1}\right)}} \int_{\frac{\rho_1}{\rho_0}}^{1} \frac{d\eta}{\sqrt{\left(\dfrac{P_2}{P_1}\right)^{\frac{2}{\gamma}} \eta^{\gamma - 1} - \left(\dfrac{P_2}{P_1}\right)^{\frac{\gamma + 1}{\gamma}}}} \qquad (3)$$

where: t = *discharge time*

V = *tank volume*

ρ = *vapor density in tank at time t*

η = *mass fraction of fluid left in tank at time t* = $\dfrac{V\,\rho}{V\,\rho_0}$

There is no simple analytical solution to this integral, so the calculation of this time must be done numerically.

For pressures greater than the critical pressure, the corresponding equations for mass flow rate and discharge time to reach any specific mass fraction of the original gas are given by the following equations:

$$w = A_h\, C_d \sqrt{\gamma\, P_1\, \rho_1 \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma + 1}{\gamma - 1}}} \qquad (4)$$

To solve for the length of time the tank actually vents, equation 5 is used to calculate the venting time starting when the tank is pressurized by the hydrogen burn (P_1 equals about 8 atmospheres) to the time when the critical pressure is reached (P_2 equals about 2 atmospheres). Equation 3 is

$$t = \frac{\frac{V}{A_h\ C_d}}{\sqrt{\gamma \left(\frac{P_1}{\rho_1}\right)\left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma + 1}{\gamma - 1}}}} \left(\frac{2}{\gamma - 1}\right)\left[\left(\frac{\rho_2}{\rho_1}\right)^{\frac{1 - \gamma}{2}} - 1\right] \qquad (5)$$

then used to calculate how long the remainder of the venting takes.

Using the characteristics of air for the gas in the head space of the tank, equation 5 predicts that it takes 0.54 seconds for the tank to vent to the critical pressure.

$$t = \frac{\frac{(0.017\ m^3)}{(1.27\ x\ 10^{-4}\ m^2)\ (0.5)}}{\sqrt{(1.4)\left(\frac{810\ kPa}{1.18\ \frac{kg}{m^3}}\right)\left(\frac{2}{2.4}\right)^{\frac{2.4}{0.4}}}} \left(\frac{2}{0.4}\right)\left[\left(\frac{0.42\ \frac{kg}{m^3}}{1.18\ \frac{kg}{m^3}}\right)^{\frac{-0.4}{2}} - 1\right]$$

$$= \frac{(268\ m)}{\left(567\ \frac{m}{sec}\right)}\ (5)\ (0.229)$$

$$= 0.54\ sec$$

From equation 3, it takes another 0.40 seconds to finish de-pressurizing the tank.

$$t = \frac{\frac{(0.017\ m^3)}{(1.42\ x\ 10^{-4}\ m^2)\ (0.5)}}{\sqrt{2\left(\frac{1.4}{0.4}\right)\left(\frac{1.9\ x\ 10^5\ Pa}{0.43\ \frac{kg}{m^3}}\right)}} \int_{0.423\ \frac{kg}{m^3}}^{0.269\ \frac{kg}{m^3}} \frac{d\eta}{\sqrt{\left(\frac{1.92\ x\ 10^5\ Pa}{1.01\ x\ 10^5\ Pa}\right)^{\frac{2}{1.4}} \eta^{0.4} - \left(\frac{1.92\ x\ 10^5\ Pa}{1.01\ x\ 10^5\ Pa}\right)^{\frac{2.4}{1.4}}}}$$

$$= \frac{(268\ m)}{\left(1.782\ x\ 10^3 \frac{m}{sec}\right)} \int_{0.634}^{1} \frac{\delta\eta}{\sqrt{(0.402\ \eta^{0.4} - 0.335)}}$$

$$= 0.40\ sec$$

Assuming turbulent flow, the amount of liquid forced out of the tank during the venting is given by the following equation (Crane 1957):

The outlet piping going to the pump suction has a diameter of 1 in. From the discharge of the pump, the solution would have to travel up to the second floor and horizontally out of the glove box. The vertical run is about 15 feet and the horizontal run is about 25 feet. There are three manual valves

$$q_s = 0.525\, d^2 \left(\frac{\Delta P}{K\, \rho_s}\right)^{0.5} \qquad (6)$$

where: q_s = *flow rate of solution* $\left(\frac{ft^3}{sec}\right)$

d = *diameter of outlet piping (in)*

ΔP = *pressure difference* $= \frac{(initial\ \Delta P + final\ \Delta P)}{2}$

K = *resistance coefficent*

$= 0.015 \left(\frac{length\ of\ piping}{diameter} + length\ equivalent\ for\ valves\right)$

ρ_s = *weight density of solution* $\left(\frac{lb}{ft^3}\right)$

and one motor operated valve in this run. Four globe valves (each equivalent to 340 feet) and 40 feet of 1 in. pipe give a resistance factor, K, equal to 33.

As the tank vents, the pressure decreases and the driving force for pushing the liquid out of the tank decreases. The pressure difference is taken as the average of the initial and final pressure differences. The final pressure is the pressure required to lift 1.7 M solution a height of 10 feet or about 26 psig. Since this pressure is about the same as the critical pressure, P_{crit}, the time of 0.54 seconds calculated by equation 5 is also representative of the length of time solution is forced from the tank.

Using equation 6, the average volumetric flow rate of liquid out of the bottom of the tank is 0.059 ft^3/sec.

$$q_s = 0.525\ (1\ in)^2 \sqrt{\frac{44.9\ psi}{33\left(106 \frac{lb}{ft^3}\right)}}$$

$$= 0.059\ \frac{ft^3}{sec}$$

The total amount pushed out over 0.54 seconds is about 0.032 ft^3 of solution. This volume of fluid is small compared to the volume of gas flowing out of the vapor space through the vent. This confirms that the length of time required to vent the pressure is determined by the characteristic of the gas flow out of the vent line and not the liquid flow.

At 450 g/liter, a maximum of about 410 g of Pu could be released as a liquid spill into 236-Z for complete break of the 1 in. solution pipe. For a viscous solution with less than a 3-m fall, DOE (1994) suggests a release

fraction of 3 x 10^{-5} with a respirable fraction of 70%. Therefore, the respirable amount of Pu released to the second floor of 236-Z would be:

$$410\ g\ Pu\ (3.0 \times 10^{-5})\ (0.7) = 0.009\ g\ of\ respirable\ Pu$$

This analysis neglected the effect of the inertia of the solution so the calculated release is significantly higher than what would actually occur. This event requires that a transfer be occurring at the same time as the seismic event, long term loss of the ventilation system, ignition of the gas in the vent line with the propagation back into the tank and a failure of encased lines. Considering the conservative assumptions in the above calculations, this release is negligible.

Room 27 maintenance glovebox and shelf storage have been declared inactive since the above analysis was originally performed. The release estimate is retained for conservatism, pending a future update to the entire seismic accident analysis.

9.2.4.6.3.2.A.o Accident Analysis-Calculations, 236-Z, Solvent Extraction, PRF AMU Room and Storage Rooms-- Potentially vigorous interactions between spilled tank contents and/or reagent package contents are:

1. The HNO_3 and hydroxylamine nitrate solutions (solution removed)
2. The HNO_3 and NaOH and Na_2CO_3.

The hazards at PRF have been addressed further in HNF-SD-CP-HA-001, "Plutonium Finishing Plant Chemical Hazard Assessment" (BWHC 1997)

Hydroxylamine Nitrate and HNO_3. When hydroxylamine nitrate, as an about 17 wt% solution, is added in small increments to a large reservoir of 12.2M HNO_3, it is decomposed rapidly after each incremental addition with smooth evolution of small bubbles of colorless gas. After the solution has warmed due to heat evolved upon decomposition, it then reacts to successive additions of 17 wt% hydroxylamine nitrate solution rapidly with vigorous evolution of large bubbles of brown-red gas and copious but transitory foaming. Concentrated HNO_3 additions to 17 wt% hydroxylamine nitrate solutions exhibit no effects except slight warming due to heats of dilution up to terminal acidities of about 9M. Above that level, rapid decomposition occurs with vigorous evolutions of large bubbles of brown-red gas and copious but transitory foaming. Addition of a relatively large quantity of concentrated HNO_3 to a concentrated hydroxylamine nitrate solution leads promptly to vigorous evolution of reddish-brown gas with little foaming.

Explosions and fires are not anticipated. Personnel would suffer chemical burns and severe inhalations of HNO_3 and oxides of nitrogen.

HNO_3 and NaOH and Na_2CO_3 Solutions and Solids. Vigorous neutralization reactions are observed between HNO_3 and basic materials. Steam formation and splattered corrosive liquids can occur and overpressurization could occur. Personnel could experience scalding and chemical burns, and inhalation of HNO_3 vapors and various corrosive mists.

9.2.4.6.3.2.B Accident Analysis Calculations, 236-Z, S&C. The slag and crucible process is no longer required for production at the PFP. Therefore, the Slag and Crucible process is not presently in use. If future use is required, the accident will be analyzed.

9.2.4.6.3.2.C Accident Analysis Calculations, 236-Z, Balance of Facility.

9.2.4.6.3.2.C.a Accident Analysis-Calculations, 236-Z, Crane Falls in Canyon--Same as in Section 9.2.4.6.3.2.A.c.

9.2.4.6.3.2.C.b Accident Analysis-Calculations, 236-Z, Chemical Preparation--See Section 9.2.4.6.3.2.A.o.

9.2.4.6.3.2.C.c Accident Analysis-Calculations, 236-Z, Miscellaneous Treatment Gloveboxes--Room 41 contains five MT gloveboxes (MT-1, MT-3, MT-4, MT-5, and MT-6). These gloveboxes are connected via a conveyor. These gloveboxes are inactive and the conveyor is normally empty. No release is postulated for these gloveboxes.

9.2.4.6.3.2.C.d Accident Analysis-Calculations, 236-Z, Room 27--Room 27 contains the maintenance and product handling glovebox and storage shelving (currently inactive) for packaged plutonium containers, neither of which are seismically qualified. The CPS limit for the glovebox is 1,000 g and the room limit (i.e., glovebox plus storage) is 5,500 g. This material is assumed to be >10% ^{240}Pu as there are no restrictions on isotopic composition. A release fraction of 1.5×10^{-4} is conservatively applied per Case 2. Application of this release fraction to the entire inventory is judged to be conservative in that the plutonium container packaging is not expected to fail should it fall from the shelving. The release is calculated to be 0.83 g:

$$5500g\ (1.5x10^{-4}) = 0.83g$$

9.2.4.6.3.3 Accident Analysis-Calculations, 236-Z, Product Handling. The release as a result of solution spills was described in the analysis of the PFPAL and room 166 of Building 234-5Z (9.2.4.6.3.1.H). The release, even for very concentrated solutions falling from great heights, is small and will be considered as negligible.

9.2.4.6.3.4 Accident Analysis-Calculations, Vaults. In addition to the arguments presented in the scenario section and the calculation presented for rooms 174, 175, and 190, *Parametric Heat Transfer Study - Loss of Air Circulation in the Plutonium Storage Vault, 2736-Z Building*, (Allen 1981) and *Control of Thermal Loading in Plutonium Storage Vaults, Building 234-5Z*, (Panesko 1976) show that a loss of ventilation does not lead to excessive container pressures.

9.2.4.6.3.5 Accident Analysis-Calculations, Outside Building.

9.2.4.6.3.5.A Accident Analysis-Calculations, Outside, HF--HF is no longer used in large quantities at the PFP, but it may be used in small quantities for experimental purposes.

9.2.4.6.3.5.B Accident Analysis-Calculations, Outside, Nitrogen Tank--The nitrogen tank may be propelled off its stand if the tank fails in the right location. Failure of the tank and release of its contents do not create a significant hazard.

9.2.4.6.3.5.C Accident Analysis-Calculations, Outside, Drain Lines--Failure of the drain lines between Buildings 234-5Z and 241-Z could result in some release to the ground if the trench also fails or cracks. The consequence to the offsite individual is very small and is considered in the Hanford Defense Waste - Environmental Impact Statement (DOE 1987, Appendix R).

9.2.4.6.3.5.D Accident Analysis-Calculations, 2735-Z (Outside Facility), Failure of the HNO_3 Storage Tank--Although the HNO_3 storage tank has been drained and is not in service, the analysis has been retained to present a bounding toxic chemical release. Since the outside HNO_3 storage tank is not seismically qualified, it is assumed to fail and release HNO_3 to the retention basin. A seismic event causing a failure of the storage tank is analyzed in Section 9.2.8.

9.2.4.6.3.6 Accident Analysis-Calculations, 2736-Z Complex.

9.2.4.6.3.6.A Accident Analysis-Calculations, 2736-Z Complex, Argon Release. Argon lines can fail as a result of the earthquake, but there are only consequences for the facility workers. Facility workers will evacuate should an earthquake occur. The out-of-facility releases will be diffused due to flow through the facility prior to release.

9.2.4.6.3.6.B Accident Analysis-Calculations, 2736-Z Complex, Flooding. If a fire line fails in the room, it may be possible to flood the room. Provisions are made so that the room drains, but these may have failed or been made less effective as a result of the earthquake. Flooding the room will not result in a criticality.

9.2.4.6.3.6.C Accident Analysis-Calculations, 2736-Z Complex, Criticality. See Section 9.2.4.2.11.F.

9.2.4.6.3.6.D Accident Analysis-Calculations, 2736-Z Complex, Container Heatup. The 2736-Z complex contains plutonium in two buildings; 2736-Z and 2736-ZB. The plutonium storage in the 2736-ZB Building consists of floor storage of waste drums and cubicle storage of SNM containers within open-faced cabinets. Due to the size of the rooms and the openness of the storage cabinets, the heatup of containers stored in the 2736-ZB Building is bounded by the heatup of containers stored in the 2736-Z Building.

In 2736-Z there are four storage vaults. Vault 1 contains pedestal storage in thick concrete cubicles. The cubicles are solid concrete except for the top which is the exhaust duct for the cubicle. The cubicle contains double front doors which are concrete and overlap tightly when closed. A small gap in the front at the bottom of the cubicle lets air into the cubicle. The cubicles are butted one to another and hold 45 containers of plutonium each. If the ventilation is lost, the containers will start to heat up.

The heatup calculation will follow the equations and data in Section 9.2.4.6.3.1.I with the following assumptions.

1. Heat transfer will only be allowed out the front of the cubicle. No heat transfer is allowed out the sides or back due to the presence of heating containers in these cubicles.

2. Credit will be taken for convection inside the cubicle. The convection is due to natural convection from the floor (which is cold) into the cubicles through the gap in the bottom of the door and out the exhaust ducts.

3. Each container generates 15 W and there are 45 containers per cubicle.

4. Assume 48 h of heatup time.

The same equations and data as in Section 9.2.4.6.3.1.I will now be used.

$$T_w = \frac{2g}{kA}\left[\frac{at}{3.14}\right]^{0.5}$$

where:

$$q = \text{Heat rate, in Btu/h} = \left[\frac{15\ W}{\text{container}}\right]\frac{3.4\ \text{Btu}}{W\text{-}h}\ (45\ \text{containers})$$

$$= 2{,}295\ \text{Btu/h}$$

k = Thermal conductivity = 0.79
a = Thermal diffusivity = 0.021
A = Area on which heat impacts = 8 ft by 2 ft = 16 ft^2
t = Time, h = 48
T_w = Temperature rise on inside of wall, °F.
T_w = 205.7 °F

The room ambient temperature is assumed to be 100 °F (normally around 75 °F). Therefore, the temperature on the inside of the concrete door is 305.7 °F.

To find the container temperature this equation is solved.

$$q = (0.1718 \times 10^{-8})\ A\ \frac{1}{0.429}\ [(T_c+460)^4 - (T_w+460)^4]$$

$$+ 0.22\ (T_c-T_w)^{0.33}\ (0.5)(T_c-T_w)$$

where: A = Surface area of the containers = 0.52 ft^2(45) = 23 ft^2
T_w = Wall temperature = 305.7
q = Heat rate = 2,295 Btu/h.

Solving for T_c yields 320 °F. Computer code calculations from Allen (1981) show 346 °F using 18-W containers. Using the same calculations as above but assuming 96 h the container temperature is 405 °F.

Again, using the data of Section 9.2.4.6.3.1.I, the possibility of container failure can be assessed. At t = 0, the container is at 17.7 lbf/in^2. When T_c = 320 °F, the container pressure is

$$\frac{P}{17.7} = \frac{(460+320)}{(460+180)} = 1.22$$

$$P = 21.6 \text{ lbf/in}^2$$

When T = 405 °F, P = 23.9 lbf/in^2.

So by the calculations and reasoning used previously the containers will not fail.

The containers in Vaults 3 and 4 will be less hot because there are fewer locations per cubicle (28 versus 45) and the doors are not solid. They contain about a 4-in. wide floor-to-ceiling perforated metal covering.

9.2.4.6.3.6.E Accident Analysis-Calculations, 2736-Z Complex, Storage Container Failure. Building 2736-Z, Vault 2 houses metal racks used for the storage of Pu containers. Two different types of racks are used: one for the storage of 7-in. cans and one for the storage of lard cans. The storage racks are seismically qualified.

Although the storage racks are seismically qualified (i.e., they do not fall over), it is conceivable that storage cans could fall to the floor due to seismically-induced movement of the racks. Accordingly, engineered features have been designed and installed that prevent cans from falling from the racks. In the case of the 7-in. can storage racks, each storage location is provided with a positioning ring into which the can is set. In addition, the racks are equipped with 20-gauge diagonal-mesh metal doors. The lard can racks are not provided with positioning rings or doors; however, they are provided with chains that run across the face of each storage shelve.

For this analysis it is assumed that an operator fails to properly latch one of the lard can storage rack retaining chains such that it swings open during the seismic event. A lard can rack was chosen for analysis as the 7-inch can racks have redundant means of preventing cans from falling (i.e., sleeves and doors). Each lard can storage rack has four shelves on which cans are stored three across and two deep. It is assumed that six cans fall from the top shelf to the floor, a distance of 61.5 inches, or approximately

5 feet. Note that six cans randomly falling from a shelf does not constitute a criticality concern. Criticality Prevention Specification CPS-Z-165-80100 permits the storage of lard cans in an infinite array stacked four high (see Section 9.2.4.6.3.6.C).

Plutonium stored in lard cans is provided with a minimum of two containment barriers. As required by Operating Specification Document OSD-Z-184-00013, "Special Nuclear Material Storage," Pu stored in lard cans must first be packaged in a series of two mechanically sealed food pack cans. The permitted exception is S&C fragments which may be sealed in a single untinned steel can. Additionally, cans stored inside lard cans are typically enclosed in one or more plastic bags.

For a release of Pu to occur, both the inner packaging (i.e., food pack cans) and outer packaging (i.e., lard can) must fail due to the fall from the shelf, or, alternatively, the inner and outer packaging must be in a failed condition prior to the seismic event. Tests have been conducted (Hammond 1976a) in which food pack cans filled with nonradioactive materials (to simulate can loading) were dropped from a height of ten feet. Although deformation occurred, in no case were any of the can seams split open. Drop tests have also been conducted on lard cans (Hammond 1976b). In contrast to the food pack cans which have mechanically sealed lids, the lid on a lard can is taped into place. A seam failure occurred when a can loaded with 90 pounds was dropped from a height of 80 inches. In addition, a short length of the lid was almost pushed out of the tape seam. It is important to note that the 90 pound test weight exceeds the weight of any lard can currently in storage. Based on storage records, the mass of lard cans in stored vault 2 is on the order of 30 pounds.

As stated above, a release of Pu could also occur given the inner and outer cans are in a failed condition prior to the seismic event. Failure of the cans could result from either corrosion, pressurization, or mechanical stress (e.g. punctures). Packaging requirements stipulated in OSD-Z-184-00013 are intended to prevent internal corrosion and pressurization. Specifically, corrosive salts and other materials that are reactive with iron over short or indefinite periods of time are not permitted. To prevent pressurization, reactive materials (i.e., those which may easily generate gasses in their containers) are not permitted. Examples of such materials include Pu oxalate and centrifuge solids. A LOI criteria of a weight loss of one percent or less has also been established for stored materials. In addition, each lard can is inspected on a monthly basis for corrosion, penetrations, dents, or bulging. A container is considered bulged if a straight rod can be placed across the lid seams and the center of the lid touches the rod.

Considering the above discussion, it is assumed that one of the six lards cans postulated to fall to the floor contains a failed inner container and the fall to floor breaches the lard can tape seal. The quantity of Pu stored in a lard can is limited to 400 g by CPS-Z-165-80100. The respirable release fraction applied to powder spills from a height of 2 m is 1.5×10^{-4} (see Section 9.2.4.6.2) For this analysis, a release fraction of 1.5×10^{-5} is applied. This order-of-magnitude reduction accounts for several facts:

- The material-at-risk is contained during the drop; in contrast, the release fraction value of 1.5×10^{-4} was derived from the free drop of powders
- Although the inner container(s) are assumed to be failed, it is believed that an actual breach due to corrosion or overpressurization would be small in size such that the majority of the Pu would be retained in the inner container and thus not available for release
- Although the lard can tape seal is assumed to be breached, it is believed that the lid would remain in place such that the release pathway would be relatively small.

Applying a release fraction 1.5×10^{-5}, the release of Pu to vault 2 would be 0.006 g,

$$(400\ g) \times (1.5 \times 10^{-5}) = 0.006\ g$$

Given a release of 0.006 g Pu into Vault 2, the quantity of Pu released to the environment depends on the operability of the HEPA-filtered ventilation system. As stated in Section 9.2.4.1.1, the post-DBE function and operability of the system is reasonably provided for based on the structural integrity and anchorage/stability of the equipment. As the system is expected to be functional and operable, the 0.006 g would be released via two stages of HEPA filtration, effectively reducing the release to zero. If the supply air fans and exhaust fans were both inoperable, there would be no significant motive force to transport the airborne Pu outside of the facility, and the release would be essentially zero. Lastly, it is conceivable that the exhaust fans could fail while the supply fans continued to operate. This is a very specific failure mode and would also require failure of the existing instrumentation and control system which would otherwise remove power to the supply fans given loss of the exhaust fans. Two supply fans provide a total of 11,000 cfm to Building 2736-Z. Given failure of the exhaust fans, the majority of this air would still exit 2736-Z via the 20-in. by 38-in. exhaust duct and, thus, be HEPA filtered. However, as the building would be at a positive pressure relative to atmospheric, leakage through unfiltered pathways would occur. For example, the seismic analysis of the HEPA filter system predicts the opening of very small holes in the interface duct assembly between 2736-Z and 2736-ZA, and Figure 9-18 shows 1,000 cfm of inleakage via unspecified pathways. Based on (1) the ratio of normal inleakage to normal supply air, and (2) the ratio of the area of a 0.5 in. opening about the circumference of the interface duct (116 in^2) to the area of the duct itself (840 in^2), it is estimated that from 10-25 percent of the airborne Pu, or from 0.0006 to 0.0015 g, could be released via unfiltered pathways. A release in this range has a negligible impact on the radiological consequences of a seismic event relative to releases from other PFP facilities. Even if it were conservatively assumed that all 0.006 g airborne within Vault 2 was released, the impact would still be negligible as 0.006 g represents approximately 0.3% of the total Pu release from other PFP facilities.

9.2.4.6.3.7 Accident Analysis-Calculations, 242-Z. As discussed in Section 9.2.4.2.7, it is estimated that there are 110 g of Pu remaining on walls and in hoods in Building 242-Z. Applying a release fraction of 1.5×10^{-4} per Case 2 yields 0.017 g of airborne respirable Pu. However, the Pu present is that remaining following cleanout activities. As such, it is not present as process powders or solutions in storage containers or process vessels, but rather it is comprised of thin layers of pu deposited over large surface areas. Such material adheres tightly to the surface on which it is deposited such that a release fraction significantly lower than 1×10^{-4} (which is based on the free fall of powders) would be applicable. Accordingly, the contribution of Building 242-Z to the total release from all PFP facilities is negligible.

9.2.4.6.3.8 Accident Analysis-Calculations, 241-Z. A potential release from Building 241-Z was discussed in the Plutonium Finishing Plant FSAR Safety Evaluation Report (DOE 1995). As discussed in Section 5.2.4 the coverblocks, as well as the support walls are seismically qualified and will not fail given a 0.2-g DBE. However, the pre-engineered steel structure, monorail and monorail supports are not seismically qualified. Thus there is the potential for interaction events.

A failure of the pre-engineered structure or crane supports and crane have the potential to dislodge the coverblocks. Assuming a coverblock is dislodged and falls into a tank, one-half of the contents in the tank may be ejected to the atmosphere, due to piston effects. The bounding ARF/RF values (1E-4 and 1.0, respectively) (DOE 1995) for a release of this type were applied to determine the mass fraction of droplets 10um or less in diameter. DOE 1995 applied the ARF/RF values to the maximum plutonium content contained in all 5 tanks. Assuming each tank contains 400 grams Pu (criticality limit) 2,000 grams Pu in the 5 operating tanks. Assuming half of the contents are released due to piston effects, and applying the bounding ARF/RF values, 0.10 grams respirable of greater than 10% ^{240}Pu would be released to the atmosphere from spilled liquids. The doses resulting from this release are discussed in Section 9.2.4.8.

Transfers to Building 241-Z have very low plutonium concentration (0.033 g Pu/L) and the amount of liquid transferred is on the order of 200 L. It has been assumed that the release to the soil column from liquid spills that do not become airborne will be under or adjacent to the structure and little will rise to the surface, thus limiting exposures to the facility worker, and onsite and offsite individual.

9.2.4.6.3.9 Accident Analysis-Calculations, 291-Z. The analysis for the filter rooms and upstream duct work of 234-5Z (9.2.4.6.3.1.X) showed the release from vibratory motion of the duct to be small. The same will be true in 291-Z because the number of grams on the surface and the surface area are similar. The release from the previous section was less than 0.01 g.

9.2.4.6.3.10 Accident Analysis-Calculations, 232-Z. Building 232-Z originally contained a series of process enclosures housing equipment used for the recovery of plutonium from various waste substrates. Since deactivation of the facility, some of these enclosures (e.g., the leaching gloveboxes and sorting hood) have been removed. Remaining enclosures include:

- Scrubber cell
- Filterboxes 1 and 2
- One multisection glovebox (sometimes referred to as the "Incinerator") made up of 3 sections. For purposes of this report these sections are identified as separate gloveboxes as follows:
  - Feed glovebox
  - Incincerator glovebox
  - Ash glovebox.

The 232-Z Building has recently been cleaned out. The facility has a maximum total holdup of 661 g based on NDA measurements performed following equipment removal and cleanout. The majority of this material (i.e., 405 g) is located in the incinerator. The cyclone separator contains 102 g, the scrubber cell contains 77 g, and the remaining 77 g is located in miscellaneous glovebox ventilation ducting.

A review of operations, process tests and cleanup activities, showed the following:

- Holdup in the incinerator is likely in the form of thick slag coatings on the combustion chamber walls.
- Holdup in the cyclone separator is likely in the form of fixed material.
- It is possible that ash exists outside the combustion chamber but inside the glovebox.

Accident Scenario. The postulated bounding accident is a seismic event that causes damage to the existing plutonium containments and collapses the building. The effects of the seismic event on the foundation of the 232-Z Building are displacements and forces in both the horizontal and vertical direction. These displacements and forces are transmitted to the walls and roof of the structure and to the gloveboxes contained therein. Based on glovebox analysis presented in the FSAR, it appears that the incinerator glovebox as originally constructed would topple. This assumption is reasonable given the large mass associated with the firebrick and the relatively long glovebox support legs. Recently, additional glovebox bracing was installed to preclude toppling, however, this analysis takes no credit for it and conservatively assumes damage to the glovebox from toppling.

In the analysis credit was taken for a "leak path factor" out of the glovebox, into the facility. The leak path factor is based on testing of a shipping container subjected to various drop tests. *The Safety Analysis Report for Packaging: CI 6712 Container (HCS-058-003-00)*, RHO-SD-RE-SAP-009 (Cahow 1982) and *Evaluation of the CI 6712 Shipping Container and Burial Container for Onsite Use*, RHO-CD-1523 (Van Meter 1981) describe a shipping container of similar size to the glovebox. The tests showed that the body of the container suffered very little damage. The energy of the 4 ft drop of the shipping container is greater than that of the toppled glovebox and, therefore, the damage should be comparable. Keep in mind also that the

glovebox, being 10 ft tall, will fall onto other pieces of equipment, the wall, or columns if it falls. However, credit is not taken for the reduction in energy afforded by these obstacles. To establish a bounding maximum consequence of the accident scenario the analysis assumes roof collapse at earthquakes greater than 0.09-g (even though structural calculations show favorable load to capacity ratios for 0.20-g earthquakes). This coincides with an annual probability of the event being less than 2×10^{-3}. It was assumed that the leak path factor for the building is 1.0.

Since the roof will not likely free fall due to the partial restraining action of the columns and the walls, the energy is judged to be similar to that of the "4-ft drop." That is, the effect on the glovebox of the roof falling onto it will be similar to the damage sustained by the shipping container dropped 4 ft onto an unyielding surface. Since, the damage to the shipping container was minor, the damage to the glovebox is judged to be minor as well.

Consequences and Probability. For the purposes of this analysis, the source term is defined as the quantity of respirable plutonium released to the environment. The quantity released is a function of the initial inventory, the ARF, the RF of the material made airborne, and facility leakpath factors (LPF). The source term released from the facility is comprised of the release from the multi-section glovebox, scrubber cell, and the ducts.

For the purposes of this analysis, the following is assumed:

- Total holdup in the multisection glovebox is 405 g.
- Scrubber cell contains 77 g.
- Total holdup in the cyclone separator is 102 g.
- The ducts contain 77 g of plutonium.
- Ducts are a maximum of 13 ft off of the floor.

One of the activities undertaken in the 232-Z remediation activity involved cleaning of the cyclone separator. In order for this activity to progress, it was first necessary to remove the asbestos insulation that surrounded the cyclone separator assembly. Upon removal of the insulation, the collection canisters (two) that were located directly beneath the tapered portion of the cyclone chambers were removed and checked for ash. Neither one of the canisters contained material. The operators then inserted a steel rod vertically through the bottom of the tapered portion of the cyclone chambers up to the 2 1/2-in. return pipe (approximately 30 in.) and rodded out this portion. This activity failed to produce ash material. The operators then tapped the cyclone separator assembly and associated piping with a hammer. Nothing came out of the open cyclone chambers. The operators then gave it two more vigorous hits. At this point the conclusion was drawn that the separator assembly was indeed empty. Therefore, if there is material in the cyclone separator, it is likely in the form of tightly adhered material on the wall and not subject to being released.

It is assumed that during the seismic event the glovebox falls. As the glovebox falls, some of the ash and insulating material (depending on the magnitude of the friction forces holding it in place as compared to the forces tending to draw it out of place) is simply suspended into the open space. Should this material impact the brick, and be allowed to rebound, unimpeded, the release fraction would be that for spilled powder. However, at impact, the bricks from one side impact the bricks and combustion chamber on the other side of the open portion in the center of the glovebox. The impacting bricks will intercept most of the suspended ash, and therefore, there is no (or very little) release due to "free fall of powders". The effect of a single brick on a pile of ash is to suspend it via aerodynamic stresses (DOE 1994, Section 4.4.3.3.2, "Large Falling Object Impact or Induced Air Turbulence") or by response of the solid substrate (DOE 1994, Section 4.4.3.3.1, "Vibration Shock").

For this case, the most appropriate resuspension data are those from *Simulated Seismic Event Release Fraction Data - Progress Report - April 1987*, RFP-4161 (Langer 1987). In Langer's experiments, 2 to 4-lb rocks, were dropped 3.7 m onto 1,000 g of powder lying free on a piece of plywood, or in an open can propped at a 60° angle to assure spilling. These conditions resemble bricks and blocks falling onto ash lying on other bricks and blocks. Langer's data for objects falling onto free powder would be appropriate for the case of a single brick. In this case, however, many bricks are falling onto many smaller quantities of powder. As a result, there is an inhibiting effect of the neighboring bricks on the release from a single brick, since the aerodynamic stresses are less (interruption of the air flow), the neighboring bricks will capture some of the material suspended (impaction or capture), and prevention of the substrate from fully responding.

Langer's data for a stone being dropped on to free powder shows an airborne release fraction of 1.2×10^{-3} and respirable fraction of 0.27 for drops onto aluminum oxide. This powder has properties very similar to the ash since the density (4 g/cm^3) and fraction of small particles (24% less than 25 μm vs 15% less than 10 μm for plutonium ash) are close. As a result, the RF suspended is 3.2×10^{-4}.

The RF released into the glovebox and carried out, will be less than that determined by Langer, who dropped stones onto free powder. The reduction is know as the LPF. This reduction is due to:

- The smaller volume for resuspension (the glovebox volume is limited to a total of 3×10^4 in^3). The effective volume into which ash suspended by the drop of one brick is much less.
- The presence of the other block that hinders the ability of the air to carry it away.
- Air flow for only a short period of time (if at all).

These factors are taken into account by assigning a LPF of 0.20 for a bounding scenario.

The release of plutonium from the multi-section glovebox falling and the roof hitting the glovebox is:

$$\text{Release} = 405\ \text{g}\ (3.2 \times 10^{-4})\ (0.20) = 2.6 \times 10^{-2}\ \text{g}$$

The release of plutonium contained in the ducts and scrubber is modeled based on a spill from 4 m (13 ft). Release fractions for spills of powders from 1-m (3-ft) and 3-m (10-ft) heights are presented in *Aerosols Generated by Spills of Powders and Solutions in Static Air* (Sutter et al. 1981). The total release fraction (both respirable and nonrespirable powders) for a 1-m spill was 7×10^{-5}, and 7×10^{-4} for a 3-m spill. From these values, a release fraction of 7×10^{-3} can be derived for a 4-m spill via extrapolation. However as shown in the *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, NUREG-1320 (Ayer et al. 1988), the release fraction is proportional to "H^2", where "H" is the height of the fall in centimeters. Using this relationship and a release fraction of 7×10^{-5} for a 1-m spill, the value of a 3-m spill is nine times more, or 6.3×10^{-4} (which approximates the value of 7×10^{-4} given in Sutter et al. [1988]). The value for a 4-m spill is 16 times more, or 1.1×10^{-3}.

Langer (1987) shows respirable release fractions of 3.3×10^{-4} to 2.5×10^{-6} for situations where concrete blocks were dropped onto containers holding sand, sand and Al_2O_3, Al_2O_3 alone, or nickel (to simulate PuO_2). The blocks were dropped from 3.7 m (12 ft). Scaling the result of 3.3×10^{-4} (Langer 1987) by the ratio of $(4\ \text{m})^2$ to $(3.57\ \text{m})^2$ yields 4×10^{-4}. This value is within a factor of four of the value of 1.1×10^{-3}. Therefore, a release fraction of 1.1×10^{-3} is judged appropriate for use in this accident analysis. Given an inventory-at-risk of 154 g, collapse of the ceiling results in a release of:

$$\text{Release} = 154\ \text{g}\ (1.1 \times 10^{-3}) = 1.7 \times 10^{-1}\ \text{g}.$$

This value is conservative since the scrubber is a cell (like a "hot cell") and resembles more of a small room than a glovebox. It contains two scrubbers, two demisters, and two HEPA filter housings. In addition, there is much conservatism in the release fraction for the ducts. The free-fall spill of powders is based on ball-milled powder, almost all of which is less than 10 μm in diameter. It was shown that Langer's data could also be used, resulting in a factor of three reduction in the release fraction. Recent duct cleanout (see attached letter G. B. Chronister to J. J. Roemer) shows that not all of the material is loose; much is adhered to the piping.

The plutonium held up in the cyclone separator is probably slag adhered to the walls of the separator since there is no location where large quantities of loose powder can remain and still escape the rodding and impacting done during cleanout. The only location in which loose powder can be held up are the horizontal sections that are fairly short. Recall that 1 kg Pu equals 50 to 300 in^3. As a comparison, DOE (1994) presents the results of impact of hard objects onto brittle materials. This is a closer approximation to slag on walls. Jardine performed experiments in which a weight was dropped onto spheres of brittle material. This case is similar since the impact of the cyclone separator having adhered material imparts

somewhat similar forces. The respirable release fraction is a function of "E/V" where "E" is in Joules and "V" is in cm^3. In this case:

$$E/V = mgh/(m/\rho)$$

where: m = mass of powder and cyclone separator, kg
g = 9.8 m/sec^2
h = height of fall, m
= 3 m
ρ = density of iron, g/cm^3
= 7.9

Solving yields "E/V" equal to 0.23 J/cm^3. The RF is found to be 3×10^{-5}. This is believed to be a more representative case than that of "cans containing powder" shown above. This is because the material is believed to be adhered to the walls of the separator. The LPF is taken to be 0.5 since not all of the suspended material will get out of the cyclone separator due to the many turns and small openings. The release from the cyclone separator is:

$$\text{Release} = 102\ g\ (3.0 \times 10^{-5})\ (0.50) = 1.5 \times 10^{-3}\ g$$

The total release is therefore 0.20 g (0.026 g + 0.17 g + 0.0015 g). The above discussion shows that the value of 0.20 g for the bounding accident is conservative.

As shown in Vogt (1994), Section 9.2.4A.8, the onsite bone-surface dose is limiting. That is, the onsite bone-surface dose more closely approaches the WHC Risk Acceptance Guidelines (see Table 9-49) than do the onsite EDE or the offsite EDE or bone-surface doses. The onsite bone-surface dose is calculated by multiplying the source term by:

a) a bone-surface mass-weighted average unit inhalation dose conversion factor of 3.2×10^8 rem/g, which is the same as that used in the FSAR for release from 232-Z [from Table 9.3.5-7 of Vogt (1994)]. This value contains the peak calculated value for ^{241}Am based on aging.
b) an onsite atmospheric dispersion coefficient of 8.72×10^{-4} s/m^3 (from Table 9.3.4-2 of Vogt (1994))
c) and a breathing rate of 3.3×10^{-4} m^3/s (from Table 9.3.6-1 of Vogt (1994)).

Applying these values, the onsite bone-surface dose is calculated to be 18 rem for the 0.20 g release (bounding analysis).

$$(0.20\ g)\ (3.2 \times 10^8\ rem/g)\ (8.72 \times 10^{-4}\ g/m^3)\ (3.3 \times 10^{-4}\ m^3/s) = 18\ rem$$

The offsite bone-surface dose is calculated to be 0.34 rem for the 0.20 g release.

$$(0.20\ g)\ (3.2 \times 10^{8}\ rem/g)\ (1.62 \times 10^{-5}\ g/m^3)\ (3.3 \times 10^{-4}\ m^3/s) = 0.34\ rem$$

The onsite EDE is calculated to be 1.61 rem as follows:

$$(0.20\ g)\ (2.8 \times 10^{7}\ rem/g)\ (8.72 \times 10^{-4}\ g/m^3)\ (3.3 \times 10^{-4}\ m^3/s) = 1.61\ rem$$

The offsite EDE is calculated to be 0.03 rem as follows.

$$(0.20\ g)\ (2.8 \times 10^{7}\ rem/g)\ (1.62 \times 10^{-5}\ g/m^3)\ (3.3 \times 10^{-4}\ m^3/s) = 0.03\ rem$$

Section 9.2.4.5 states that the smallest earthquake that will cause damage is the earthquake with a frequency of 1×10^{-3}/yr. This is consistent with the discussion above based on 2×10^{-3} (a more likely event). As a result, earthquakes of greater frequency than 2×10^{-3}/yr will not result in significant damage to the building or gloveboxes within the rest of the PFP.

Tables 9-32 through 9-36 summarize the results of the PFP seismic analyses, including the contributions from the 232-Z structure for both a 0.09-g (annual probability 2×10^{-3}) and a 0.20-g (annual probability 1×10^{-4}) seismic event.

9.2.4.6.3.11 Accident Analysis-Calculations, Criticality. Previous sections have shown how a criticality may be possible in the west gallery glovebox. A criticality in this area is assumed.

9.2.4.6.3.12 Accident Analysis-Calculations, Release Into Facility. See Section 9.2.4.6.4.

9.2.4.6.3.13 234-5Z and 236-Z Gloveboxes and Ducts. The seismic accident analyses in Section 9.2.4.6 have been modified from previously issued versions to account for gloveboxes standing or falling in accordance with their seismic qualification as given in Table 9-25.

9.2.4.6.4 Summary of Releases into Facilities. Section 9.2.4.6.3 presented accident analysis calculations that quantified the release of respirable plutonium into facilities. The specific subsections and associated facilities are as follows:

- Section 9.2.4.6.3.1: Building 234-5Z, excluding the release from the Laboratory Prototype Calciner which is addressed in Section 9.2.4.9 but is not authorized for operation. Also excludes the releases from the Magnesium Hydroxide Precipitation Process Gloveboxes, HC-230C-3 and HC-230C-4, and BTS glovebox, HA-53BTS.

These are discussed in Section 9.2.4.10 and 9.2.4.11 respectively.

- Section 9.2.4.6.3.2: Building 236-Z
- Section 9.2.4.6.3.3: Building 236-Z, Product handling
- Section 9.2.4.6.3.4: Vaults
- Section 9.2.4.6.3.5: Outside areas
- Section 9.2.4.6.3.6: 2736-Z complex
- Section 9.2.4.6.3.7: Building 242-Z
- Section 9.2.4.6.3.8: Building 241-Z
- Section 9.2.4.6.3.9: Building 291-Z
- Section 9.2.4.6.3.10: Building 232-Z

Table 9-31 summarizes the results of the analyses contained in the above listed sections. Table 9-31 shows the total release into the PFP facilities, as a result of a seismic event, excluding the Laboratory Prototype Calciner release which is discussed in Section 9.2.4.9 but is not authorized for operation. Therefore, seismic initiated releases from the calciner are not included in the total facility releases. Releases from the Magnesium Hydroxide Precipitation Process gloveboxes and BTS gloveboxes are discussed in Section 9.2.4.10 and 9.2.4.11.

9.2.4.7 Accident Analysis, Release Out of the Facility. In the previous section, the release of respirable Pu into the facility resulting from various accident scenarios was calculated. To perform dose consequence calculations, the release of Pu out of the facility must be determined. For Buildings 291-Z and 232-Z, the release out of the facility is assumed to be equal to the release into the facility (i.e., 0.01 g for 291-Z and 0.20 g for 232-Z). For buildings 234-5Z and 236-Z, the release out is determined in the following subsections for two cases. In the first case, it is assumed that the 234-5Z and 236-Z ventilation systems shut down. In the second case, it is assumed that the supply fans shut down, that the E-3 and E-4 HEPA filters fail (e.g., fallen from filter frames) and that the exhaust fans continue to run.

9.2.4.7.1 "No Ventilation" Case. In the event of a design basis earthquake, it is anticipated that the 234-5Z and 236-Z ventilation supply and exhaust systems will shut down due to a loss of normal electrical power. Redundant systems (one automatic, one manual) are in place to shut down the ventilation systems should normal electric power not be lost. Although diesel-generators are provided in Building 2721-Z to provide backup power to either exhaust fan EM-1 or EM-2 on loss of normal power, it is possible that the earthquake could cause failure of the backup power system. Hence, a "no ventilation" condition is possible in the 234-5Z and 236-Z Buildings during the design basis earthquake.

To estimate the release from the facility given loss of the ventilation systems, a model has been developed based on airflow into and out of 234-5Z through open doors. A detailed description of the model, which includes particle deposition, is presented in Appendix 9.C. The doors and frames respond as follows. The door frames are metal and all of the exterior doors (and airlocks) contain strong door closers. If the door is closed at the time of the earthquake, the base of the door frame will move with the floor as the floors in 236-Z Building and 234-5Z Building move parallel with the ground (vertical motion is very small per *Seismic (SSE) Evaluation for the 236Z*

Building at the Hanford Site (URS, 1987 and URS, 1988b). The top of the frame moves more than does the base. The movement is as large as three-fourths of an inch (234-5Z Building, ground floor, half of movement of the duct level floor with respect to the ground). The maximum in plane displacement of the top of the door is 3/4 in. with respect to the base of the door. The door frame will also tend to move out of plane. The maximum movement is 0.1 in. If the door is closed initially, the movement may cause it to buckle. A buckled door is assumed to be warped and contain "wrinkles." Doors with glass panels, in addition to buckling, will be damaged by the glass breaking. It may not be possible to open the door if it buckles. If it can be opened, it may close (if the buckling is in the top of the door such that the base clears the floor) or it may not close (if the buckling is in the bottom of the door such that the base digs into the floor). Airlock doors contain one door with a glass window. It is assumed that the doors with the windows will close again but that the glass has shattered. The 234-5Z doors are as follows:

Door number	Type[a]
103	A
828	E
105A	frequently blocked open
105	F
122	A
124A	A
124	F
123	A
125	F
126	A (it is not F)
720	B
129	F
113	F
131	A
133	A
135	F
135A	F
137	A
138	A
712	F
139	Like A but with small glass panels
101	glass door
107	A
128	A

[a] Type A doors are metal with no glass window and are 2 ft 6 in. wide by 7 ft tall. Type F doors are two Type A doors side by side. Type E doors are like Type A doors but with a 2-ft by 3-ft glass window. The Type A and F doors appear to be either hollow metal or metal shell with a filling.

The doors in Building 236-Z are similar to Type A doors. There are concrete blocks above the doors on the first, second, and fourth floors. The blocks cover an area of about 3 ft wide and 2 ft tall.

For Building 234-5Z, it will be assumed that half of the Type A and Type F doors buckle such that they close but have an opening of 1.75 ft^2 (10% of the door area) and half are opened but wedge in the open position. The open position is assumed to be half open so the flow area is 9 ft^2 (half of 17.5 ft^2 opening). Doors at 236-Z are assumed to fully close based on seismic qualification of the structures; thus, there is no contribution from 236-Z for the no-ventilation case.

It was found that the concrete walls which surround the RMA and RMC Lines will withstand the seismic forces but data does not exist on the other walls. It is assumed that they collapse so that the first floor of Building 234-5Z is basically open except for the vaults and the RMC/RMA Line areas. Vault doors are very thick and latch much more positively than room doors. Therefore, it is assumed that the vault doors suffer no damage.

Room 166 is a vault and room 227 has vault-like doors. The doors of room 227 are in the RMC concrete wall and will not see shearing motion. The bending is small (URS 1987) and people are not usually in this room. It is therefore assumed that the doors in room 227 do not fail. The doors in the RMC Line are similar and therefore will not fail either. Releases in rooms 166 and 227, RMC, RMA, and HA-23S will therefore remain in those rooms.

If the wind is from the south (blowing north) there are six doors through which the wind can blow. The wind will cause a flow through the building, but it will flow from the south side to the RMC Line concrete wall (Column 7 to Column 22), go around the concrete wall, and leave the building out the front. The flow area is 3 doors at 9 ft^2 and 3 doors at 1.75 ft^2 or 32 ft^2. Using the equations in Appendix 9.C, the flowrate for east-west flow is found to be 14,080 ft^3/min. The area of the flow is that from Columns 1 to 24 and A to G minus C to E and 7 to 22 (H-2-16138) or (138 x 440) minus (52 x 300) or 45,120 ft^2. The ceilings are 9 ft high, so the volume is 406,080 ft^3.

Using these data and applying the model from Appendix 9.C for a 5 mi/hr wind:

$$M_{out} = M_{bo} \exp\left[-\frac{14,080}{406,080} + \frac{vel\ (45,120)}{406,080}\right] t$$

or

$$M_{out} = M_{bo} \exp\ [-(0.035 + 0.111\ vel)t]$$

The total carried out of the building, M_{tot}, over time is:

$$M_{TOT} = \frac{A}{-b} = \frac{0.035\ M_{bo}}{0.035 + 0.111\ (vel)}$$

where: M_{out} = mass flowrate out of the building
M_b = mass of powder dispersed in the building at any time
vel = settling velocity
t = time

The quantity available on the first floor of Building 234-5Z (given that the release within the RMC Line and Room 166 is "protected") is from the analytical lab, plutonium process support lab and standards lab. The total release from these three labs is 1.87 g (1.08 g + 0.79 g = 1.87 g) (Section 9.2.4.6.3.1.A).

Using 2.2-mi/h wind rather than 5 mi/h gives a flow of 6,195 ft^3/min rather than 14,080 ft^3/min and

$$M_{TOT} = \frac{0.015\ M_{bo}}{0.015 + 0.111(vel)}$$

Using the data for deposition velocity

Particle size (μm)	%	M_{bo}	vel (ft/min)	M_{TOT} 5 mi/h	M_{TOT} 2.2 mi/h
0 - 2	12	0.22	0.024	0.20	0.19
2 - 3	21	0.39	0.15	0.26	0.18
3 - 5	67	1.25	0.38	0.57	0.33
		1.86*		1.03	0.70 g

* Difference from total release value of 1.87 due to rounding.

Since dose is a function of grams released divided by wind speed, the dose from the 2 mi/h wind is over 1.5 times greater than the dose from the 5 mi/h wind.

$$\frac{0.70\ g/2.2\ mi/h}{1.03\ g/5\ mi/h} = \frac{0.318}{0.206} = 1.54$$

Therefore, the release (0.70 g) due to the 2.2 mi/h wind is used in this analysis for conservatism.

Of the 1.87 g release into the facility from the three laboratories, 1.08 g (or 58%) is defined as <10% ^{240}Pu (Table 9-31). Therefore, of the associated 0.70 g released out of the facility due to the 2.2 mi/h wind, 0.41 g is <10% ^{240}Pu, and 0.29 g is >10% ^{240}Pu. It is noted that the 0.70 g released out of the facility is approximately 37% of the amount (1.87 g) released into the facility.

In the duct level, it is assumed one door is buckled and wedged. Therefore, it is assumed the door is half open. Since the flowrate for the 9 ft^2 flow area is 28% of that for the 32-ft^2 opening, the previous equation for M_{TOT} for the 2.2 mi/h wind is modified by the ratio of the opening (28%) as follows:

$$M_{TOT} = \frac{0.004\ M_{bo}}{0.004 + 0.111\ (vel)}$$

As shown in Table 9-31, the release into the duct level consists of 1.15 g from the E-4 ducting and 0.83 g from filterboxes 7A and 9A for a total of 1.98 g released into the duct level. In addition, 0.07 g is released from the filter rooms on the third floor, as shown in Table 9-31, for a total release into the facility of 2.05 g respirable plutonium. Using the equation for M_{TOT} the release out of the duct level and third floor is 0.35 g. All of the duct level and filter room material is defined as <10% ^{240}Pu. Accordingly, the releases from Building 234-5Z are as follows:

<10% ^{240}Pu, labs	0.41 g
<10% ^{240}Pu, duct level and 3rd floor filter rooms	0.35 g
>10% ^{240}Pu, labs	0.29 g
Total	1.05 g

The release shown above from Building 234-5Z does not include seismically induced releases from the Laboratory Prototype Calciner in Room 188 of the PPSL. The releases related to the laboratory calciner are discussed in Section 9.2.4.9 but are not included in the facility releases since the calciner is not authorized for operation.

9.2.4.7.2 "Ventilation" Case. Although redundant systems are in place to shut down the electric supply fans, the electric-driven exhaust fans could continue to operate due to failure of software interlocks which are not specifically designed to withstand a DBE. If the exhaust fans are shut down as intended, standby power could be provided by diesel-generators located in Building 2721-Z to operate either exhaust fan EM-1 or EM-2 provided the exhaust fans, diesel-generators and control system survive the DBE. For this analysis, it is conservatively assumed that all of the exhaust fans are running (the supply fans have been shut down by the automatic shutdown switch). It is further assumed that the exhaust flow is 228,000 ft^3/min (Section 9.1.7A).

Then:

$$M_{out} = M_{bo} \exp\left[-\left(\frac{228{,}000}{2.19 \times 10^6} + \frac{vel\ (1.46 \times 10^5)}{2.19 \times 10^6}\right) t\right]$$

$$= M_{bo} \exp [-(0.10 + 0.067 \text{ vel})t]$$

Where 2.19×10^6 is the approximate volume of the Zone 3 areas of Buildings 234-5Z, 236-Z, and 242-Z (i.e., 728,640 times 3) and 1.46×10^5 is the area of the floors of those zones. The term "vel" is based on particles with a density of 4 g/cc. As in the "no ventilation" case,

$$M_{TOT} = \frac{0.10\ M_{bo}}{0.10 + 0.067\ (vel)}$$

The plutonium released into Buildings 234-5Z and 236-Z is 15.25 g respirable plutonium as shown in Table 9-31. All of this is available for release. It is assumed that the size distribution is the same as for the case of wind blowing through the facility.

Particle size (μm)	Percent	M_{bo}	vel (ft/min)	M_{TOT} electric exhaust fans
0 - 2	12	1.83	0.024	1.80
2 - 3	21	3.20	0.15	2.91
3 - 5	67	10.22	0.38	8.15
		15.25		12.86

The release from Buildings 234-5Z and 236-Z is 12.86 g. Therefore, approximately sixteen percent of the release settled out within the buildings due to gravity and 84% is released from the buildings.

Of the 15.25 g released into Buildings 234-5Z and 236-Z, 3.13 g (or 20.5%) is defined as <10% ^{240}Pu (Table 9-31). Therefore, of the associated 12.86 g released out of these buildings, 2.64 g is <10% ^{240}Pu, and 10.19 g is >10% ^{240}Pu.

The release of 12.86 g respirable from Buildings 234-5Z and 236-Z is extremely conservative because:

- It assumes that the entire E-3 duct system is intact but the filters in the filter rooms and filterboxes have fallen to the floor or are failed for some other reason
- No credit is taken for loss to impaction in duct at the bends or on the walls due to turbulence
- The air flow patterns with no supply fan flow and some internal damage is assumed to be exactly the same as that during normal operation

- No credit is taken for agglomeration either at the point of release or inside the ducts.

The releases discussed above from Buildings 234-5Z and 236-Z exclude the Laboratory Prototype Calciner in Room 188 of the PPSL in Building 234-5Z. The releases related to the laboratory calciner are discussed in Section 9.2.4.9 but are not included in the facility releases since the calciner is not authorized for operation.

9.2.4.8 Dose Calculations.

9.2.4.8.1 "No Ventilation" Case. The radiological consequences for the "no ventilation" case are based on:

a) a release of 0.76 g <10% ^{240}Pu, lung clearance Class Y, from labs, duct level and filter rooms in Building 234-5Z (See Section 9.2.4.7.1)

b) a release of 0.29 g >10% ^{240}Pu, lung clearance Class Y, from labs in Building 234-5Z (See Section 9.2.4.7.1)

c) a release of 0.10 g >10% ^{240}Pu, lung clearance Class W, from Building 241-Z (See Table 9-31)

d) a release of 0.01 g <10% ^{240}Pu, lung clearance Class Y, from Building 291-Z (See Table 9-31)

e) a release of 0.20 g <10% ^{240}Pu, lung clearance Class Y, from Building 232-Z (See Table 9-31)

f) a release of 0.42 g >10% ^{240}Pu, lung clearance Class Y, from Building 234-5Z (based on a release of 2.29 g into the rooms in the RMC/RMA Line area from the seismically initiated fire, 50% of that release escaping into other portions of the facility and 37% of that amount being released out of the facility - See Section 9.2.4.2.12.F)

g) the mass weighted average unit inhalation doses presented in Tables 9-46 and 9-47

h) atmospheric dispersion coefficients for a ground level release with building wake and plume meander (Tables 9-39 and 9-40) applied to releases (Tables 9-39 and 9-40) from Buildings 234-5Z and 291-Z

i) atmospheric dispersion coefficients for a ground level release without building wake and plume meander (Tables 9-39 and 9-40 values for release from Building 232-Z and point source ground level, respectively) applied to the release from Buildings 232-Z and 241-Z.

The resulting doses to the onsite and offsite maximally exposed individuals are shown in Table 9-32. These doses meet the Risk Acceptance Guidelines summarized in Table 9-49 for an event with a frequency of 1×10^{-4}/yr which is the estimated frequency of the Design Basis Seismic Event. The doses shown in Table 9-32 exclude the Laboratory Prototype

Calciner in Room 188 of the PPSL. The seismically initiated doses related to the laboratory calciner are discussed in Section 9.2.4.9 but are not included in the facility totals since the calciner is not authorized for operation.

9.2.4.8.2 "Ventilation" Case. The radiological consequences for the "ventilation" case are based on:

a) a release of 2.64 g <10% ^{240}Pu, lung clearance Class Y, from Building 234-5Z (See Section 9.2.4.7.2)

b) a release of 10.19 g >10% ^{240}Pu from Buildings 234-5Z and 236-Z; total includes 1.29 g from nitrate solutions (84% released from facility of the 1.54 g of solutions released into facility from Table 9-31), lung clearance Class W and 8.90 g powder, lung clearance Class Y.

c) a release of 0.10 g >10% ^{240}Pu, lung clearnace Class W, from Building 241-Z (See Table 9-31)

d) a release of 0.01 g <10% ^{240}Pu, lung clearance Class Y, from Building 291-Z

e) a release of 0.20 g <10% ^{240}Pu, lung clearance Class Y, from Building 232-Z

f) a release of 1.92 g >10% ^{240}Pu, lung clearance Class Y, from Building 234-5Z (based on 84% release from facility of 2.29 g released into facility from the RMC/RMA Line seismically initiated fire - See Section 9.2.4.2.12.F).

g) the mass weighted average unit inhalation doses presented in Tables 9-46 and 9-47. Class Y lung retention is assumed for the majority of the release that comes from PuF_4 or PuO_2 powders. Class W lung retention is assumed for the small fraction of the release that originates from $Pu(NO_3)_4$ solutions.

h) atmospheric dispersion coefficients for an elevated release applied to releases from Buildings 234-5Z, 236-Z, and 291-Z

i) atmospheric dispersion coefficients for a ground level release without building wake and plume meander (Tables 9-39 and 9-40) applied to the release from Buildings 232-Z and 241-Z.

The resulting doses to the onsite and offsite maximally exposed individuals are shown in Table 9-33. These doses meet the Risk Acceptance Guidelines summarized in Table 9-49 for an event with a frequency of 1×10^{-4}/yr, which is the estimated frequency of the Design Basis Seismic Event. The doses shown in Table 9-33 exclude the Laboratory Prototype Calciner in Room 188 of the PPSL. The seismically initiated doses related to the laboratory calciner are discussed in Section 9.2.4.9 but are not included in the facility totals since the calciner is not authorized for operation.

9.2.4.9 Analysis of Seismically Initiated Releases and Consequences from the Laboratory Prototype Calciner. This section summarizes the doses from the

seismic analysis of the Laboratory Prototype Calciner in Room 188 of the PPSL. The determination of worst case accident scenario (seismic event with concurrent fire) over other scenarios and details of release calculations and dose calculations are found in the Laboratory Prototype Calciner addendum. Since the calciner is not authorized for operation, the seismically initiated doses are not included in the facility totals for a seismic event.

The doses related to the seismic effects on the Laboratory Prototype Calciner are shown in Tables H-1 to H-8 in the Laboratory Prototype Calciner addendum to this FSAR. Table H-5 presents the maximum total dose consequence for the Laboratory Prototype Calciner in the "no ventilation" case. The maximum total dose consequence values from Table H-5 are as follows:

Onsite		Offsite	
EDE	23.62 rem	EDE	0.50 rem
Organ	282 rem	Organ	6.02 rem

Table H-7 presents the maximum total dose consequence for the Laboratory Prototype Calciner in the "ventilation" case. The maximum total dose consequence values from Table H-7 are as follows:

Onsite		Offsite	
EDE	1.78 rem	EDE	0.63 rem
Organ	21.36 rem	Organ	7.55 rem

The consequences from the Laboratory Prototype Calciner due to a seismic event are not included in the seismic event summary tables, Table 9-32, 9-33, and 9-34, since the calciner is not authorized for operation. The consequences will be reevaluated and included, as appropriate, prior to any future authorization for operation.

9.2.4.10 Contribution to the Seismic Analysis from Operation of the Magnesium Hydroxide Precipitation Process.

The Magnesium Hydroxide Precipitation Process addendum to this FSAR (Carson 2000) describes the operations and equipment involved in the Magnesium Hydroxide process and the potential accidents postulated for that process. Section 3.4.2.4 of the addendum provides the analysis of the seismic event.

The gloveboxes containing equipment necessary for the Magnesium Hydroxide process are seismically qualified. However, seismically induced releases into the facility can still occur. The seismically induced release scenarios are shown below. In each case, the release into the facility is obtained by multiplying the inventory times the appropriate airborne release fraction (ARF) and respirable fraction (RF) both obtained from the DOE handbook on airborne release fractions (DOE 1994). The resultant release values are as follows:

- Release of precipitate due to vibration – 0.093 g

- Release due to falling precipitate – 0.0022 g
- Release due to falling Pu nitrate solution – 0.008 g
- Release due to boiling nitrate solutions – 0.049 g
- Entrainment of Pu during boiling – 0.015 g

The total release into the facility is 0.167 g. The release out of the facility is 84% of the release into the facility which are results in a release to the environment of 0.14 g.

The consequences of the release are obtained using the methodology of Section 9.2.4.7. The plutonium in the release is assumed to contain >10% ^{240}Pu, lung clearance Class W. The results are as follows:

No Ventilation case -

No release outside the facility per Section 9.2.4.7.

Ventilation case -

Onsite EDE:	0.15 rem
Onsite Organ:	2.7 rem
Offsite EDE:	0.05 rem
Offsite Organ:	0.96 rem

9.2.4.11 Contribution to the Seismic Analysis from Operation of the Bagless Transfer System Glovebox.

The calculation notes for the Bagless Transfer System (BTS)(FH 2000) describe the BTS Glovebox process, equipment and postulated releases as a result of accidents. Section 4.3 of the calculation notes provides the releases as a result of accidents including those resulting from a seismic event.

Section 4.3.1 of the calculation notes (FH 2000) shows that the BTS glovebox is not seismically qualified. The release into the facility is based on the ARF and RF from the DOE handbook on released fractions (DOE 1994) for falling powders. The respirable release into the facility from the glovebox is 0.75 g. Of this amount, 84% is released from the facility which results in a release to the environment of 0.63 g.

The consequences are determined using the methodology developed in Section 9.4.3.4. The plutonium accompanying the release is assumed to contain >10% ^{240}Pu, lung clearance, Class Y. The results are as follows:

No Ventilation case -

No release outside the facility per Section1.2.4.7.

Ventilation case -

Onsite EDE:	0.57 rem
Onsite Organ:	9.1 rem
Offsite EDE:	0.20 rem
Offsite Organ:	3.22 rem

9.2.4.12 Total Facility Seismic Dose Consequence. This section presents the summation of the doses to the onsite and offsite receptors from a seismic event from Sections 9.2.4.8 (bulk of the facility), 9.2.4.10 (Magnesium Hydroxide Precipitation Process) and 9.2.4.11 (BTS).

9.2.4.12.1 "No Ventilation" Case. The radiological consequences for the "no ventilation" case for the total facility involves summing the consequences from 9.2.4.8.1 and from 9.2.4.10 and 9.2.4.11. The resulting doses to the onsite and offsite maximally exposed individuals are shown in Table 9-32. It is noted that the Magnesium Hydroxide Precipitation Process gloveboxes and BTS glovebox do not contribute to the seismic doses for the "no ventilation" case since the gloveboxes are located within the RMC and RMA Lines which confine the material inside the facility when the ventilation exhaust system is not operating.

9.2.4.12.2 "Ventilation" Case. The radiological consequences for the "ventilation" case for the total facility involves summing the consequences from 9.2.4.8.2 and from 9.2.4.10 and 9.2.4.11. The resulting doses to the onsite and offsite maximally exposed individuals are shown in Table 9-33.

9.2.5 Strong Wind

The primary buildings and some of the auxiliary buildings of the PFP were analyzed for potential damage by the design-basis, 90-mi/h wind delineated in SDC-4.1 (WHC 1991a). SDC-4.1 indicates that a 90-mi/h steady wind is to be considered for the Hanford Site rather than a tornado.

The 234-5Z and 236-Z Buildings and the 291-Z-1 stack were analyzed in *Extreme Wind Analysis PFP Structures 236-Z, 291-Z, 234-5Z*, WHC-SD-CP-DA-023, (Giller 1989c), and found to be capable of withstanding both the wind forces and the standard missile assumed to be associated with the wind. Buildings 242-Z, 291-Z, 2736-Z, 2736-ZB and the 291-Z/234-5Z stack manifold were also shown to withstand both wind and missile forces (Giller 1990). The building sheltering the 241-Z cover blocks and below-grade tanks would not withstand the wind, but no damage is expected to the tanks due to the presence of the heavy concrete cover blocks. The anhydrous HF building, 2734-ZL, is vulnerable to missile strikes but no longer contains any hazardous materials. The gas-bottle storage bay, 2734-Z (see Figure 9-5), offers little or no protection from strong wind-related hazards, but the stored gas bottles are equipped with the normal protective caps designed to withstand transportation accidents at highway speeds. Most of the remaining outside structures at the PFP either do not contain hazardous materials or store small amounts of common chemicals (i.e., a number of 1-gal cans of primer, acrylic lacquer, paint, etc.) are located in NFPA fire cabinets in 2715-ZL. The outside holding

tanks, 2735-Z, used to be exceptions. One tank used to hold HNO_3 and the other tank used to hold ANN. The contents of these tanks have been removed from the Hanford Site. Nitric acid is now supplied in 55-gal drums. The analysis of a storage tank rupture is retained as a bounding strong-wind event.

The HNO_3 and ANN storage tanks, designated as 2735-Z, are 7,000-gal tanks and are located in a retention basin that is deep enough to contain a 14,000-gal spill. A spill from 2735-Z would be contained in the retention basin. ANN is a hydrated aluminum salt solution with a very low vapor pressure. While a small amount could be aerosolized due to the dynamics of a spill and the strong wind, the solution water would preferentially evaporate leaving hydrated aluminum nitrate salt crystals. Therefore, an ANN spill should be bounded by the HNO_3 spill and will not be analyzed. As a result, only HNO_3 will be discussed further.

9.2.5.1 HNO_3 Storage Tank Rupture.

The acid has been removed; however, this accident analysis has been retained for future considerations (e.g., Decontamination & Decommissioning).

9.2.5.1.1 Scenario. The postulated event for the handling accident consists of a strong, steady-90 mi/h wind that propels a 15-lb., 2-in. by 4-in. plank at 50 mi/h. The missile breaches the transfer piping at the bottom of the HNO_3 storage tank in the 2735-Z area. The analysis conservatively assumes that the HNO_3 storage tank contains the maximum 7,000 gal and the entire contents of the tank are released through a break in the 1-in.-dia transfer pipe (see Drawing H-2-77854) at the base of the tank. As the solution exits the tank, 10% is assumed to aerosolize due to the dynamics of the spill and aerodynamic entrainment by the 90-mi/h wind. As the remaining HNO_3 solution fills the retention basin, it begins to evaporate, and the vapor is dispersed by the strong wind.

9.2.5.1.2 Mitigation. The most likely failure mode for the tank is through a puncture by the wind-generated missile. Thus, mitigation of the event is best achieved by good housekeeping of the outdoor areas of the PFP.

9.2.5.1.3 Recovery. Little could be done for recovery until the strong wind subsided. The bulk of the release is due to the aerosolization of 10% of the tank contents. In addition, a relatively small amount of the HNO_3 in the retention basin would have evaporated and been dispersed by the time the wind subsided. Once the spill was detected, day shift operations would initiate cleanup procedures.

9.2.5.1.4 Probability. The HNO_3 storage tank is protected to the north and west by the 234-5Z Building. A myriad of pipes, tanks, ladders, walkways, etc. shelter the south side of the basin. The only clear paths for a missile strike are from the east or from above. A missile approaching from the east could only compromise the tank integrity by penetrating the tank shell. Ultrasound measurements (Sequin 1987) verify that the minimum tank wall thickness is 0.14 in., which is sufficient to withstand a strike from a 15-lb., 2-in. by 4-in. plank travelling at 50 mi/h (WHC 1989b). The 1-in.-dia pipe and associated valve used to transfer HNO_3 solution from the storage tank are located on the west side of the tank near the bottom of the basin. No

analysis exists to show that the valve and transfer piping can withstand a missile strike, so they will be considered vulnerable to failure during a strong wind. A missile would, however, have to strike the tank from above or pass through the obstructions south of the tank to strike the valve and piping. When the barriers around the tank are considered together with the annual frequency of a strong wind, a large HNO_3 spill is likely an incredible event. Rather than quantify the above argument, however, a bounding analysis will be presented in the following sections that demonstrates that a total release of the HNO_3 tank contents is within the Toxicological Risk Acceptance Guidelines for both onsite and offsite individuals, even for events with an annual probability of 10^{-2}.

9.2.5.1.5 Accident Analysis.

9.2.5.1.5.1 Assumptions. It is conservatively assumed that the tank contains the maximum 7,000 gal of 57% HNO_3 solution and that the tank is breached at the transfer pipe near the bottom of the tank. The temperature of the surrounding air is assumed to be 40 °C, corresponding to a very warm day for the Hanford Site. Since the wind speed is very high and the boundary layer above the pool is turbulent, any difference between the air temperature and the pool temperature should equilibrate quickly. Thus, the temperature of the liquid HNO_3 is also assumed to be 40 °C (104 °F). The effects of evaporative cooling will act to lower the pool temperature and are conservatively neglected. As will be verified in the conclusions of the following analysis, the effects of solar radiation and conduction from the ground when the surface temperature is higher than the air temperature are small, so these heat transfer modes will also be neglected.

Data on aerodynamic entrainment due to strong winds are scarce so the magnitude of this effect is difficult to quantify. DOE(1994), Section 3.2.4.1 discusses data from aerosolization measurements over large outdoor bodies of water. Data are provided for wind speeds up to 15 m/s. The data suggest that as the wind speed is doubled, the entrainment rate increases by an order of magnitude. Extrapolating the 15 m/s data to 40 m/s (90 mi/h) implies that, for a pool the size of the retention basin, aerodynamic entrainment suspends approximately 0.01% of the spilled liquid. Thus, 1% is likely a bounding estimate of the aerosolization rate. To ensure a bounding analysis, however, another order of magnitude is included and the aerosolization rate is assumed to be 10%. Thus, as the tank drains, 10% of the effluent is assumed to aerosolize due to the dynamics of the spill and the strong wind. The remainder of the tank contents is released into the retention basin.

9.2.5.1.5.2 Release Rate. The source term consists of two parts; the 10% of the tank contents that is immediately aerosolized as it leaves the tank, and the evaporation of the remaining 90% of the solution.

The storage tank is 14 ft high and 10 ft in diameter. Using Torricelli's formula, the discharge velocity out of the pipe is:

$$V \approx (2gh)^{\frac{1}{2}}$$

where V is velocity, g is the acceleration of gravity, and h is the height of liquid. Applying conservation of mass to the liquid in the tank,

$$\frac{dh}{dt}A_1 = -VA_2$$

where A_1 is the cross-sectional area of the tank and A_2 is the cross-sectional area of the pipe. Solving the above simultaneous equations for h as a function of time, and using the initial condition that the tank is full (h = 14 ft and t = 0),

$$h = \left[(14')^{\frac{1}{2}} - \frac{A_2}{2A_1}(2g)^{\frac{1}{2}}t\right]^2$$

Setting h = 0, the time to drain the tank is:

$$t = \frac{2(14\ \text{ft})^{\frac{1}{2}}(A_1)}{(2g)^{\frac{1}{2}}A_2}$$

$$= \frac{2(14\ \text{ft})^{\frac{1}{2}}(10\ \text{ft})^2}{\left[(2)\left(32.17\frac{\text{ft}}{\text{s}^2}\right)\right]^{\frac{1}{2}}\left(\frac{1}{12}\ \text{ft}\right)^2}$$

$$= 13400\ \text{s}$$

The maximum mass flow rate of HNO_3 vapor occurs at t = 0. The flow rate drops as t increases until at t = 13400 s the flow of liquid stops. Using the fact that 57 wt% HNO_3 solution has a density of 1,235 kg/m^3, the peak mass flow rate of HNO_3 solution is:

$$\dot{Q} = \rho V_o A_2$$

$$= \left(1235\frac{\text{kg}}{\text{m}^3}\right)\left[(2)\left(32.17\frac{\text{ft}}{\text{s}^2}\right)(14\ \text{ft})\right]^{\frac{1}{2}}\left(\frac{\pi}{4}\right)\left(\frac{1}{12}\ \text{ft}\right)^2\left(0.3048\frac{\text{m}}{\text{ft}}\right)^3$$

$$= 5.725\frac{\text{kg}}{\text{s}}$$

Per the above assumption regarding the aerosolization rate, 10% of the flow out of the tank is immediately aerosolized. Of this aerosol only 57% is HNO_3, so the peak flow rate of HNO_3 vapor to the environment is 0.3263 kg/m_3.

The HNO_3 solution that is not aerosolized is retained in an irregularly shaped basin that has an area of 976 ft^2 (90.7 m^2) (see Drawing H-2-77439). The evaporation rate is calculated using the method described by *A Simple Formula for Estimating Source Strengths from Spills of Toxic Liquids*, ESL-TR-83-03 (Clewell 1983). This method uses the following empirical formula:

$$\dot{Q} = 0.08u^{0.75}AZ[1 + [4.3\times10^{-3}T_p^{\,2}]]$$

where: $\dot{Q}$ = Evaporation rate, kg/hr
u = Wind speed, m/s
A = Spill area, m^2
Z = Volatility factor
T_p = Temperature of liquid, °C

Note that the above equation is empirical and not dimensionally consistent. For the accident considered here:

u = 40.2 m/s (90 mi/h), $\dot{Q}$ is conservatively maximized by using the strong wind for the entire evaporation time, rather than assuming the 90-mi/h wind was a gust and using some lower average wind speed

A = 90.7 m^2 (976 ft^2)

T_p = 40 °C (104 °F), the pool temperature is assumed to be equal to the air temperature

Z is the volatility factor of HNO_3 in relation to hydrazine and is calculated using:

$$Z = \frac{P_{vb}M_b}{P_{vh}M_h}$$

where: P_{vb} = 3.1 mm Hg, partial pressure of HNO_3 at 40 °C
P_{vh} = 34.7 mm Hg, partial pressure of hydrazine at 40 °C
M_b = 63 g/gmole, molecular weight of HNO_3
M_h = 32 g/gmole, molecular weight of hydrazine.

Thus,

$$Z = \frac{(3.1 \text{ mm Hg})\left(63 \frac{g}{gmole}\right)}{(34.7 \text{ mm Hg})\left(32 \frac{g}{gmole}\right)} = 0.18$$

Finally, a conservative value for the evaporation rate is given by:

$$\dot{Q} = 0.08(40.2)^{0.75}(90.7)(0.18)[1 + [4.3\times10^{-3}(40°C)^2]]$$

$$= 164 \frac{kg}{hr}$$

$$= 0.046 \frac{kg}{s}$$

The preceding calculation neglected the effects of solar radiation, ground conduction, and evaporative cooling. The neglect of evaporative cooling is clearly conservative. Approximating the thermal conductivity and heat capacity of the pool of 57% HNO_3 with water properties, conservatively using the maximum solar radiation flux on the 45th parallel of 1,070 W/m^2 (NRC 1991, Table 2.1), and assuming the ground temperature is 20 °C higher than the air temperature, the HNO_3 pool temperature would increase by only 2 °C/h. This temperature difference would then drive convective heat transfer from the pool to the air, which, given the presence of the strong wind, would easily remove enough heat to keep the pool at the air temperature.

The mass-release rate due to aerosolization should not be affected by the evaporation of the pool in the retention basin. The evaporation rate is a function of the pool surface area, so during the initial stages of the spill, the evaporation rate will be lower than calculated above, since the pool takes some time to spread over the entire retention basin. The peak mass flow rate from the combined release processes is calculated by assuming that the evaporation contribution has reached its steady state level and adding the peak (t = 0) aerosolization release rate. Thus, the peak mass release rate is 0.372 kg/s.

9.2.5.1.6 Dispersion Calculation. The mass release rate of HNO_3 to the atmosphere was maximized by using the peak aerosolization rate and basing the evaporation rate from the pool of HNO_3 in the retention basin on a constant 90-mi/h wind. Since the 90-mi/h wind is likely to be a gust rather than a steady wind, and the HNO_3 release will occur for at least several hours, the average wind-speed of the highest wind speed bin in the meteorological joint frequency database (19 m/s) is used to calculate the dispersion. This conservatively reduces the effectiveness of the atmospheric dispersion.

The density of HNO_3 vapor is roughly twice the density of air, so dense gas effects may be important in the dispersion calculation. This is determined by calculating the Richardson number for a continuous release.

$$Ri_o = \frac{g(\rho_{rel} - \rho_a)\dot{V}}{\rho_a u^3 d}$$

where: g = acceleration of gravity, $9.81 \frac{m}{s^2}$

ρ_{rel} = density of the released vapor, $\frac{kg}{m^3}$

ρ_a = density of the ambient air, $\frac{kg}{m^3}$

$\dot{V}$ = volumetric release rate of vapor (Q/ρ_{rel}), $\frac{m^3}{s}$

u = wind speed, 19 $\frac{m}{s}$

d = initial length scale of release (i.e. diameter of the pool), 10.7 m

Using the perfect gas law, the density (at 40 °C) of the released HNO_3 vapor can be calculated as 2.454 kg/m^3. Using this density and the previously calculated mass flow rate due to evaporation, along with the density of air at 40 °C, the Richardson number is calculated as

$$Ri_o = \frac{9.81(2.454 - 1.225).152}{(1.225)(19^3)(10.7)} = 2.0 \times 10^{-5}$$

Since the Richardson number is quite small (<0.003), the HNO_3 vapor is considered a passive tracer and the normal Gaussian dispersion model is appropriate.

Since the meteorological joint frequency data is not applicable for extremely rare conditions such as a 90 mi/h wind, a simple straight-line Gaussian dispersion calculation was performed using conservative, very stable (Stability Class F) atmospheric conditions. The downwind concentration for a ground level release is given by

$$C = \frac{\dot{Q}}{\pi u \sigma_y \sigma_z}$$

where: $\dot{Q}$ = evaporation rate, kg/s
u = wind speed, m/s
σ_y = horizontal dispersion coefficient, m
σ_z = vertical dispersion coefficient, m

The dispersion coefficients are functions of distance and stability class. As shown in Section 9.3, the nearest onsite receptor is located at 272-WA, 550 m west north-west of 234-5Z and the nearest offsite receptor is located 12.5 km west of 234-5Z. Conservatively neglecting building wake effects and using the methodology described in DOE-TIC-11223 (Hanna et al. 1982) the dispersion coefficients are calculated below:

$$\sigma_y = \sigma_a x f(x)$$

where: x = downwind distance, m

σ_a = standard deviation of horizontal wind fluctuations in radians,

$$\sigma_a = (30.0^\circ - 2.5^\circ N_s)\left(\frac{2\pi}{360^\circ}\right)$$

N_s = 11, Class F wind stability (Hanna et al. 1982)

$$f(x) = \frac{1}{1 + 0.031(x)^{0.46}} \quad \text{for } x \le 10 \text{ km}$$

$$= 0.33\left[\frac{10000}{x}\right]^{0.5} \quad \text{for } x > 10 \text{ km}$$

Thus, the horizontal dispersion coefficient for the nearest onsite receptor is

$$\sigma_y = 550(30.0^\circ - (2.5^\circ)(11))\left(\frac{2\pi}{360^\circ}\right)\left[\frac{1}{1 + 0.031(550)^{0.46}}\right] = 15 \text{ m}$$

Using the distance to the nearest offsite receptor, the horizontal dispersion coefficient is σ_y = 162 m.

For class F stability, the vertical dispersion coefficient is given by

$$\sigma_z = \frac{0.02x}{(1 + 3.0\times10^{-4}x)}$$

where x is in meters. Thus, the vertical dispersion coefficient for the nearest onsite receptor is σ_z = 9.4 m and for the nearest offsite receptor is σ_z = 53 m.

Finally, using the Gaussian dispersion equation from the beginning of this section, the peak concentrations of HNO_3 experienced by the nearest onsite and nearest offsite individuals are 4.4×10^{-5} kg/m^3 and 7.3×10^{-7} kg/m^3, respectively.

9.2.5.1.7 Consequences. The severity of the release is determined by comparing the calculated HNO_3 concentrations to the Toxicological Risk Acceptance Guidelines in Table 9-53. The guidelines specify Emergency Response Planning Guideline (ERPG) values at various frequencies. By definition, ERPG values are 1-h averages. For added conservatism, however, the calculated peak concentrations will be compared to the guidelines rather than 1 hour average concentrations. In addition, the concentrations calculated above must be converted to ppm for comparison to the Toxicological Risk Acceptance Guidelines. The conversion formula is taken from *Guidelines for Process Equipment Reliability Data with Data Tables*, p.93 (AICHE 1989).

$$C_{ppm} = C\frac{RT_a}{PM_0}\times10^6$$

where: R = 0.082 atm-m^3/K/kgmole, gas constant
P = 1 atm, ambient pressure
M_0 = 63 kg/kgmole, molecular weight
T_a = 313 K (= 40 °C), ambient temperature

Thus, the onsite individual is exposed to

$$C_{ppm} = 4.4\times10^{-6}\frac{kg}{m^3}\frac{\left(0.082\frac{atm\text{-}m^3}{K\text{-}kgmole}\right)(313\ K)}{(1\ atm)\left(63\frac{kg}{kgmole}\right)}\times10^6 = 18\ ppm$$

Similarly, for the offsite individual,

$$C_{ppm} = 7.2\times10^{-7}\frac{kg}{m^3}\frac{\left(0.082\frac{atm\text{-}m^3}{K\text{-}kgmole}\right)(313\ K)}{(1\ atm)\left(63\frac{kg}{kgmole}\right)}\times10^{6} = 0.29\ ppm$$

The onsite concentration is below the Toxicological Risk Acceptance Guidelines, shown in Table 9-53, for an event with the strong-wind annual frequency of 10^{-2}. Even with the numerous conservatisms in the above analysis, the maximum concentration that the offsite receptor is subject to is well below the guidelines even for an event with an annual frequency 1.

9.2.6 Flood

Flood is categorized in two ways: internal and external, neither of which pose significant risk.

9.2.6.1 External Flood. External flood is addressed in Chapter 3.0. Flood from rivers or streams is shown clearly to be of very low probability due to the plant's location on the 200 Area plateau and above the depression to the east of the plant. The probability of localized flood due to heavy precipitation has not been formally evaluated. The design basis rainfall is 11 in. during a 24-h period, with an annual probability of 1×10^{-6} (Section 3.4.2.3). This is in contrast to the maximum 24-h rainfall for the area (recorded in the period 1912 to 1980) of 1.91 in. during October 1957, and the annual average for the same period of 6.3 in. (Stone et al. 1983, p. iv). Without a formal study of the surface hydrology it is not possible to state definitely that an 11-in. rainfall would drain away from the facility. Informal inspection indicates that there is drainage to the east, along the roads on the north, and south of the 234-5Z Building (Figure 9-5). The landscape around the PFP is gently sloped, and drainage paths are not readily evident.

A rain of such unusual intensity would not go unnoticed. Below grade portions of facilities would receive flood prevention attention. The consequences would be similar to those of internal flood discussed below.

9.2.6.2 Internal Flood. The three below-grade locations sensitive to problems of internal flood are the pipe tunnels under the 234-5Z Building, the 241-Z vaults, and 291-Z. In addition, gloveboxes in the various facilities have the potential of flood from within, by process chemicals or water lines, and externally from fire-fighting activities.

The pipe tunnels under the 234-5Z Building contain no equipment sensitive to water, other than 110-V lights and outlets. The primary equipment consists of the stainless steel drain pipes.

The vaults under the 241-Z Building contain the six, 5,000-gal "D" tanks. Flooding a vault with an empty or partially empty tank can cause the tank to

float, and in the process rip pipes loose. Each vault contains a sump equipped with a liquid level detection and alarm system that annunciates in the 241-ZA Sample Building.

Flooding of 291-Z could ultimately result in loss of exhaust ventilation and the various vacuum systems. The effect of exhaust system loss is detailed in Section 9.1.8.

The most sensitive portion of the 291-Z Facility to flood is the electrical equipment room containing transformers, breakers, and switch gear. The room is equipped with a water deluge system for fire suppression. Should a clean break of a water line occur, there is not enough capacity in the two sump pumps to handle more than approximately 10% to 20% of the flow (Teal 1990). Loss of the electrical supply to the facility would be noted in the power control room located on the third level of the 234-5Z Building. Automatic shutdown of the supply system would occur to prevent pressurization of the buildings (see Section 9.1.7). Failure of the electrical system would occur at a lower water level than that which would effect the instrumentation lines. Any activation of the deluge system would be detected by the supervision system that sends a signal to the 200 Area Fire Station. The HFD would respond and shut off the water. Lesser leaks could probably be handled by the sump pumps. In addition, the leaks would take a considerable time to fill the facility. The 291-Z Facility is inspected hourly by the Hanford Patrol and at least once per shift by a Power Operator. They would notify the responsible manager, who in turn would have the water turned off.

9.2.6.3 Glovebox Flood. Glovebox flood could result from process line breaks or fire fighting activities. In order to prevent such floods, gloveboxes containing process liquid lines are generally equipped with sumps, sump alarms, and some system to remove the liquid. All "wet" gloveboxes (for solution handling or where liquids are piped in) are equipped with criticality drains to prevent accumulation of more than approximately 2 in. of liquid. These drains are equipped with coarse, large-area screens to prevent them from plugging. In addition, the outside portion of the drain system is equipped with guards to protect the mechanism from damage.

Glovebox flood is considered as one of the contingencies in criticality-control documentation.

9.2.7 Aircraft Accident

Airspace above the Hanford Site is used by many types of aircraft, typically on a limited basis. Currently, the Hanford Site airspace is used by commercial air carriers, air taxis, general aviation, military aviation, contracted pesticide and herbicide aerial applicator aircraft, and Hanford Site bioscience surveillance aircraft. Commercial aircraft are considered the most credible threat to the PFP on the basis that commercial aircraft are the largest craft to routinely overfly the site. These aircraft are analyzed in Section 9.2.7.1.

In addition to commercial and military air traffic, helicopter overflights of the Hanford Site have been performed for the purposes of gathering radiological survey data. These flights, which differ from those

described above since the helicopter intentionally flies at low altitudes and in relatively close proximity to nuclear facilities, are analyzed in Section 9.2.7.2.

9.2.7.1 Commercial Aircraft and Contract Aerial Applicator Operations. The cumulative probability of an aircraft accident involving the PFP has been determined to be incredible (less than 10^{-6}, or 1.28×10^{-8}).

9.2.7.1.1 Airport and Airways in Hanford Vicinity. There are no public, military, or high-volume airports within 20 mi of the PFP, and no federal airways pass directly over the PFP. There are several low-altitude federal airways and one military training route that either cross above or just at the margin of the Hanford Site, all of which are only lightly used. Airways in the vicinity of the PFP are federal low-altitude airway V187, 6.5 statute miles (smi) northeast; federal low-altitude airway V497, 6.5 smi northwest; federal low-altitude airway V204, 10.5 smi south; and military training route VR1350, 9 smi west. Federal low-altitude airways are 8 nautical miles (nmi) in width (4 nmi on either side of center); therefore, none pass directly over the PFP.

The PFP is located in a remote area with no airports in the immediate vicinity. There are three private airports located northwest of the PFP; the closest airports are at 13 to 17 smi to the PFP. These are private fields listed on the charts as having emergency or landmark value and are only lightly used by light civilian or agricultural aircraft. The Richland airport, 17,500 operations (arrivals and departure) per year, is located 22.5 smi south-southeast of the PFP; and the Pasco airport, 88,500 operations per year, is located 33 smi southeast of the PFP. See Section 9.2.7.1.5 for distances to all airports and official airways.

9.2.7.1.2 Federal Airspace Usage Restrictions. The Hanford Site is classified as uncontrolled airspace by the Federal Aviation Administration (FAA). Aircraft are required to maintain 1,000-ft clearance over the highest obstacle in a congested area or 500-ft clearance from any person, structure, or vehicle in an uncongested area. Aircraft operating above the Hanford Site are requested by the FAA, for reasons of national security, to avoid flight below 2,400 ft mean sea level (MSL) over the site, as stated on the *Seattle Sectional Aeronautical Chart*, (DOC 1989).

The Hanford Site airspace usage is extremely light due to its remote location, distance from any airports, and general expanse. The Pasco airport is the largest airport in the proximity of the Hanford Site and serves several commercial air carriers, an air taxi, and general aviation traffic. The probabilities of an aircraft incident that could involve the PFP were investigated and analyzed for several of the most credible or consequential categories of overflights. The largest users of the Hanford Site airspace (both in terms of gross weight and volume of traffic) would be those aircraft departing the Tri-Cities area on instrument flight rule (IFR) flights to the Seattle-Tacoma area on the V187 airway. Aircraft on IFR flights to the Tri-Cities area from the west use the V204 airway, which lies on the southern edge of the Hanford Site. All other airways and the military training route are not as significant a hazard to the PFP when compared to airway V187, either due to volume of traffic and/or due to proximity to the PFP. Only one airway comes as close to the PFP as airway V187 and all other airways

historically have experienced smaller volumes of traffic and smaller-sized aircraft.

9.2.7.1.3 Air Traffic Patterns in Vicinity of the PFP and Hanford. The aircraft departing the Tri-Cities area and using airway V187 on flights to the Seattle-Tacoma area, principally the commercial aircraft and some general aviation light aircraft on IFR flights, make up a small percentage of the flights originating in the Tri-Cities. In addition, due to federal flight-safety airspace-separation requirements, approximately half of the commercial aircraft departing the Pasco airport to Seattle use a radar standard instrument departure (SID) before they intercept the V187 airway. The SID takes them east and then north of the site, far from the PFP.

Flights using airway V187 are at distances and altitudes that, by the time they reach the vicinity of the PFP, are historically the safest segments of a flight. Flight crews in the Hanford Site area must take into consideration the necessity to ensure vertical clearance over the highest point on the Hanford Site (Rattlesnake Mountain at 3,629 ft MSL) and the Cascade Range farther west (mountaintops are 6,000 to 8,000 ft MSL, with one peak at 14,410 ft MSL). Generally, commercial air-carriers would be at an altitude of 10,000 ft MSL and general aviation would be above an altitude of 4,000 ft MSL in the vicinity of the PFP.

Review of National Transportation Safety Board (NTSB) accident data reveals that the PFP is located in an area that has experienced the lowest rate of aircraft accidents of any type. Most aircraft accidents occur within several miles of an approach to or departure from an airport. Using the available data, the probability of an aircraft accident involving the PFP has been determined to be highly incredible. An analysis of probabilities of all aircraft accidents is in Section 9.2.7.1.7.

9.2.7.1.4 Hanford Contract Aerial Applicator Aircraft Operations. The contracted biosciences and pesticide/herbicide aerial-applicator aircraft that operate occasionally above the Hanford Site is another category of aircraft operations that could pose a threat to the safety functions of the PFP. The actual flights above the site are infrequent and normally are not done in the vicinity of the PFP. Based on a conservative assumption of flights in the immediate vicinity of the PFP, it has been judged that an accident involving the PFP was incredible (less than or equal to 1.29×10^{-9}/yr). See Section 9.2.7.1.6 for analysis of applicator aircraft accidents.

9.2.7.1.5 FAA Airway Chart Review to Identify Airways Above the Hanford Site. The FAA airway charts (DOE-RL 1985; DOC 1989; NOAA 1989a, 1989b) were reviewed to determine if any federal airways passed over or near the PFP. A review was also made to determine if there were any airspace restrictions over the Hanford Site and, if so, what the restrictions were. With the aid of the FAA charts and the Hanford Site Map, measurements were made to determine distances from the PFP to identified airways and airports in the proximate area of the Hanford Site.

The following features were identified and distances to the PFP calculated.

1. There are no jet airways directly over the Hanford Site; the closest approach to the PFP is in excess of 25 nmi.

2. Low altitude federal airway V187 passes over the Hanford Site directly above the 609 Fire Station (100 Area) on a grid azimuth of 140°/320°. Airway V187 is used primarily by Visual Flight Rules (VFR) traffic departing the Pasco or Richland airports and destined for Seattle.

3. Low altitude federal airway V497 passes over the Hanford Site directly above the junction of Route 6 and State Highway 240 (Gate 127) on a grid azimuth of 025°/205°. Airway V497 is assumed to be used primarily by VFR traffic between Grant County Airport (Moses Lake) and destined for The Dalles, Oregon airport.

4. Military training route VR1350, a low-altitude military-controlled airway, passes slightly more than 4 smi west of the junction of Route 6 and State Highway 240 (Gate 127) on a grid azimuth of 004°/184°. Traffic on this route includes military traffic en route to the Boardman Restricted Area R-5701.

5. Low-altitude federal airway V204 passes over the southern edge of the Hanford Site directly above the peak of Rattlesnake Mountain on a grid azimuth of 109°/289°. Airway V204 is used primarily by IFR traffic arriving in Pasco or Richland airports from the Seattle area.

9.2.7.1.6 Probability of Contract Aerial Applicator Crashes Involving the PFP. The probability of a contracted herbicide or pesticide aerial-applicator aircraft or helicopter striking any critical building structure or piece of equipment at the PFP (and thereby causing a release of materials in excess of 10 CFR 100, "Reactor Site Criteria" (10 CFR 100) limits) must be evaluated. If an aerial-applicator crash involving the PFP can be shown to be an incredible event (less than 10^{-7}/yr) further analysis is not required in accordance with the criteria of Regulatory Guide 1.70 *Standard Format and Content Guide for Nuclear Power Plants*, (NRC 1978), Section 2.2.3.1. The criteria in *A Guide to Radiological Accident Consideration for Siting and Design of DOE Nonreactor Nuclear Facilities* (Elder et al. 1986) use less than 10^{-6}/yr.

The following assumptions are made where data do not exist, in order to provide a basis for calculating the credibility of an aerial-applicator accident involving PFP.

1. The *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, NUREG-0800 (NRC 1987) data relating to general aviation accident data are applied to the conduct of a contracted herbicide or pesticide aerial-applicator aircraft or helicopter, and that fatal crash data would represent sufficient energy to potentially penetrate or disrupt a PFP safety system.

2. An aerial-applicator accident might potentially cause a penetration of the PFP roof or walls at a critical location, or the aircraft fuel could breach the PFP roof or walls at a critical location and

lead to a release. This assumption is considered to be very conservative since the PFP is a substantial structure and the probability of striking a potentially critical location and violating the structural integrity or functions of safety systems is remote.

3. Less than 50 contract herbicide or pesticide aerial-applicator aircraft or helicopter flights are made in the vicinity of the PFP per year.

Following is the calculated probability of a contract herbicide or pesticide aerial-applicator aircraft or helicopter crash into PFP, that is significant enough to potentially cause a release in excess of 10 CFR 100 citing guidelines. For civilian and military airports and heliports, the probability of an aircraft crashing into site is given by the following equation.

$$P_{CA} = C \times N \times A$$

where:

C = Probability per square mile of a significant crash per aircraft movement
N = Number (per year) of movements by aircraft in vicinity of plant
A = Effective plant area (in square miles). For PFP this value is approximately 200 ft x 300 ft (60,000 ft^2 or 0.00215 mi^2)

$$P_{CA} = (1.2 \times 10^{-8} \text{ crash/mi}^2\text{-aircraft movement}) \times (50 \text{ aircraft movements/yr}) \times (0.00215 \text{ mi}^2)$$

$$= 1.29 \times 10^{-9} \text{ crashes/yr.}$$

9.2.7.1.7 Aircraft Hazard Analysis of Standard Review Plan Criteria. The criteria for the analysis of the probability of an aircraft accident at a nuclear plant were utilized for this section. Regulatory Guide 3.39, *Standard Format and Content of License Applications for Plutonium Processing and Fuel Fabrication Plants* (NRC 1976) does not specify an analysis technique, rather it identifies that a specific analysis is required if primary and secondary confinement can be "credibly breached." The criteria of the referenced NUREG-75/087, *Standard Review Plan* (NRC 1975) were used as a basis for analysis of the probability of an aircraft accident and the determination that it was, conservatively, an incredible event.

Criterion 1. Section 3.5.1.6, Subsection II.1. states that "The plant is considered adequately designed against aircraft hazards if the probability of aircraft accidents resulting in radiological consequences greater than 10 CFR Part 100 exposure guidelines is less than about 10^{-7}/yr."

Response.

Type of air traffic	Route	Probability
Commercial air carrier	V187	2.85 E-10
Commercial air carrier	V497	1.42 E-10
Commercial air carrier	V204	3.42 E-10
General aviation	V187	3.75 E-09
General aviation	V497	1.87 E-09
General aviation	V204	4.49 E-09
Military	VR1350	6.44 E-10
Contract chemical applicators	200 West Area	1.29 E-09
Total		1.28 E-08

Criterion 2. Section 3.5.1.6, Subsection II.2. states that "The probability is considered acceptable by inspection if the level of aircraft activity near the site falls below the criteria given in Section 2.2.3 of Regulatory Guide 1.70... for analysis of hazards due to commercial, experimental, and general aviation aircraft." (Section 2.2.3.1 states: "Design basis events... are those accidents that have a probability of occurrence on the order of about 10^{-7}/yr or greater...").

Response. See response to Criterion 1 above.

Criterion 3. Section 3.5.1.6, Subsection II.2. states that "For military airspace, a minimum distance of 5 mi from the reactor is adequate for low level training routes except those associated with usage greater than 1,000 flights per year or activities (such as practice bombing) where an unusual stress situation exists."

Response. Military low level training route VR1350 passes above the western edge of the Hanford Site, 9 mi west of the PFP. The traffic over VR1350 is approximately 1,800 sorties per year (according to the military authority responsible for the route). The R-6714 B&E Restricted Area (Yakima Firing Center) closest boundary to the PFP is 14.3 smi. Military air operations may occasionally overfly the PFP area (675 ft MSL), but due to the proximity of Rattlesnake Mountain (3,629 ft MSL), a low approach is generally not routine. Aircraft tend to maintain significant vertical separation in the Hanford area either due to the FAA request or for safety considerations around the mountain.

Criterion 4. Section 3.5.1.6, Subsection III.1. states that "Data describing aviation uses in the airspace near the proposed site, including airports and their approach paths, federal airways, FAA restricted areas, and military uses is obtained from Section 2.2 of the SAR. For many cases, no detailed analysis need be made as the probability can be judged adequately low based on a comparison with analyses previously performed."

Response. See Criteria 1 and 3 above.

Criterion 5. Section 3.5.1.6, Subsection III.2. states that "For situations where federal airways or aviation corridors pass through the

vicinity of the site, the probability per year of an aircraft crashing into the plant (P_{FA}) should be estimated. This probability will depend on a number of factors such as the altitude and frequency of the flights, the width of the corridor, and the corresponding distribution of past accidents.

One way of calculating P_{FA} is by using the following expression:

$$P_{FA} = C \times N \times A/w$$

where:

C = Inflight crash rate per mile for aircraft using airway
w = Width of airway (plus twice the distance from the airway edge to the site when the site is outside the airway) in miles
N = Number of flights per year along the airway
A = Effective area of plant in square miles."

Response. The value of A for the PFP is approximately 200 ft by 300 ft (60,000 ft^2 or 0.00215 mi^2).

w = 8 mi + 2 x 2.5 mi = 13 smi factor PFP to V187 (6.5 smi to airway centerline).

Airway ID#	PFP to Airway centerline	Airway width	w =
V187	6.5 smi	8 smi	13 smi
V204	10.5 smi	8 smi	21 smi
V497	6.5 smi	8 smi	13 smi
VR1350	9.0 smi	8 smi	18 smi

(The PFP facility is outside of all federal low-level airways: V187, V204, and V497 airways are 8 nmi wide, 4 nmi either side of airway centerline.)

Air traffic type	C[b]	N	Route	P_{FA}
Commercial air carrier	0.12 E-08	1,438	V187	2.85 E-10
General aviation	1.20 E-08	1,892	V187	3.75 E-09
Commercial air carrier	0.12 E-08	719[a]	V497	1.42 E-10
General aviation	1.20 E-08	946[a]	V497	1.87 E-09
Commercial air carrier	0.12 E-08	1,726[a]	V204	3.42 E-10
General aviation	1.20 E-08	2,270[a]	V204	4.49 E-09
Military aviation	0.30 E-08	1,800	VR1350	6.44 E-10
Contract aerial applicators	Analysis applicable to federal airway usage only			

[a]Assumptions: V204 N = 1.2 times V187 N; V497 N = 0.5 times V187 N; based on FAA Telcon.
[b]Source: NRC (1975).

Criterion 6. Section 3.5.1.6, Subsection III.3. states that "The probability of an aircraft crashing into the site should be estimated for cases where either of the following apply:

a. An airport is located within 5 mi of the site.

b. An airport with projected operations greater than 500 d^2 movements per year is located within 10 mi of the site, or an airport with projected operations greater than 1,000 d^2 movements per year is located beyond 10 mi from the site, where "d" is the distance in miles from the site."

Response.

a. Does not apply; nearest airport is 22.5 mi away.

b. Does not apply; Pasco Airport is the highest volume airport in the vicinity of the Hanford Site and it is 33 mi away from the PFP. Pasco Airport had only 88,459 operations (departures and arrivals) in all of 1988. This is far below the required 1.089M operations required by the "1,000 d^2 movements per year" criterion above.

$$P_{CA} = i\sum_{(1-L)} j\sum_{(1-M)} (C_j x N_{ij} x A_j)$$

where: $i\Sigma_{(1-L)}$ = Summation over all flight trajectories, for i = 1 to L, affecting the site
$j\Sigma_{(1-M)}$ = Summation over all different types of aircraft, for j = 1 to M, using the airport.

9.2.7.2 Radiological Survey Helicopter Overflights. This analysis evaluates the probability of a helicopter malfunction and subsequent crash into the PFP during the performance of an aerial radiological survey. A helicopter crash into the PFP is considered to be an incredible event as long as the helicopter does not operate in the near proximity of the PFP (i.e. a 2,300 ft square centered on the 291-Z-1 stack). A single helicopter is able to map and record data for an aerial radiological survey. During surveys, the helicopter typically flies at an elevation of 200 ft and a speed of 80 knots (approximately 90 mph).

For this analysis, it is assumed that a failure results in autorotation. The average sink rate of a helicopter with autorotation is 1,700 ft/min as given in *Hanford Aviation Safety Assessment* (WHC 1992b). Using a flight elevation of 200 ft, the time to reach the ground is approximately 7 s. Given a forward speed of 90 mph, the helicopter could travel approximately 900 ft horizontally before striking the ground.

Based on the dimensions of the buildings comprising the PFP, a simplifying assumption is made that the area of concern wherein a crash would release radiological materials is represented by a 500 ft square building centered on the 291-Z-1 stack. Accordingly, a failure within 1150 ft (i.e., 900 ft plus 250 ft) from the center could potentially impact the building. Stated another way, a failure anywhere within a 2,300 ft square centered on the 291-Z-1 stack could potentially impact the building.

Given that a helicopter flies in parallel paths 400 ft apart, and a width of 2,300 ft, it would take approximately 7 flights to cover the area of concern. This is equivalent to a total distance of 16,100 ft, or 3 mi. Given a speed of 90 mph, the helicopter would spend approximately 0.034 h (2 min) within the area of concern.

Helicopter failure rate data are available from several sources:

- Hanford aviation operations: 1×10^{-3} to 10^{-4}/hr (WHC 1992b)
- NTBS data: 6.8 to 13.4 x 10^{-5}/hr (WHC 1992b)
- U.S. Army Safety Center: 15.4 x 10^{-5}/hr (WHC 1992b)
- NTBS\FAA: 1.6 x 10^{-5}/hr.

These values are presumed to include all causes (e.g., equipment failure, human error, and maintenance errors). For this analysis, the 15.4 x 10^{-5}/hr failure rate was selected for conservatism and because the helicopter is similar to military aircraft. Applying the failure rate and a mission time of 0.034 hr, the probability of failure during the mission is 5.2 x 10^{-6}. Assuming the failure occurred within the area of influence, the helicopter would have an equal probability of crashing in the direction of the PFP as in the opposite direction, and the probability of heading toward the PFP after a malfunction is 2.6 x 10^{-6}.

To determine the likelihood of striking the PFP if the malfunctioning helicopter is heading towards the PFP, the fraction of area represented by the PFP versus the total area of influence must be determined. The hazard area represented by the PFP is 250,000 ft^2 (i.e., 500 x 500). The total area of influence is 5,290,000 ft^2 (i.e., 2,300 x 2,300). Therefore, the hazard area represents 5% of the total area. Because of the potential for flying debris from a nearby crash impacting the PFP, the hazard area is assumed to be 10% of the total area. This yields a probability of the crash affecting the PFP of 2.6 x 10^{-7} (i.e., 0.10 x 2.6 x 10^{-6}).

The failure rate data used above is for routine helicopter operation. The radiological survey flights differ greatly from routine operations, thus the data for routine operation does not correlate directly. The probability of a crash during the mission is believed to be increased by several considerations as follow:

1. Pilots unfamiliar with the Hanford Area - factor of 2
2. Flying at a low altitude - factor of 2
3. Multiple tall stacks and towers - factor of 2
4. Complexity of survey operation - factor of 2.

The above considerations result in an increase by a factor of 16, yielding a probability of 4.2 x 10^{-6} (i.e., 16 x 2.6 x 10^{-7}). If any two of the above four factors were judged appropriate, the probability would be 1 x 10^{-6}

(i.e., $4 \times 2.6 \times 10^{-7}$). It is estimated that the analysis has an uncertainty of 10^{-1} to 10^{+1} associated with this probability.

The above analysis shows a helicopter crash into the PFP during the performance of an aerial radiological survey, within the area of the PFP, is a credible (although extremely unlikely) event. However, analysis shows that a helicopter crash into the PFP is an incredible event when helicopter operation is not permitted in the near proximity of the PFP, which is defined by a 2,300 ft square centered on the 291-Z-1 stack. Therefore, flight restrictions prohibit helicopter operation in the near proximity of the PFP. These restrictions are documented in the USQ Evaluation performed for the helicopter overflights.

No radiological or toxicological consequences were calculated since a helicopter accident involving the PFP is an incredible event.

9.2.8 Toxic Chemical Release

This section considers the release of toxic chemicals due to improper handling. Chemical releases obey the laws of physics as radioactive releases do, in regard to release mechanisms and air transport. Chemical release limits, however, are stated in terms of concentration rather than dose. Therefore, only those chemicals with substantial potential for becoming airborne need to be considered. Most of the chemicals used at the PFP are delivered as crystalline substances, which are then dissolved in water, or as aqueous solutions. However, some materials are delivered as gases.

The potential onsite exposure for chemicals used at the PFP is bounded by an analysis done for the HNO_3 storage tank. The HNO_3 storage tank has been drained and is not in service. Nitric acid is now supplied in 55-gal drums. The analysis of the 7,000 gal tank has been retained as the bounding case for a toxic chemical release. The HNO_3 is a candidate for consideration partly because the 57% material that is stored in the 7,000-gal tank has a moderately high vapor pressure, and produces oxides of nitrogen following a spill as it reacts with its surroundings. In addition, the volume available for release is large compared to other chemicals used at the PFP. The most likely cause for a large spill and for lack of mitigating actions would be a seismic event. A large HNO_3 release is also discussed in Section 9.2.5, "Strong Wind."

A total release of the 7,000-gal capacity HNO_3 tank in 2735-Z results in HNO_3 vapor concentrations, using conservatively stable weather conditions, at the maximum onsite and offsite receptor locations that are well below the Toxicological Risk Acceptance Guidelines for an event with frequency of 1/yr.

It is assumed that the outside HNO_3 storage tank fails and releases HNO_3 to the retention basin. The basin is large enough to retain the entire capacity of both the HNO_3 and ANN storage tanks. ANN is a hydrated aluminum salt solution with a very low vapor pressure. While a small amount could be aerosolized due to the dynamics of a spill, the solution water would preferentially evaporate, leaving hydrated aluminum nitrate salt crystals. Thus, an ANN spill should be bounded by the HNO_3 spill and will not be analyzed. The area of the retention basin which is irregularly shaped, is 976 ft^2 (90.7 m^2) (see Drawing H-2-77439). The HNO_3 storage tank is conservatively assumed to contain the maximum 7,000 gal of 57% HNO_3 and to fail in such a way that the entire 7,000-gal capacity drains into the retention basin. The temperature of the surrounding air is assumed to be 40 °C, corresponding to a very warm day for the Hanford Site. The temperature of the liquid HNO_3 is also assumed to be 40 °C (104 °F). The effects of evaporative cooling will act to lower the pool temperature and are conservatively neglected. As will be verified in the conclusions of the following analysis, the effects of solar radiation and conduction from the ground when the surface temperature is higher than the air temperature are small, so these heat transfer modes will also be neglected. In addition, it is assumed that aerosolization effects due to the ambient wind and the dynamics of the spill are small enough (a small percentage of the total volume should participate in such effects) that the conservatism built into the evaporation analysis provide a sufficient margin of safety.

The evaporation rate is based on the method described by Clewell, 1983. This method uses the following empirical formula:

$$Q = 0.08u^{0.75}AZ[1 + [4.3\times10^{-3}T_p^2]]$$

where: Q = Evaporation rate, kg/hr
u = Wind speed, m/s
A = Spill area, m^2
Z = Volatility factor
T_p = Temperature of liquid, °C

Note that the above equation is empirical and not dimensionally consistent. For the accident considered here:

u = 4.47 m/s (10 mi/h), this speed corresponds to the wind speed for the 99.5% meteorology $\overline{\chi}/Q$ values calculated for the seismic event in Section 9.3
A = 90.7 m^2 (976 ft^2)
T_p = 40 °C (104 °F), the pool temperature is assumed to be equal to the air temperature

Z is the volatility factor of HNO_3 in relation to hydrazine and is calculated using

$$Z = \frac{P_{vb}M_b}{P_{vh}M_h}$$

where: P_{vb} = 3.1 mm Hg, partial pressure of HNO_3 at 40 °C
P_{vh} = 34.7 mm Hg, partial pressure of hydrazine at 40 °C
M_b = 63 g/gmole, molecular weight of HNO_3
M_h = 32 g/gmole, molecular weight of hydrazine.

Thus,

$$Z = \frac{(3.1 \text{ mm Hg})\left(63\frac{g}{gmole}\right)}{(34.7 \text{ mm Hg})\left(32\frac{g}{gmole}\right)} = 0.18$$

Finally, a conservative value for the evaporation rate is given by

$$Q = 0.08(4.47)^{0.75}(90.7)(0.18)[1 + [4.3\times10^{-3}(40°C)^2]]$$

$$= 30.9\frac{kg}{hr}$$

$$= 8.6 \times 10^{-3}\frac{kg}{s}$$

Since the HNO_3 is stored as a 57% solution, the mass release rate of HNO_3 is 4.9×10^{-3} kg/s.

The preceding calculation neglected the effects of solar radiation, ground conduction, and evaporative cooling. The neglect of evaporative cooling is clearly conservative. Approximating the thermal conductivity and heat capacity of the pool of 57% HNO_3 with water properties, conservatively using the maximum solar radiation flux on the 45th parallel of 1,070 W/m^2 (NRC 1991, Table 2.1), and assuming the ground temperature is 20 C° higher than the air temperature, the HNO_3 pool temperature will increase by only 2 C° per hour. This temperature difference will then drive convective heat transfer from the pool to the air, which would act to reduce the pool temperature.

The density of HNO_3 is roughly twice the density of air, so dense gas effects may be important in the dispersion calculation.

This is determined by calculating the Richardson number for a continuous release.

$$Ri_o = \frac{g(\rho_{rel} - \rho_a)\dot{V}}{\rho_a u^3 d}$$

where: g = acceleration of gravity, $9.81\frac{m}{s^2}$

ρ_{rel} = density of the released vapor, $\frac{kg}{m^3}$

ρ_a = density of the ambient air, $\frac{kg}{m^3}$

$\dot{V}$ = volumetric release rate of vapor ($=Q/\rho_{rel}$), $\frac{m^3}{s}$

u = wind speed, 4.47 $\frac{m}{s}$

d = initial length scale of release (i.e. diameter of pool), 10.7 m

Using the perfect gas law, the density (at 40 °C) of the released HNO_3 vapor can be calculated as 2.454 $\frac{kg}{m^3}$. Using this density and the previously

calculated mass flow rate due to evaporation along with the density of air at 40° C, the Richardson number is calculated as

$$Ri_o = \frac{9.81(2.454 - 1.225).000349}{(1.225)(4.47^3)(10.7)} = 3.3 \times 10^{-5}$$

Since the Richardson number is quite small (<0.003), the HNO_3 vapor is considered a passive tracer, and the normal Gaussian dispersion model is appropriate.

To determine the onsite and offsite HNO_3 concentration resulting from the spill, the rate at which the acid evaporates from the pool formed in the basin is multiplied by the appropriate $\overline{\chi}/Q$ values from Tables 9-39 and 9-40. Even though the HNO_3 tank is surrounded by buildings and piping, the concentration at the location of the maximum onsite and offsite individuals will be conservatively based on a point source ground level release with no consideration for building wake effects.

The onsite $\overline{\chi}/Q$ (point-source ground-level release) is 8.72×10^{-4} s/m^3. The concentration at the location of the maximally exposed onsite individual is therefore 4.3×10^{-3} g/m^3.

$$C = \left(4.9 \frac{g}{sec}\right)\left(8.72\times10^{-4} \frac{sec}{m^3}\right) = 4.3\times10^{-3} \frac{g}{m^3}$$

The offsite $\overline{\chi}/Q$ (point-source ground-level release) is 1.62×10^{-5} s/m^3. The concentration at the location of the maximally exposed offsite individual is therefore 7.9×10^{-5} g/m^3.

$$C = \left(4.9 \frac{g}{sec}\right)\left(1.62\times10^{-5} \frac{sec}{m^3}\right) = 7.9\times10^{-5} \frac{g}{m^3}$$

For comparison to the Toxicological Risk Acceptance Guidelines shown in Table 9-53, the above concentrations must be converted to ppm. The conversion formula is taken from AICHE (1989) p. 93.

$$C_{ppm} = C\frac{RT_a}{PM_0}\times10^6$$

where: R = 0.082 atm-m^3/K/kgmole, gas constant
P = 1 atm, ambient pressure
M_0 = 63 kg/kgmole, molecular weight of HNO_3
T_a = 313 K (= 40 °C), assumed ambient temperature

Thus, the onsite individual is exposed to

$$C_{ppm} = 4.3\times10^{-6}\frac{kg}{m^3}\frac{\left(0.082\frac{atm\text{-}m^3}{K\text{-}kgmole}\right)(313\ K)}{(1\ atm)\left(63\frac{kg}{kgmole}\right)}\times10^{6} = 1.8\ ppm$$

Similarly, for the offsite individual,

$$C_{ppm} = 7.9\times10^{-8}\frac{kg}{m^3}\frac{\left(0.082\frac{atm\text{-}m^3}{K\text{-}kgmole}\right)(313\ K)}{(1\ atm)\left(63\frac{kg}{kgmole}\right)}\times10^{6} = 0.032\ ppm$$

Both onsite and offsite concentrations are well below the respective Toxicological Risk Acceptance Guidelines shown in Table 9-53 for a seismic event with a frequency of 1 x 10^{-4}/yr (i.e., 24 ppm and 7.7 ppm, respectively) and even meet the guidelines for an event with a frequency of 1 (i.e., 15 ppm onsite and 2 ppm offsite). Thus, the above conservative analysis demonstrates that the onsite and offsite consequences of a HNO_3 spill are acceptable.

9.2.9 Accidents for the Plutonium-Bearing Solution Stabilization Process Using the Production Vertical Denitration Calciner

The following sections develop the bounding accident scenarios postulated for the plutonium-bearing solution stabilization process using the Production Vertical Denitration Calciner (VDC) in Glovebox HC-230C-2. The accident scenarios for analysis were identified based on categorization and screening of the HazOp analysis contained in Appendix 9D. The accident categories (bins) identified for the plutonium-bearing solution stabilization process are summarized in Appendix 9D, Table 9D-3. The accident categories were screened from the HazOp analysis contained in Table 9D-4 (also see Section 9.0.2.1A). The accident categories represent types of events associated with the Production VDC operations in Glovebox HC-230C-2 that have the potential to breach confinement barriers, resulting in significant spread of radiological or toxicological contamination to Zone 3 or Zone 4 areas within Building 234-5Z and the potential to cause a significant release of radiological or toxicological material from the building to the atmosphere. Each of the accident categories from Table 9D-3 are discussed in turn below.

Each accident category has also been compared and evaluated against the original accident analyses contained in Sections 9.2.1 through 9.2.8. New detailed accident analyses are provided in Sections 9.2.9.1 through 9.2.9.4 for accident categories found not to be adequately represented by the prior analyses contained in Sections 9.2.1 through 9.2.8.

Release from Transfer Line: This accident category involves leaks from the encased transfer lines that run between the HC-227S and HC-230C-2

gloveboxes. For the majority of leaks that could occur from primary transfer lines, the leaked fluid will drain back to the glovebox at either end, collect in the sump and be detected by the glovebox sump level detectors. The release remains confined because of the glovebox structure and ventilation system. The more significant accident scenario is less likely and would require the failure of the encasement pipe along with the primary transfer line failure. Such an event could result in a leak of radioactive liquid to Zone 3 areas on the first floor or to the floor of the duct level where facility workers could be exposed (e.g, to aerosols generated by splatter of the solution off the floor). As normal transfers between Glovebox HC-227S and Glovebox HC-230C-2 occur in relatively small 9 to 10 L draws, the exposure potential is limited. Except in a DBE, the airborne release to Zone 3 from a failed transfer line and encasement pipe would be filtered by the E-3 exhaust system and the consequences outside the plant would be insignificant. The consequences of a leak from the encased transfer line (non-seismic initiated) are considered to be adequately represented by the radioisotope bearing liquid spill analyzed in Section 9.1.1. The release from the transfer line in a seismic event is considered to be adequately covered in seismic accident analysis in Section 9.2.4, as that accident analysis assumes a fountain-like liquid release from a sheared transfer line within Glovebox HC-227S. No separate analysis was found to be warranted for this accident category.

Flammable Gas Deflagration in the Production Vertical Denitration Calciner: Should feed containing a significant quantity of separable organic be pumped into the calciner, a deflagration could occur in the Production VDC vessel or in the vessel offgas system. The deflagration would pressurize the calciner and force a fraction of its PuO_2 powder bed to become airborne. The heat and offgases produced in the deflagration could also pressurize the glovebox, causing a spread of radiological material to Room 230C. This accident cannot be easily compared to a pre-existing accident analysis and is therefore analyzed as a new accident in detail in Section 9.2.9.1.

Criticality: Glovebox HC-230C-2 processes and is allowed to store up to approximately 27 kg of Pu material at any given time. The Criticality Safety Evaluation Report (CSER) for the Production VDC (Hillesland 1997) establishes mass limits and separation requirements to minimize the likelihood of a criticality in Glovebox HC-230C-2. The glovebox is equipped with a criticality drain sized to handle credible infiltration of water from the facility fire sprinkler systems. In addition, the glovebox supports are seismically qualified to prevent toppling in the design basis earthquake which might pool liquids and solids together in a corner of the glovebox. In the extremely unlikely event a criticality occurs in Glovebox HC-230C-2, the consequences would be expected to be bounded by the criticality accident presented in Section 9.2.3. An additional criticality accident is not required specifically for Glovebox HC-230C-2 to assess facility risk.

Glovebox HC-230C-2 Fire: Glovebox HC-230C-2 is constructed out of stainless steel, with fire-resistant Lexan™ (polycarbonate) or wire-mesh reinforced glass shield windows. Combustible loading in the glovebox is limited to cartons used to bag cans in and out of the glovebox, rags, gloves, wire insulation, and equipment grease. Due to the high heat load and hot surfaces in the glovebox, small fires are possible in the glovebox, but a large fire that consumes the glovebox and spreads to other portions of the RMC

line is not anticipated. The Glovebox HC-230C-2 fire is evaluated in Section 9.2.9.2.

Glovebox HC-230C-2 Loss of Confinement: This category includes all failure scenarios not covered by other specific accident analyses that can result in the spread of radiological material from Glovebox HC-230C-2 to the Room 230C atmosphere. Postulated scenarios include pressurization of the glovebox due to an imbalance between the ventilation supply and exhaust on the RMC line, pressurization of the glovebox from compressed air line failures within the glovebox or from failure of the compressed air supply regulator, pressurization of the glovebox due to loss of calciner temperature control, diffusion of contamination from a stagnant glovebox caused by loss of both supply and exhaust flow, contamination spread caused by improper transfer of cans and other items into or out of the glovebox through the bag-in port, contamination spread through failed glovebox windows caused by internal or external equipment or tool impacts, and vapor releases back through the chemical addition line due to chemical reactions in the flush tank. (Note: A funnel break has been added between the flush and chemical addition tanks to preclude releases through the chemical addition line into Room 230C. Isolation valves would also have to be left open for such a release to occur).

The pressurized glovebox scenarios would produce the largest release from the glovebox. Scoping calculations indicate that failure of compressed air lines within the glovebox will not significantly pressurize the glovebox. The heat produced by the calciner will only significantly overpressurize the glovebox if ventilation flow through the glovebox is lost. The calciner is provided with a temperature control system and overtemperature alarm. In addition, glovebox air temperature is monitored. The worst-case pressurization scenario is a scenario where the E-4 exhaust system is shutdown but supply air to the RMC line continues. Interlocks are provided between the glovebox supply and exhaust systems to prevent this from occurring. Pressure indication is provided at Glovebox HC-230C-2 to warn operators of an overpressurized glovebox. CAMs strategically located in Room 230C will also alert operators to an airborne contamination hazard.

The potential release of contamination from the pressurized glovebox to Zone 3 could be expected to be similar to the powder spill addressed in Section 9.1.3 or to the conservative pressurized powder release analyzed in Section 9.1.4. The release from the glovebox would be filtered by the E-3 system and the consequences outside the facility would be negligible, as with the events addressed in Sections 9.1.3 and 9.1.4. No further evaluation of this accident category was therefore judged to be necessary to assess facility risk.

Toxic Chemical Release Inside Facility: The solution stabilization process using the Production VDC utilizes NaOH (for offgas scrubbing) and nitric acid (for flushing the VDC feed line). Fifty-five gallon drums used to feed the scrubber can be spilled or pumped through a failed transfer line to the floor of Room 230C. Small quantities of nitric acid transferred to the chem add tank can be similarly spilled. Operator training and procedures are primarily relied on to limit operator exposures. Such spills have the potential to cause burns to facility workers and to expose workers to airborne vapors due to evaporation of the spilled solutions. Outside the facility, however, airborne concentrations would be too low to be of concern due to

dilution with the plant air, release through an elevated stack and atmospheric dispersion. The consequences of a spill of NaOH or nitric acid associated with the Production VDC process are bounded by the toxic material release evaluated in Section 9.2.8. No further evaluation is necessary.

Failure of Compressed Air Supply Bottles: The atomizing air and filter back pulsing air for the Production VDC are supplied from compressed air cylinders. The compressed air cylinders present a significant stored energy source. Should a cylinder rupture or have its supply valve sheared off in a handling accident, it could be propelled as a missile injuring workers and causing damage to the facility. Because of the large number of compressed air cylinders required to support Production VDC operations, the failure of a cylinder due to a handling accident was determined to warrant detailed analysis, which is provided in Section 9.2.9.3.

Storage Canister Rupture: The HazOp analysis identified numerous process upsets and failures that could result in inadequately stabilized PuO_2 being produced by the Production VDC. If the inadequately stabilized oxide is not detected before sealing up the powder in site convenience cans, the cans could rupture in storage due to internal pressurization. A reaction between absorbed water and PuO_2 produces hydrogen gas that can cause overpressurization of the can. This accident is not unique to the Production VDC process as oxides stabilized in furnaces in other PFP gloveboxes have the same potential to overpressure canisters. Instrumentation is provided in the storage vault pedestals to detect bulging cans. Should a canister rupture while being handled within the 234-5Z Building, any released PuO_2 would be drawn through the E-3 ventilation exhaust system and filtered. In the Building 2736-Z storage vaults, the release from a ruptured can would be confined and filtered by the vault ventilation system. The consequences outside the plant would be negligible. The potential consequences of an overpressurized storage container are developed in Section 9.1.4. No further analysis was deemed to be necessary for this accident bin.

Natural Phenomena, Seismic Event: The Pu inventory in Glovebox HC-230C-2 potentially adds to the total facility source term in the seismic event. The potential release from Glovebox HC-230C-2 in the design basis earthquake (DBE) is developed in Section 9.2.9.4.

Natural Phenomena, Ashfall: A volcanic ashfall is considered to be a potentially occurring natural phenomenon in the same category with tornado and earthquake. With an appropriate wind pattern, the cloud of ash from a volcanic eruption could be directed toward the PFP.

Ash causes three immediate concerns to the PFP safety. The ash is extremely abrasive to any exposed mechanical equipment, ash may cause pluggage problems with the ventilation system, and heavy accumulations on top of the facility may exceed roof loading limits. Chapter 5.0, Section 5.2 states that the 234-5Z Building was analyzed and found to acceptably resist combined volcanic ashfall and snowfall (Giller 1990).

In the event of ashfall at the PFP, most exterior equipment that would be exposed to the abrasiveness of the ash would be shut down, including the vehicles such as the process and sample trucks. Normal ventilation may be maintainable during an ashfall, however, it may be necessary to shut down

normal ventilation and utilize emergency ventilation fans. It also may become necessary for the PFP personnel to clear the roof of the ash before excessive buildup occurs. This action is included in the plant emergency planning for response to volcanic eruption.

The PFP FSAR did not develop consequence calculations for an ashfall. This was based on two considerations, first the ability to take corrective action before roof loading became a problem and second, with regard to ventilation, the assumption that some level of ventilation could be maintained during the ashfall event. However, even if all ventilation were lost, the consequences were determined to be acceptable (Chapter 9.0, section 9.1.8). The addition of Glovebox HC-230C-2 does not introduce any new considerations for the loss of ventilation event as compared to existing analysis.

Natural Phenomena, High Wind: The PFP has been evaluated for capability to withstand high winds. It was determined that the facility could withstand the 90 mi/h wind called for in the Hanford Site design criteria document. The analyses referenced in Section 5.2.1.1.2 of the PFP FSAR show that the main load-bearing structure is not over stressed by the extreme wind or adversely impacted by the design criteria specified plank traveling at 50 mi/h. Section 9.2.5 evaluated the effect of high wind on the PFP. It was concluded that only facilities and components exterior to the 234-5Z Building would be vulnerable to high wind effects. The location of Glovebox HC-230C-2 inside Building 234-5Z precludes any affect from the wind or wind driven missiles.

External Event, Facility Wide Loss of Power: The PFP facility power loss can occur from many causes. Loss of power could be caused by lightning strikes, high wind, aircraft striking high voltage power lines, switch gear failure, and human error. A loss of ventilation would occur if both the supply fans and exhaust fans were to simultaneously lose power. This would occur only during a simultaneous loss of two electrical circuits and the backup power supply.

There are two concerns that result from a 234-5Z Building wide loss of power, both of which involve the loss of ventilation. The first is generation of hydrogen gas from tanks containing plutonium solutions. Provided that solutions are present, calculations indicate it would take nearly four weeks to accumulate sufficient hydrogen to result in a structure-threatening deflagration. The second is loss of confinement. Even if all ventilation were lost, the consequences were determined to be acceptable (Chapter 9.0, Section 9.1.8). The addition of Glovebox HC-230C-2 does not introduce any new considerations for the loss of ventilation event as compared to existing analysis.

External Event, Range Fire: Vegetation is removed routinely within and adjacent to the PFP site fencing for security purposes. This creates a large area devoid of material capable of allowing a fire to get within close proximity to the PFP. Also, the nature of the desert vegetation surrounding the 234-5Z Building coupled with the large vegetation control area does not support the presence of airborne embers capable of igniting the roof of the facility.

However, range fires do create conditions where loss of site power can occur. Although the main Hanford Site electrical system that provides power

to the 200 Areas is carried on metal towers, the distribution of that power to various locations in the 200 Areas is on wood poles. These poles are vulnerable to fire damage that could cause failure of the pole structure with resulting line faults and power loss. Therefore, range fires are a way of initiating site power loss and causing a facility ventilation failure. Ventilation failures are discussed under Loss of Power above.

External Event, Aircraft Crash: Aircraft accidents involving the PFP are evaluated in Chapter 9.0, Section 9.2.7. The frequency of a commercial or military aircraft accident involving the PFP was determined for several of the most credible or consequential categories of overflights. Using the available data, the frequency of a commercial or military aircraft accident involving the PFP has been determined to have a total value of less than 1.0×10^{-7}/yr, indicating that the event is not credible. Helicopters are also occasionally used to perform radiological surveys of the Hanford Site. A helicopter crash into the PFP is determined in Section 9.2.7 to not be credible as long as helicopters do not operate in a square 2,300 feet on a side centered on the 291-Z-1 Stack. Therefore this event is not evaluated further for the HC-230C-2 Glovebox.

9.2.9.1 Flammable Gas Deflagration in the Production Vertical Denitration Calciner. The aqueous solutions processed by the Production VDC contain small concentrations of entrained residual organic solvents from processing. It is possible that the immiscible organic material in the feed solution may coalesce and separate out from solution in the feed pump tank prior to being injected into the Production VDC. Because the Production VDC operates at very high temperature (in excess of 1000 °C), the injection of feed solution with a high organic content may result in a flammable gas burn inside the calciner. Thermal stabilization of plutonium-bearing solutions using the Production VDC are not currently authorized. The likelihood and consequences of a flammable gas burn associated with VDC operation will be developed prior to operation of the VDC.

9.2.9.2 Glovebox HC-230C-2 Fire. If combustible loading is not controlled in Glovebox HC-230C-2 and comes into contact with the hot surface of the Production VDC, a fire could result. Operation of the calciner is currently not authorized. The likelihood and consequences of a Glovebox HC-230-2 fire will be evaluated prior to initiation of calciner operations.

9.2.9.3 Compressed Air Cylinder Failure. The atomizing air and filter back-pulsing air for the Production VDC is supplied from compressed air cylinders. The cylinders are connected to the air supply line for the Production VDC from a bottle rack located outside Room 230C in Corridor 6. The layout of 234-5Z Building is provided in Figures 9-1 and 9-2. Four cylinders are contained in the bottle rack at a time. As is shown in Section 9.2.9.3.3 below, approximately 1000 cylinders will be needed to support Production VDC operations during the one-year solution stabilization campaign. The air cylinders, when full, contain 250 standard cubic feet of air at a pressure of approximately 2400 psi. Each cylinder brought into the facility presents a significant stored energy source. With the large number of cylinders needed, there is concern that a cylinder could be damaged and ruptured in a handling accident. In such an event, pressurized air ejected from the gas cylinder could accelerate the cylinder, turning it into a missile that could injure workers and cause damage to the facility.

9.2.9.3.1 Scenario. Compressed gas cylinders can fail in a number of ways. The cylinder itself could spuriously rupture because of a manufacturing flaw or internal corrosion. The cylinder could rupture from overpressure, if exposed to high temperatures in a fire (requires pressure relief valve to also fail). Or the cylinder could be punctured by impact with another object. The most likely way, however, for a compressed gas cylinder to become a missile is for the supply valve on top of the cylinder to be sheared off or otherwise damaged during handling of the cylinder. There have been several cases in the chemical industry where this has occurred. Within the DOE complex, at the Oak Ridge Site in 1995, a 100-pound-capacity cylinder containing carbon dioxide discharged its contents and became airborne after workers incorrectly manipulated a discharge-valve, hand-lever attachment. The cylinder narrowly missed the workers as it was propelled out of the storage enclosure. The cylinder hit a paved parking area and travelled an additional 30 feet before striking an inclined concrete ramp (ORPS Report ORO--MMES-Y12SITE-1995-0025).

For this accident analysis, it is assumed that one of the numerous compressed air cylinders brought into the plant to support Production VDC operations is mishandled and dropped in such a manner that the supply valve contacts the wall or another piece of equipment and is sheared off.

9.2.9.3.2 Mitigation. In DOE Facilities, compressed gases are handled, stored and used in compliance with Compressed Gas Association CGA P-1-1991, "Safe Handling of Compressed Gases in Containers." The compressed air cylinders are stored and used in an area that is dry, well ventilated, and of fire resistant construction. When not being moved, the cylinders are secured to prevent falling. Recycled cylinders are retested in accordance with the requirements of Code of Federal Regulations 49 CFR 173.304, *Qualification, Maintenance and Use of Cylinders.*

The likelihood of spurious cylinder failures is minimized by the safety factors built into the design of the cylinders, initial pressure testing of the cylinders, and periodic inspection by the supplier. The cylinders are provided with a pressure relief device to protect against high temperature exposure.

The likelihood of a handling accident resulting in failure of a compressed air cylinder is minimized by operator training and procedures. The air cylinders are transported on a cylinder hand truck. Rolling or "walking" of cylinders is prohibited. By procedure, when the cylinders are not in use, a cover (cap) is required to be installed over the cylinder supply valve. When installed, this cover protects the cylinder supply valve in most handling accidents.

9.2.9.3.3 Probability. Blanton and Eide (1993) recommends a failure rate for rupture of pressurized gas cylinders of 5.0×10^{-9}/cylinder-h. It is unknown whether this failure rate includes cylinder ruptures caused by handling errors, or if it applies only to passive storage and use of canisters restrained in bottle racks. Use of the Blanton and Eide failure rate is therefore potentially nonconservative for representing handling accidents. A second method of estimating the accident frequency is therefore provided below. For determining the annual probability of a cylinder rupture inside the PFP using the Blanton and Eide failure rate, it is necessary to determine the total cylinder-hours of exposure inside the facility. There are 8760

hours in a year. At any given time, four pressurized cylinders can be expected to be in the plant (assuming gas cylinders are normally stored outside the plant). Multiplying the Blanton and Eide failure rate (5.0×10^{-9}/cylinder-h) by the number of cylinder hours (8760 x 4) gives an annual probability for a cylinder accident inside the plant of 1.8×10^{-4}. Note that this annual probability does not include potential ruptures in the storage location outside the plant.

Assuming handling errors result in the majority of catastrophic cylinder failures, an alternate way to estimate the annual probability of an accident inside the facility is to use typical human error rates and engineering judgment. Typical human errors of commission or omission range from one in ten to one in one hundred operations, depending on training, the complexity of the task, and the stress involved in performing the task (Swain and Guttmann 1983). If the midrange human error value is used, roughly one in a hundred cylinders could be expected to be dropped or toppled during handling. It can also be assumed that human error results in roughly one in 100 cylinders being handled without the protective cover installed over the supply valve. Based on engineering judgement, it is assumed that one in ten cylinders that are mishandled falls or topples with the supply valve contacting a wall or another piece of equipment with enough force to be sheared off, provided the protective cover is not in place. It is estimated that approximately 1000 cylinders will be needed to complete the solution stabilization campaign. This number was arrived at as follows: The calciner is planned to be operated 24 h per day, 5 days per week. The total capacity of air in each cylinder is 250 scf, and the nominal flowrate of air to the calciner when it is operating is 40 scfh (Stubbs 1997). Dividing the cylinder capacity by the air flowrate gives 6.25 hours of operation per cylinder or approximately 3.8 cylinders per day. Multiplying the number of cylinders per day (3.8) by the number of days per week of calciner operation (5) and by 52 weeks per year gives a total of 990 cylinders used each year. This number is rounded up to 1000. Multiplying the drop probability (1/100) by the probability the protective cap is off (1/100), by the conditional probability that the drop occurs in such a manner that the exposed supply valve is impacted (1/10), and by the total number of cylinders handled (1000), gives a point probability estimate for the accident of 1.0×10^{-2}.

Based on the two approaches discussed above, and acknowledging uncertainties, the likelihood of the cylinder failure accident inside the facility is estimated to be in the "unlikely" frequency range (between 1.0×10^{-2}/yr and 1.0×10^{-4}/yr).

9.2.9.3.4 Consequence Analysis. In an event where the supply valve on a compressed gas cylinder is sheared off, the cylinder will be accelerated due to the expulsion of compressed gas from the cylinder. The acceleration of the cylinder is proportional to the mass expulsion rate and the velocity of the expelled gases, and is inversely proportional to the mass of the cylinder and its contents. The mass flowrate of air expelled from the cylinder is proportional to the pressure in the cylinder. However, the pressure in the cylinder drops as the gas is expelled per the ideal gas law. Likewise the mass of the cylinder drops as the air is expelled. The momentum and material balance equations for the cylinder are developed in Appendix 9E.

The model in Appendix 9E assumes that the sheared-off supply valve leaves a one-inch diameter hole in the top of the cylinder. The leak path is assumed to have flow characteristics similar to a square-edged orifice. Appendix 9E shows that the flow of air from the cylinder is choked (e.g., limited to sonic velocity) until the pressure in the cylinder drops to 28 psia. The model assumes the cylinder is unconstrained and unconfined (e.g., the cylinder does not lose energy bouncing off or penetrating through objects). Aerodynamic drag forces on the cylinder are ignored.

The key results of the analysis in Appendix 9E are provided in Figure 9-36. Figure 9-36 shows that acceleration of the cylinder is initially very high (266 ft/s^2) and decays in an exponential manner as the air in the cylinder is expended. Figure 9-36 also shows that the cylinder approaches an asymptotic velocity of approximately 166 ft/s 2.8 s after the supply valve is sheared off. At 2.8 s the flow of gas ejected through the orifice drops below sonic velocity. The cylinder is predicted to travel a total of 366 ft over the 2.8 s time frame. The model was not carried beyond 2.8 s due to the diminishing mass ejection rate, gas ejection velocity, and cylinder acceleration.

A compressed air cylinder weighs approximately 138 lb when fully charged and 119 lb empty. A ruptured cylinder can clearly cause serious injuries or fatalities to individuals in the path of the cylinder. From the perspective of the onsite and offsite receptors, however, a significant consequence occurs only if the failed cylinder causes a release of radioactive material to the atmosphere. As discussed previously, the cylinders are connected to the VDC air supply line at a bottle rack located outside room 230C in Corridor 6. The bottle rack holds four cylinders. The cylinders are brought into Corridor 6 through room 171 from the loading dock on the South side of Building 234-5Z or potentially through the loading dock door at the west end of the corridor. Excess cylinders are stored outside the facility.

The most likely scenario is that the cylinder handling accident would occur in room 171 or in corridor 6. The areas of the facility that contain large quantities of radioactive material are protected by reinforced concrete walls with a minimum thickness of 8 inches. The relevant areas for the cylinder accident are the RMC line and the PR-can storage areas. The following calculations show that the failed cylinder will not achieve enough momentum to penetrate into these areas.

The penetration distance of a non-deforming projectile into an infinitely thick concrete wall can be estimated using the following equation developed by the National Defense Research Committee (ASCE 1988):

$$x = \sqrt{4\,K\,N\,W\,d\,b_1}$$

where: x = penetration distance, inches
K = $180/(fc)^{1/2}$
fc = compressive strength of concrete, in psi
N = nose factor
= 0.72 for flat nose

= 0.84 for blunt nose
= 1.0 for spherical nose
= 1.14 for pointed nose
W = weight of projectile, lbs
d = diameter of projectile, inches
$b_1 = (v/(1000*d))^{1.8}$
v = velocity at impact, ft/s

This equation is valid when $x/d < 2$. It will be shown that $x/d < 2$ in this case.

The penetration depth for the infinitely thick wall, estimated using the above equation, can in turn be used to estimate the maximum perforation thickness and scabbing thickness. The perforation thickness is the maximum target thickness that the projectile at the given velocity will completely penetrate. The scabbing thickness is the thickness required to prevent spalling of material from the rear face of the target.

The following equations for estimating the perforation and scabbing thicknesses have been proposed (ASCE 1988):

$$e/d = 3.19(x/d) - 0.718(x/d)^2, \text{ for } x/d < 1.35$$

$$s/d = 7.19(x/d) - 5.06(x/d)^2, \text{ for } x/d < 0.65$$

where: e = perforation thickness, inches
s = scabbing thickness, inches

Figure 9-36 shows that the cylinder requires room to build up momentum. To reach a velocity of 80 ft/s (approximately 50% of the cylinder's maximum velocity), the cylinder has to travel, unimpeded, a distance of approximately 16 ft. To reach a velocity of 123 ft/s (approximately 75% of the cylinder's maximum velocity), the cylinder must travel, unimpeded, a distance of approximately 56 ft (from Appendix 9E, Table 9E-1). Because of the tight spaces in which the accident is likely to occur (room 171 and corridor 6 are less than 15 ft wide and tall), the cylinder would be expected to impact and reflect off the walls, floor, or ceiling a short distance from where the missile originated. Multiple, glancing blows are likely with each impact limiting the missile's momentum. For this analysis, the cylinder is conservatively assumed to reach a speed of 123 ft/s (75% of its maximum speed) before striking a wall. The compressive strength of concrete, fc, ranges from 3000 to 4000 psi. The lower value of 3000 psi is conservatively applied here. The cylinder has a flat bottom so a value of 0.72 is used for N. The weight of the cylinder (conservatively ignoring its contained air) is 119 lbs. The diameter of the cylinder is 9 in. The penetration distance (x), perforation thickness (e), and scabbing thickness (s) are therefore calculated as follows:

$$K = 180/(3000)^{1/2} = 3.29$$

$$b_1 = [(123 \text{ ft/s})/((1000)(9))]^{1.8} = 4.41 \times 10^{-4}$$

$$x = [(4)(3.29)(0.72)(119)(9)(4.41 \times 10^{-4})]^{1/2} = 2.12 \text{ in.}$$

$$x/d = 2.12/9 = 0.235$$

$$e = [3.19(2.12/9) - 0.718(2.12/9)^2](9) = 6.4 \text{ in.}$$

$$s = [7.91(2.12/9) - 5.06(2.12/9)^2](9) = 14.2 \text{ in.}$$

The above equations are based on impact tests with non-deformable missiles (armor-piercing projectiles). Being hollow, the gas cylinder would be expected to deform considerably in impacts at high speed. The minimum thickness of the concrete walls protecting the RMC line and PR-can storage areas is 8 in. Given the conservatisms in the above analysis, it is concluded that the cylinder will not perforate the walls, although back face scabbing can be expected.

The dense metal doors on the south wall of the RMC line area and on the north wall of the PR-can storage rooms 174 and 175 are expected to also provide adequate resistance to perforation. The doors are subject only to glancing impacts at limited speeds due to the factors discussed previously. The doors open out into the corridor and are thus well supported against impacts from the corridor side. There is no door in the RMC line south wall that is lined up with room 171 that could be subjected to a head-on impact.

Based on the above assessments, it is concluded that the most likely outcome should a compressed gas cylinder become a missile in corridor 6 is for the cylinder to ricochet down the corridor in either an east or west direction. Depending on direction, the cylinder is likely to penetrate through the doors separating corridor 6 from corridor 5 or corridor 7. Worker injuries in the corridors or adjacent offices not protected by thick concrete walls are possible. Because the gloveboxes and Pu storage areas in the plant are protected behind thick concrete walls that can withstand the maximum cylinder velocity, no significant radiological release within the facility is expected. Penetration of the doors separating corridors 5 and 7 from corridor 6 will cause only minor ventilation imbalances within the facility.

The potential for the cylinder to penetrate through the ceiling and cause damage in the duct level has not yet been evaluated. Use of the Production VDC to stabilize Pu-bearing solutions, however, is not currently authorized. An evaluation of the damage potential in the duct level will be added to the FSAR before use of the Production VDC is authorized.

9.2.9.3.5 Conclusions. Cylinder ruptures or handling accidents that result in the cylinders being propelled as missiles can cause severe worker injuries or fatalities. Strict adherence to the Compressed Gas Association guidelines and plant procedures regarding the storage, handling, and use of compressed air cylinders is vital to minimize facility worker risk.

Significant releases of radiological material outside the plant are not expected in a compressed air cylinder missile accident.

9.2.9.4 Glovebox HC-230C-2 Seismic Release. The plutonium-bearing solution stabilization equipment (known as the Production VDC) and Glovebox HC-230C-2

were added to the RMC Line after the seismic analysis contained in Section 9.2.4 was developed. Glovebox HC-230C-2 contains considerable quantities of $Pu(NO_3)_4$ and PuO_2 when in use and has the potential to add significantly to the total release from the facility in a seismic event. The analysis presented in this section estimates the potential release from Glovebox HC-230C-2 in a seismic event and compares this release with the releases estimated for the remainder of the PFP facility in Section 9.2.4. The estimated release for Glovebox HC-230C-2 has been factored into the dispersion and dose analyses in Section 9.2.4.

9.2.9.4.1 Scenario. The equipment in Glovebox HC-230C-2 and the solution stabilization process using the Production VDC are described in detail in Chapter 5.0, Section 5.2.1.2 and Chapter 6.0, Section 6.4.1, respectively. Glovebox HC-230C-2 contains the Production VDC, storage tanks for plutonium nitrate feed solution and nitric acid flush solution, a scrubber to treat the offgas stream from the calciner, a phase separator tank, and spent scrub solution receiver tanks. The calciner, scrubber, and phase separator are connected to the plant process vacuum system. The process vacuum system is supplied with a vacuum trap inside the glovebox to prevent carryover of liquid into the E-4 exhaust system. Treated offgases from the Production VDC pass through the process vacuum system into the E-4 exhaust system. With the exception of the Production VDC, the vessels inside the glovebox are made out of glass pipe to allow visual monitoring of tank liquid and solids levels. Glovebox air is supplied through conveyor Glovebox HC-3. Conveyor Glovebox HC-3 connects the glovebox to the rest of the RMC line. Glovebox air is exhausted through the E-4 ventilation system.

The potential combination of failures possible in a large earthquake are numerous. The seismic event can cause failure of some vessels and transfer lines while other vessels and lines can remain intact. The seismic event can fail some utilities (e.g., plant vacuum system) while leaving other utilities running (e.g., compressed process air). Active components like pumps can fail or can continue to operate. Partial or total loss of power is possible. To determine the potential combination of failures that are likely in a seismic event, it is first necessary to examine the seismic qualification of the items of concern.

The Glovebox HC-230C-2 structure is qualified to withstand the effects of a 0.2 g seismic event (DBE) without toppling. The primary benefit of seismically qualifying the glovebox is that it ensures the glovebox does not fall on a corner or edge and provide a potential collection volume for spilled solutions, powders and fire water (that may infiltrate into the glovebox in an earthquake). The seismically qualified glovebox design and the glovebox's criticality drain preclude the potential for a DBE-induced criticality. The E-4 ductwork connection to the glovebox is designed to shear in a 0.2 g seismic event to prevent loads from being transmitted to the glovebox. Similarly, the HC-3 Conveyor Glovebox is not qualified for an earthquake larger than UBC size and may fail providing a leakage path to Room 230C for Pu material released inside the glovebox. The interface between Glovebox HC-230C-2 and the HC-3 Conveyor Glovebox has been evaluated to verify that movement of the HC-3 Conveyor Glovebox will not compromise the seismic qualification of Glovebox HC-230C-2.

The tank supports and piping inside the glovebox are designed to UBC seismic requirements. The glass tanks are not specifically qualified to withstand seismic forces. It is therefore assumed in this analysis that the glass tanks are vulnerable to rupture due either to the direct loads imparted in the seismic event or due to pipe whip interaction.

None of the utilities feeding Glovebox HC-230C-2 (i.e., plant process vacuum, plant process air, compressed instrument air, and electrical power) are specifically qualified for the 0.2 g DBE. It is possible for these to fail or to continue operating after the seismic event.

The most important item in Glovebox HC-230C-2, from an accidental release perspective, is the Production VDC. By design it produces fine PuO_2 powder. Normally, the powder is confined to the calciner vessel. In the seismic event, the worst-case scenario for the calciner is that it loses process vacuum but continues to receive feed from an intact feed pump tank and continues to receive atomizing air feed through the injector nozzle. The water vapor flashed from the oxide bed in the calciner and the flow of atomizing air will result in pressurization of the calciner and the release of PuO_2 powder through the calciner relief port into the glovebox air. If software interlocks designed to shut down the calciner on high pressure fail in the seismic event, PuO_2 powder could be lofted continually through the relief path. Continuous feed of atomizing air to the calciner could sparge the PuO_2 bed in the calciner resulting in continuous release of powder through the relief port even after the feed pump tank was pumped dry. Continuous operation of the calciner agitator would contribute to the release of powder through the relief port.

A calciner pressurization event caused by a loss of calciner vacuum is evaluated in Section 9.1.10.1. The release in that abnormal event is postulated to occur over a 30 minute time frame before being shut down by operators. Because operators will evacuate the PFP in a seismic event and may not reenter for some time, the continuous release from the calciner after a seismic event could occur over a much longer time frame (e.g., 24 hours). At the nominal feed rate of 2.5 L/h, the 10 L feed pump tank would take 4 hours to drain. Hence, the potential release from a pressurized calciner in the seismic event could be at least eight times higher than estimated in Section 9.1.10.1, with continued flow of atomizing air and continued operation burning contaminated rags, polyjars, etc., would be expected to be very small in comparison to the conservatively estimated splatter and resuspension releases in this analysis and is therefore not specifically modelled.

Regarding potential chemical releases, two chemical sources are relevant to the plutonium-bearing solution stabilization process using the Production VDC: the 55-gal drum of NaOH used to feed the caustic scrubber, and the nitric acid that could be contained in the chem add and flush tanks (combined volume of 14 L) at the time of the accident. Both sources could be spilled and resuspended in a similar manner to the $Pu(NO_3)_4$ solution spilled in Glovebox HC-230C-2. However, the airborne release quantities from resuspension would be very small and would not pose a significant health threat to persons outside the plant, especially after being diluted with other air from the plant before being released through the 291-Z-1 exhaust stack or building doors. The consequences outside the plant from a spill of 55 gal of caustic or 14 L of nitric acid would clearly be negligible in comparison to the

receptor exposures estimated for the postulated spill of the 5000 gal outdoor nitric acid tank in a seismic event in Section 9.2.8. That spill is shown to have airborne concentrations below guidelines even for an event with an annual frequency of 1. The consequences of seismic-induced spill of the NaOH and nitric acid supplies to Glovebox HC-230C-2 are therefore not addressed further in this analysis.

9.2.9.4.2 Mitigation. The 234-5Z Building has been shown by analysis to survive the loads of a 0.25 g seismic event with minimal damage (see Section 9.2.4.1). The RMC line concrete walls and vault-like doors experience limited bending (URS 1987) and will not fail in the seismic event. The seismic qualification of the 234-5Z Building and the RMC line walls and doors ensures that releases inside the RMC line rooms remain confined to those rooms in the "no ventilation" case, as discussed in Section 9.2.4.7.1. The seismic shutdown interlock on the building supply fans prevents the pressurization of the RMC line rooms (such as Room 230C containing Glovebox HC-230C-2) and prevents the spread of contamination from those rooms to other areas of the plant.

The potential release from the Production VDC is limited by its seismic shutdown system. As discussed above, the calciner seismic shutdown shuts off liquid feed, atomizing air, and filter back pulsing air. This eliminates driving mechanisms which could continually force PuO_2 powder through the calciner relief path following a seismic event.

The Glovebox HC-230C-2 supports are bolted to the floor and designed to withstand DBE forces. This ensures the glovebox will not topple in the DBE. The interface between the qualified glovebox and the unqualified HC-3 Conveyor has been assessed to ensure the response of the HC-3 Conveyor in the seismic event will not compromise the seismic qualification of Glovebox HC-230C-2. Glovebox HC-230C-2 is provided with a criticality drain sized to handle potential infiltration of water from the building fire suppression system in the seismic event. DBE-induced criticalities are precluded in Glovebox HC-230C-2 because of the seismic qualification of the glovebox, the presence of the criticality drain, and administrative controls on fissile inventory in the glovebox.

The potential magnitude of a post-DBE fire in glovebox HC-230C-2 is limited by the metal design of the glovebox, the use of fire resistant Lexan™ and wire reinforced glass windows in the glovebox and the limited quantity of transient combustibles needed in the glovebox to perform calciner operations.

9.2.9.4.3 Probability. The annual probability of the 0.20 g earthquake is shown in Section 9.2.4 to be 1.0×10^{-4} (see Table 9-29). The tank and calciner vessel failures postulated in this analysis are conservatively assumed to occur with a conditional probability of 1, given the occurrence of a 0.2 g level earthquake.

Failure of the calciner seismic shutdown interlock system concurrent with a 0.2 g seismic event is considered to be incredible (i.e. to have a combined annual probability $< 1.0 \times 10^{-6}$). Seismic switches and electrical relays are highly reliable, with failure rates of 6.7×10^{-7}/h (IEEE 1984) and 7.6×10^{-5}/demand (SAIC 1989), respectively. The most likely way for the seismic interlock system to fail is for the air supplies to the calciner to

remain flowing due to failure of the solenoid operated valves on the atomizing air and back pulsing air lines. The failure rate for solenoid valves (failure to close on demand) is 2.8×10^{-3}/demand (SAIC 1989). Combined with the 1.0×10^{-4} annual probability of the earthquake, the probability of failure to shut off the two air supplies in the large seismic event is $(5.6 \times 10^{-7}) \times [(1.0 \times 10^{-4})(2 \text{ valves})(2.8 \times 10^{-3} \text{ valve failure/demand})]$. The seismic shutdown interlock system is therefore credited to work as intended in this analysis.

9.2.9.4.4 Source Term Analysis. The airborne releases from spilled $Pu(NO_3)_4$ solutions and exposed PuO_2 powders within the compromised glovebox HC-230C-2 are quantified separately below. The total release from glovebox HC-230C-2 is then compared to the sum of the estimated releases for the remainder of the 234-5Z building from Section 9.2.4.

Airborne Releases from Spilled Solutions. Should the glass tanks in glovebox HC-230C-2 rupture in the seismic event, the spilled solutions from the tanks will produce an initial "puff" release caused by splatter of liquid off of equipment in the glovebox and the glovebox floor. The splatter release will be followed by a long term resuspension release due to air flowing over the surface of the spilled solution.

For the splatter release, an airborne respirable release fraction (ARRF) of 2.0×10^{-5} is used. This is the bounding ARRF recommended in DOE-HDBK-3010-94, (DOE 1994), *Airborne Release Fractions/Rates and Respirable Fractions For Nonreactor Nuclear Facilities*, Section 3.0 for free-fall spills of concentrated heavy metal solutions. This release fraction is very conservative because it is based on free-fall spills of solution from 3 m, a height that is much higher than is possible for spills from tanks inside glovebox HC-230C-2. The total capacity of the feed receipt and the feed pump tanks is 20 L (10 L apiece). It is conservatively assumed that each tank contains the maximum allowed concentration of 450 g/L. The total Pu splatter release from the two tanks is therefore:

Release from Open Slip-Lid Can. For the open slip-lid can, there is short-term release due to sliding and impacting of the can with other objects in the glovebox, followed by a longer term resuspension release. To estimate the short-term release, the 1 m free-fall powder release fraction of 4.0×10^{-5} is once again utilized. As with resuspension of the powder spilled from the calciner, only the top layer of powder contained in the can (assume 10%) is subject to release from seismic motion. Applying the free fall spill release fraction to the top 10 % of the powder in the open can should give very conservative results as the shearing forces on a slug of fine powder free falling over a distance of 1 m would seem to be much greater than the deagglomeration forces exerted on the top layer of powder in an open can sliding around in the bottom of the glovebox for a short period of time associated with a seismic event. For resuspension in the glovebox air after cessation of seismic motion, the resuspension release rate of 4×10^{-5}/h from above is once again used.

The capacity of the slip-lid can is 0.5 L. The maximum plutonium density in the calcined product allowed by the CSER for the Production VDC (Hillesland 1997) is 5.5 kg/L. The Pu inventory in the can is therefore 2.75 kg.

Applying the free fall and resuspension release fractions to the top 10% of the powder in the can gives a total release over 24 hours of:

$$\text{Release, open can} = (2750\ \text{g})(0.1)[4 \times 10^{-5} + (4 \times 10^{-5}/\text{h})(24\ \text{h})]$$

$$= 0.28\ \text{g}$$

Release from Broken Collection Jar. This release is estimated in the same way as the open slip-lid can case. The capacity of the jar is approximately 0.75 L. At the maximum plutonium density allowed for the calcined powder in the CSER of 5.5 kg/L, the total inventory of Pu in the jar is 4.125 kg. The total release over 24 hours is:

$$\text{Release, broken jar} = (4125\ \text{g})(0.1)[4 \times 10^{-5} + (4 \times 10^{-5}/\text{h})(24\ \text{h})]$$

$$= 0.41\ \text{g}$$

Total Airborne Seismic Release from Glovebox HC-230C-2. The total of the respirable airborne releases from $Pu(NO_3)_4$ solutions and exposed PuO_2 powders in Glovebox HC-230C-2 is 1.64 g (0.27 g + 0.68 g + 0.28 g + 0.41 g). This compares to the total release estimated in Section 9.2.4 for all the PFP facilities of 15.3 g (see Table 9-31).

9.2.9.4.5 Dose Analysis. The release from Glovebox HC-230C-2 does not factor into the "no ventilation" case seismic release discussed in Section 9.2.4.7.1, as the release would remain confined within the RMC line walls and would not be available to be swept from the building in wind blowing through the facility through open evacuation doors. The release from Glovebox HC-230C-2 would, however, add to the release in the "ventilation" case discussed in Section 9.2.4.7.2 because the release, along with releases from the other RMC line gloveboxes, would be drawn through the E-3 and E-4 exhaust systems and expelled, unfiltered, through the 291-Z-1 exhaust stack. The E-3 and E-4 filters are assumed to fail in the seismic event.

The release model in the ventilation case analysis (Section 9.2.4.7.2) includes gravitational settling of material within the building before release out the 291-Z-1 exhaust stack. Assuming the same particle size distribution for the material released from Glovebox HC-230C-2 as for the releases from the other RMC line gloveboxes, the percentage of the Glovebox HC-230C-2 release deposited in the facility due to gravity settling will be the same as for the releases from the remainder of Building 234-5Z. Section 9.2.4.7.2 shows that 16% of the material released within the facility will gravity settle out before discharge through the 291-Z-1 exhaust stack. Therefore of the 1.64 g released from Glovebox HC-230C-2, 1.38 g will be emitted from the stack to the environment.

The onsite and offsite receptor doses are estimated using the atmospheric dispersion and dose models presented in Section 9.3. The release from Glovebox HC-230C-2 is conservatively assumed to be composed of an isotopic mixture containing >10% ^{240}Pu. This is conservative because the majority of

the Pu to be processed by the vertical denitration calciner contains <10% ^{240}Pu, which has a lower unit dose factor. A discussion on the isotopic composition of Pu contained in the PFP is contained in Section 9.3.5. Of the 1.38 g released from the facility 0.23 g originates from $Pu(NO_3)_4$ solutions. The unit dose factors corresponding to class W lung retention from Table 9-46 are used to estimate inhalation doses for this portion of the release. The unit dose factors from Table 9-46 corresponding to class Y lung retention are used to estimate the inhalation doses associated with the remaining oxide portion of the release.

The onsite and offsite receptor EDE dose estimates corresponding to the seismic release from Glovebox HC-230C-2 are summarized in Table 9-58 and are 0.67 and 0.24 rem, respectively. The onsite and offsite receptor dose estimates for the base case seismic event (ventilation case) from Section 9.2.4 are summarized in Table 9-33. Adding the Glovebox HC-230C-2 dose estimates to the base case estimates gives onsite and offsite EDE exposures of 7.5 and 2.0 rem, respectively. The combined doses are below the previously approved onsite and offsite doses reported in prior revisions of the FSAR. The total seismic dose estimates, with the Glovebox HC-230C-2 release included, are below the previously approved estimates due to reductions in maximum dispersible inventory limits in several gloveboxes.

9.2.9.5 Changes to the RMC Line Fire Analysis from Glovebox HC-230C-2. Glovebox HC-230C-2 is located at the West end of the RMC line. The hazards analysis for the Pu-bearing solution stabilization process postulates that the RMC line fire evaluated in Section 9.2.2A possibly spread to Glovebox HC-230C-2 by consuming the plastic panels in the HC-2 and HC-3 conveyors. An airlock, however, is located in the between the HC-2 and HC-3 conveyors in Room 230B. The airlock doors are kept closed except during short time periods when materials are being transferred from the HC-2 to HC-3 conveyors. The airlock doors are kept closed to ensure proper operation of the glovebox dry fire suppression systems in the RMC line. The airlock doors and the walls of the conveyor between both airlock doors are constructed of metal. The RMC line fire analyzed in Section 9.2.2A has a duration of 40 minutes. The time frame over which the airlock would be subjected to the heat of the fire would be much less. The airlock is thus assumed to remain intact during the fire, preventing spread of the fire to Glovebox HC-230C-2. This assumption is consistent with the PFP Fire Hazards Analysis (McKinnis 1998) that credits the airlock with preventing the spread of fire. It is concluded that Glovebox HC-230C-2 will not add source term to the RMC line fire accident.

9.2.10 Accidents for Reactive Plutonium-Bearing Material Stabilization Operations.

The following sections develop the bounding accident scenarios postulated for the thermal stabilization of plutonium oxide process in glove boxes HC-21A, HC-2, HC-21C, HC-3, HC-4, HA-21I, HC-18BS, and HC-18M. The accident scenarios for analysis were identified based on categorization and screening of the PHAs contained in Appendices 9F and 9G. The accident categories were screened from the PHAs shown in Tables 9F.23, 9G.4, 9G.8, 9G.9, 9G.13, and 9G.20 and are discussed in Appendices 9F, Section 9F.4.3.3, and 9G, Section 9G.4.2, respectively. The same catgories also apply to seal-in/seal-out operations in glovebox HC-13MD and thermal stabilization operations in

gloveboxes HA-28 and HA-22B. The hazard analysis and accident categories for stabilization of plutonium metals are presented in HNF-4823, Hazards Evalauation of Plutonium Metal Opening and Stabilization (FDH 1999). The accident categories represent types of events associated with the thermal stabilization operations that have the potential to breach confinement barriers, resulting in significant spread of radiological or toxicological material from the building to the atmosphere. Each of the accident categories from Tables 9F.23, 9G.4, 9G.8, 9G.9, 9G.13, and 9G.20 are discussed below in alphabetical order of accident category. New detailed accident analyses are provided in Sections 9.2.10.1 through 9.2.10.5 for accident categories not found to be adequately represented by the prior analyses contained in Sections 9.2.1 through 9.2.9.

Criticality:

Relatively large masses of plutonium are handled during thermal stabilization activities. Placing enough material in a glovebox or having sufficient material in a non-safe geometry due to human error could result in a criticality. Therefore, without controls, criticalities are possible within Gloveboxes HC-21A, HC-21C, HC-1, HC-2, HC-13MD, HC-3, HC-4, HA-21I, HC-18BS, HA-28, HA-22B, and HC-18M. Controls to prevent criticalities include administratively controlled mass and spacing limits within the gloveboxes, hardware to physically separate containers of Pu oxide, exclusion of water in the gloveboxes, and limiting the number and size of containers allowed in each glovebox. The specific controls that provide double-contingency protection against criticalities in the various gloveboxes used for thermal stabilization are specified in the following CSERs (listed by gloveboxes):

- HC-1, HC-2, HA-22B — CSAR 81-007 (RHO 1981)
- HC-4 and HA-28 — CSAR 80-022 (RHO 1980)
- HC-13MD — CSAR 79-015 (RHO 1979)
- HC-18M — CSER 98-005 (HNF-1998c)
- HC-18BS — CSER 98-004 (HNF 1998b)
- HC-21A — CSERs 98-003 (HNF 1998a), 99-002 (HNF 1999), 99-007 (HNF 1999a), and 00-002 (HNF 2000)
- HC-21C — CSERs 94-007 (WHC 1994), 99-002 (HNF 1999), and 99-007 (HNF 1999a)
- HA-21I — CSER 99-007 (HNF 1999a).

It is assumed that the Criticality Prevention Program requirements for PFP (including the above referenced CSERs) are adequate to ensure criticality safety.

External Events - Aircraft Crash, Facility Wide Power Loss, and Range Fire:

Aircraft Crash: Aircraft accidents involving the PFP are evaluated in Section 9.2.7. The frequency of a commercial or military aircraft accident involving the PFP was determined for several of the most credible or consequential categories of overflights. Using available data, the frequency of a commercial or military aircraft accident involving the PFP has been

determined to have a total value of less than 1.0×10^{-7}/yr, indicating that the event is not credible. Helicopters are also occasionally used to perform radiological surveys of the Hanford Site. A helicopter crash into the PFP is determined in Section 9.2.7 to not be credible as long as helicopters do not operate in a square 2,300 feet on a side centered on the 291-Z-1 stack. Therefore this event is not evaluated further for the thermal stabilization process.

Facility Wide Loss of Power: The PFP facility power loss can occur from many causes. Loss of power could be caused by grid collapses, lightning strikes, ice storms, high wind, range fires (see below), aircraft striking high voltage power lines, switch gear failure, and human error. A loss of ventilation would occur if both the supply fans and exhaust fans were to simultaneously lose power. This would occur only during a simultaneous loss of two electrical circuits and the backup power supply.

There are two concerns that result from a 234-5Z facility wide loss of power, both of which involve the loss of ventilation. The first is loss of confinement. Even if all ventilation were lost, the consequences were determined to be acceptable (Chapter 9.0, Section 9.1.8). The addition of the plutonium oxide thermal stabilization process does not introduce any new considerations for the loss of confinement caused by a ventilation failure event as compared to existing analysis. The second concern is the potential for accumulation of flammable gasses (ethylene) if plastic material is present in a furnace boat being thermally stabilized in a furnace in either glovebox HC-21C or glovebox HA-21I and ventilation flow is lost due to a facility wide loss of power. Analysis of deflagrations are presented in section 9.2.10.2.

Range Fire: Vegetation is removed routinely within and adjacent to the PFP site fencing for security purposes. This creates a large area devoid of material capable of allowing a fire to get within close proximity to the PFP. Also, the nature of the desert vegetation surrounding the 234-5Z coupled with the large vegetation control area does not support the presence of airborne embers capable of igniting the roof of the facility.

However, range fires do create conditions where loss of site power can occur. Although the main Hanford Site electrical system that provides power to the 200 Areas is carried on metal towers, the distribution of that power to various locations in the 200 areas is on wood poles. These poles are vulnerable to fire damage that could cause failure of the pole structure with resulting line faults and power loss. In addition, electrically conductive smoke can cause power lines to short to ground even if the wooden poles or metal towers are not significantly damaged in the fire. Therefore, range fires are a way of initiating failures discussed under Loss of Power above.

Flammable Gas Deflagration In Glove Box:

Deflagrations are postulated to occur in gloveboxes from several causes. The magnitude of the deflagration is postulated to be sufficient to cause releases that could severely impact the facility worker. In glovebox HC-21A there is a potential for a radiolysis created hydrogen gas release and subsequent burn when a plutonium oxide containing can is opened. Opening a can containing organics caused by an incorrect container being selected as a result of erroneous labeling or human error can also result in hydrogen

release and ignition. A burn of flammable gas upon opening Pu containers in Glovebox HC-21A is evaluated in detail in Section 9.2.10.1. In glovebox HC-21C or HA-21I, flammable gas can be generated and ignited if plastic contaminants are allowed to be heated in the thermal stabilization furnace because they are not identified and removed from the plutonium oxide feed. Loss of offgas flow through the stabilization furnace during heat up is required for flammable gases to build up in the furnace. Loss of offgas flow is possible during normal operation or during a seismic event. A flammable gas deflagration in the Glovebox HC-21C or HA-21I furnaces during normal operation is evaluated in detail in Section 9.2.10.2. A seismically induced flammable gas deflagration is analyzed in Section 9.2.10.3.

Loss of Glovebox Confinement Due To Ventilation Failure:

This category includes all failure scenarios not covered by other specific accident analyses that can result in the spread of radiological material from the gloveboxes associated with the plutonium oxide thermal stabilization process. Postulated scenarios include pressurization of the glovebox due to an imbalance between the ventilation supply and exhaust on the RMS line, stagnation of the gloveboxes due to complete ventilation failure (not associated with power loss), and overheating the HC-21C or HA-21I glovebox due to a lack of heat removal caused by inadequate ventilation flow. The worst-case pressurization scenario is a scenario where the E-4 exhaust system is shutdown but the supply air to the RMC continues to be present. Interlocks are provided between the glovebox supply and exhaust systems to prevent this from occurring. Pressure indication is provided to warn operators of an overpressurized glovebox. CAMs strategically located in rooms 230C and 235B will also alert operators to an airborne contamination hazard.

The potential release of contamination from the pressurized glovebox to Zone 3 could be expected to be similar to the powder spill addressed in Section 9.1.3 or to the conservative pressurized powder release analyzed in Section 9.1.4. The release from the glovebox would be filtered by the E-3 system and the consequences outside the facility would be negligible, as with the events addressed in Sections 9.1.3 and 9.1.4. No further evaluation of this accident category was therefore judged to be necessary. The pressurized glovebox case bounds the stagnant glovebox case.

Overheating the glovebox can result in loss of confinement from several different causes. Port bags, gloves, and viewing windows can be failed due to overheating which have the potential for creating large openings through which radioactive material can escape. Activation of the glovebox dry fire suppression system in a glovebox overheating scenario could contribute to expulsion of radiological material from the compromised glovebox. The glovebox (E-4) ventilation is designated safety significant in Chapter 4, (Table 4-7). This system is connected to backup power and is considered sufficiently reliable to protect glovebox HC-21C or HA-21I from overheat damage. An interlock is also provided to shut down the furnaces on detection of high temperature in the glovebox.

Natural Phenomena - Seismic, Ashfall, And High Wind:

Seismic: The Pu inventory in the glove boxes used for thermal stabilization potentially adds to the total facility source term in the seismic event.

Ashfall: A volcanic ashfall is considered to be a potentially occurring natural phenomenon in the same category with tornado and earthquake. With an appropriate wind pattern, the cloud of ash form a volcanic eruption could be directed toward the PFP.

Ash causes three immediate concerns to the PFP safety. The ash is extremely abrasive to any exposed mechanical equipment, ash may cause pluggage problems with the ventilation system, and heavy accumulations on top of the facility may exceed roof loading limits. Chapter 5.0, Section 5.2 states that the 234-5Z Building was analyzed and found to acceptably resist combined volcanic ashfall and snowfall (Giller 1990).

In the event of ashfall at the PFP, most exterior equipment that would be exposed to the abrasiveness of the ash would be shut down, including the vehicles such as the process and sample trucks. Normal ventilation may be maintainable during an ashfall, however, it may be necessary to shut down normal ventilation and utilize emergency ventilation fans. It also may become necessary for the PFP personnel to clear the roof of the ash before excessive buildup occurs. This action is included in the plant emergency planning for response to volcanic eruption.

The PFP FSAR did not develop consequence calculations for an ashfall. This was based on two considerations, first the ability to take corrective action before roof loading became a problem and second, with regard to ventilation, the assumption that some level of ventilation could be maintained during the ashfall event. However, even if all ventilation were lost, the consequences were determined to be acceptable (Chapter 9.0, Section 9.1.8). The addition of the thermal stabilization process does not introduce any new considerations for the loss of ventilation event as compared to existing analysis.

An ashfall event can also cause a loss of power which has the potential to lead to a loss of offgas flow through the thermal stabilization furnaces. Loss of offgas flow has been postulated as a cause of a flammable gas deflagration in the furnace. The loss of offgas flow accident is covered in Section 9.2.10.2. An ashfall event is characteristically a slow developing event at any appreciable distance from the volcanic eruption that causes it. Emergency response as a result of an ashfall event would result in processes in PFP being shutdown and placed in a safe condition. Sufficient time would be available to shutdown the thermal stabilization furnaces so that the likelihood of glovebox overheating and potential flammable gas deflagrations would be minimized. The availability of backup power for ventilation would reduce even further the likelihood of ashfall induced ventilation failures resulting in glovebox overheating or flammable gas deflagration.

High Wind: The PFP has been evaluated for capability to withstand high winds. It was determined that the facility could withstand the 90 mi/h wind called for in the Hanford Site design criteria document. The analyses referenced in Section 5.2.1.1.2 of the PFP FSAR show that the main load-bearing structure is not over stressed by the extreme wind or adversely

impacted by the design criteria specified plank traveling at 50 mi/h. Section 9.2.5 evaluated the effect of high wind on the PFP. It was concluded that only facilities and components exterior to the 234-5Z facility would be vulnerable to high wind effects. The location of glove boxes for thermal stabilization activities precludes any affect from the wind or wind driven missiles. High wind is also a potential initiator for loss of facility power. Loss of power has the potential to lead to a loss of glovebox ventilation and stabilization furnace offgas flow with subsequent glovebox overheating or flammable gas deflagration. The loss of offgas flow accident is covered in Section 9.2.10.2.

Pyrophoric Reaction in Glove Box:

The PHA analyses identified one event involving pyrophoric reaction causing slight pressurization of the glovebox. This could only occur if significant hydride contamination was present in the Pu oxide material being processed. The glovebox ventilation system (E-4) would have to fail for significant quantities of material to escape from the glovebox. This event is considered to be bounded by the loss of glovebox confinement event.

Rupture of Container In Storage Vault:

The PHA analyses identified numerous process upsets and failures that could result in inadequately stabilized plutonium oxide. If the inadequately stabilized oxide is not detected before sealing up the powder in Hanford Site convenience cans, the cans could rupture in storage due to internal pressurization. A reaction between absorbed water and plutonium oxide produces hydrogen gas that can cause overpressurization of the can. This accident is not unique to the thermal stabilization process as oxides that have been dried in furnaces in other PFP glove boxes have the same potential to overpressurize canisters. Instrumentation is provided in the storage vault pedestals to detect bulging cans. Should a canister rupture while being handled within the 234-5Z Building, any released plutonium oxide would be drawn through the E-3 ventilation exhaust system and filtered. In the Building 2736-Z storage vaults, the release from a ruptured can would be confined and filtered by the vault ventilation system. The consequences outside the plant would be negligible. The potential consequences of an overpressurized storage container are developed in Section 9.1.4. No further analysis was deemed to be necessary for this accident bin.

Uncontrolled Fire In Glove Box:

An uncontrolled fire in a glovebox associated with the thermal stabilization of plutonium oxide process can occur only if an ignition source is combined with a combustible material supply. These ignition sources would normally be associated with the thermal stabilization furnaces located in gloveboxes HC-21C and HA-21I. The amount of combustible material available determines the potential severity of such a fire. Combustible loading in the gloveboxes is limited to cartons used to bag cans in and out, rags, gloves, wire insulation, and equipment grease. However, portions of the RMC line have large Lucite (PMMA) viewing panels, which represent a significant quantity of combustible material. Two general types of events could result in glovebox fires. The first is errors that bring combustible materials in contact with the hot furnace surfaces. The second is combustible materials being brought

into contact with hot furnace surfaces by seismic events. Both of these scenarios are developed in Sections 9.2.10.4 and 9.2.10.5 respectively.

9.2.10.1 Hydrogen Deflagration in Glovebox HC-21A from Opening Pressurized Containers. Plutonium storage containers are opened in Glovebox HC-21A. Flammable gases, primarily hydrogen, may be present in these containers due to the thermal and radiolytic decomposition of plastic packaging materials and moisture. As shown in the following analysis, the release and subsequent ignition of the hydrogen potentially present in the specific plutonium storage containers to be processed in Glovebox HC-21A does not result in a breach of the glovebox.

9.2.10.1.1 Scenario. Plutonium is stored in multiple overpack containers using standard food-pack cans. Stored plutonium oxide may be contained in two, three, or four nested containers. In all cases, the outer container is a crimp-sealed, 7-Inch Can (see Figure 6-10).

The generation of hydrogen can result in pressurized containers. Pressurization criteria have been developed that correlate storage can deformation to internal can pressure, as shown in Figure 9-37. For the thermal stabilization of reactive plutonium-bearing material, only Type A or B Cans will processed and, therefore, opened in Glovebox HC-21A.

For the purposes of this analysis, it is assumed that a Type D Can pressurized to 30 psig is inadvertently placed in glovebox HC-21A and opened. Type D Cans are defined as having a pressure in the range of 20 to 40 psig. In terms of physical appearance, a Type D Can has either a lid that protrudes outward showing severe signs of stress or has several ripples in the lid. A value of 30 psig was chosen for analysis because containers may vent at their seams beginning at a pressure of 30 psig.

Given a pressure of 30 psig, the quantity of gas in a container can be calculated using the Ideal Gas Law:

$$PV = nRT$$

where: P = pressure, atm
V = volume, L
T = absolute temperature, K
n = number of moles
R = universal gas constant, 0.0825 atm liter/mol K

The volume of a 7-Inch Can is 1.5 L. Some fraction of this volume will be filled by the plutonium oxide, inner can or cans, and packaging materials. Accounting for these items, it is estimated that the free volume within the 7-Inch Can is 1.25 L.

Given a free volume of 1.25 L and assuming a temperature of 300 K, the number of moles of gas present at a pressure of 30 psig is:

$n = [(44.7 \text{ psia})(1 \text{ atm}/14.7 \text{ psia})](1.25 \text{ L})/(0.0825 \text{ atm-L/mol-k})(300 \text{ K})$

$n = 0.15$ moles

The 0.15 moles of gas in the 7-Inch Can at 30 psig is comprised of the hydrogen generated by thermal and radiolytic decomposition of plastic packaging materials and moisture and the air initially present in the container. Applying the Ideal Gas Law, the quantity of air in the can before pressurization can be shown to be 0.05 moles. Therefore, the 7-Inch Can contains 0.05 moles of air and 0.10 moles of hydrogen at the time it is opened.

Plutonium storage containers are opened in Glovebox HC-21A by use of an electric can opener. As the can opener punctures and begins to open the 7-Inch Can, a flammable mixture of hydrogen and air will be released. Because of its low ignition energy, nominally small heat producing sources (e.g., friction and static generation) can result in the prompt ignition of hydrogen. Should this occur, the hydrogen would burn as a jet or flare. This short duration, unconfined burn would not pressurize the glovebox.

If the hydrogen does not burn as it exits the 7-Inch Can, it will, given its high diffusivity, rapidly mix with the glovebox atmosphere. Glovebox HC-21A, with dimensions of 10 ft 8 in. by 3 ft 6 in. by 3 ft, has a volume of 3,150 L. Subtracting the 680 L volume of the Inert Atmosphere Confinement portion of the glovebox yields a volume of 2,470 L. Applying the Ideal Gas Law, this volume can contain 100 moles of gas. If the 0.10 moles of hydrogen released from the 7-Inch Can were to mix uniformly within the volume of the glovebox, the resultant concentration would be 0.10%, which is significantly below the lower flammability limit of 4%. Accordingly, the hydrogen would not burn but would be swept from the glovebox via the E-4 ventilation system and further diluted.

As the hydrogen is released from the 7-Inch Can and mixes with the glovebox atmosphere, localized concentrations within the flammability range will exist for a short period of time. Assuming that all of the hydrogen is released as a puff and is ignited before mixing below the lower flammability limit, the instantaneous energy release would be:

$$Q = (240 \text{ kJ/g-mole})(0.10 \text{ moles}) = 24 \text{ kJ}$$

where: Q = heat generated
kJ/g-mole = heat of combustion of hydrogen.

Conservatively assuming 100% of the heat from the hydrogen burn is transferred to the air in the glovebox, the increase in temperature can be calculated by:

$$\Delta T = Q/mC_p$$

where: ΔT = change in temperature (K)
Q = heat generated (kJ)
m = mass of air in glovebox (kg)
C_p = specific heat of air (kJ/kg-K).

The mass of air in Glovebox HC-21A is equal to the volume of air multiplied by its density:

$$m = (\text{volume})(\text{density}) = (2.47\ \text{m3})(1.16\ \text{kg/m3}) = 2.86\ \text{kg}$$

Solving for ΔT yields a temperature increase of:

$$\Delta T = 24\ \text{kJ}/(2.86\ \text{kg})(1.007\ \text{kJ/kg-K}) = 8.33\ \text{K}$$

Applying the Ideal Gas Law, the pressure in the glovebox given a temperature rise of 8.33 K is calculated as follows:

$$(P_{final}/P_{initial}) = (T_{final}/T_{initial})$$

$$P_{final} = (14.7\ \text{psia})(300\ \text{K} + 8.33\ \text{K})/(300\ \text{K}) = 15.1\ \text{psia}$$

The increase in pressure is therefore 0.4 psig.

A pressure increase of 0.4 psi is not expected to fail the glovebox gloves. Walden (1980) suggests gloves fail at an overpressure of 0.6 psi. A pressure increase of 0.4 psig could breach the glovebox via failed seal-in ports. Although a pressure increase of 0.4 psig can be conservatively calculated, such an increase would not be realized for three principal reasons. First, 100% of the hydrogen released in a puff would not burn as assumed. A stoichiometric mixture of 0.10 moles of hydrogen and air has a volume of 8.4 L, which would fill approximately 0.4% of the glovebox. Accordingly, the hydrogen would burn as an unconfined cloud, the efficiency of which can be significantly less than 100%. As stated in *Evaluation of Unconfined Vapor Cloud Explosion Hazards* (Pugh 1987), when small unconfined vapor clouds are ignited, the vapors usually burn without pressure effects and with a low flame speed. Second, 100% of the heat from the hydrogen burn would not be transferred to the air as assumed above, i.e., the system is not adiabatic. Third, Glovebox HC-21A is not a sealed vessel. A 3 ft. by 17 in. opening in the north end of Glovebox HC-21A provides access to Conveyor Glovebox HC-2. Qualitatively considering these factors, it is concluded that the release and subsequent ignition of hydrogen from a pressurized Type D Can will not breach Glovebox HC-21A since there would be little or no pressure increase. This conclusion is consistent with operating experience at PFP and throughout the DOE complex.

9.2.10.1.2 Mitigation. Mitigation is provided by administratively limiting the introduction of pressurized plutonium storage containers to Type

A or B criteria as defined in Figure 9-37. This control limits the quantity of hydrogen and other flammable gases potentially released into Glovebox HC-21A.

9.2.10.1.3 Probability. The burning of flammable gas released from Type A and B Cans is an anticipated event, defined in Table 9-49 as having an annual probability in the range of 1 to 1 x 10^{-2} per year. This probability is based on the planned introduction and opening of Type A and B Cans in Glovebox HC-21A and the low ignition energy of hydrogen.

The burning of flammable gas released from a Type D Can is an unlikely event, defined in Table 9-49 as having an annual probability of occurrence in the range of 1 x 10^{-2} to 1 x 10^{-4} per year. This probability is based on the relatively small number of Type D Cans at PFP and the fact that Type D Cans are readily discernable from Type A or B Cans based on physical appearance.

9.2.10.1.4 Consequence Analysis. The analyzed scenario does not result in a breach of the glovebox. The quantity of plutonium potentially suspended inside Glovebox HC-21A by burning hydrogen is judged to be small relative to that suspended by normal operations (e.g., pouring oxide through a sieve, use of mortar and pestle).

9.2.10.1.5 Conclusions. The release and ignition of hydrogen from Type D plutonium storage containers is an unlikely event. The small pressure increase, if any, due to the burning hydrogen would not be sufficient to breach the glovebox. Accordingly, from a pressurization event perspective, the hydrogen does not pose a risk to workers, the public, or the environment. The burning hydrogen does represent an ignition source for a glovebox fire that, if not prevented or mitigated, could potentially breach the glovebox. The probability and consequences of a fire in thermal stabilization gloveboxes is presented in Section 9.2.10.4 below.

9.2.10.2 Deflagration in Glovebox HC-21C or HA-21I. Thermal stabilization of plutonium-bearing compounds will take place within the two muffle furnaces in Glovebox HC-21C or the three muffle furnaces in Glovebox HA-21I. Thermal stabilization is accomplished by heating the plutonium bearing materials to 1000 °C driving off components that affect long-term storage.

The analysis discussion for a deflagration in either Glovebox HC-21C or Glovebox HA-21I is presented in two sections. Section 9.2.10.2.1 will address deflagrations resulting from decomposition of polymeric compounds. Section 9.2.10.2.2 will address deflagrations resulting from decomposition of tributylphosphate (TBP) in Plutonium Reclamation Facility (PRF) sludge.

Glovebox HC-21C contains two furnaces. Each furnace is equipped with a temperature controller and two interior air space gas flows; one from the CO_2 system and one from the 26-in.-Hg vacuum system. Glovebox HA-21I contains three furnaces. The temperatures in the three HA-21I furnaces are fedback through a programmable logic controller (PLC), and the only gas flow through these furnaces is from a dedicated 5-in. mercury process vacuum system. Therefore the three furnaces in Glovebox HA-21I can not be used to process PRF sludges or any feed containing organic materials. (Section 6.4.1.4.2) The air flow from the 26-in.-Hg vacuum system or the dedicated 5-in. mercury process vaccuum system is used for processing feed types other than PRF sludge only

during the cool-down portion of the cycle (Section 6.4.1.5.1). For processing PRF sludge, which can only be performed in Glovebox HC-21C furnaces, both the CO_2 purge flow and air flow from the 26-in.-Hg vacuum system are needed. The air flow rate is 1.0 ft^3/min. The flow rate is calculated to be sufficient for complete combustion of the contaminants and removal of the off-gas (water and CO_2). The temperature controller or PLC limits the heat up rate of the furnace to 5 °C/min from room temperature to 500 °C, 3.3 °C/min from 500 °C to 700 °C, 2 °C/min from 700 °C to 900 °C and 1.25 °C/min from 900 °C to 1000 °C. The "full-on" ramp rate is about 7 °C/min. The "full-on" ramp rate can result in coil failure, hence the need for a more controlled ramp rate. The time for heat-up to 1000 °C is 5.7 hours. The oxide remains at 1000 °C for two hours and then the power to the furnace is cut off. It takes about five hours to cool to 200 °C when the furnace boats can be removed.

The plutonium-bearing material covered by this analysis is plutonium oxide (both "clean" and non-product quality) and other non-product quality feed materials. Non-product quality feed materials include non-product quality (impure) plutonium oxides, mixed uranium and plutonium oxides (MOX), floor sweepings, plutonium oxalate, and PRF sludges.

Flammable gases are generated by the thermal decomposition of organic contaminants potentially present in non-product feed materials (impure oxide, MOX, floor sweeps, and oxalates) or by the thermal decomposition of TBP and its degradation products known to be present in PRF sludges. Organic contaminants of concern potentially present in the feed materials include polymeric compounds (e.g., plastics), hydraulic oil, and sealants (e.g., elastomers). These materials behave similarly when heated to high temperatures.

9.2.10.2.1 Deflagration in Glovebox HC-21C or Glovebox HA-21I Due to Decomposition of Polymeric Compounds. The deflagration analysis related to polymeric compounds (primarily plastics) is presented in the following sequence. First it is shown that it is possible for plastics to be in the oxide as a contaminant. Following this, the types of plastics present and their thermal degradation products are discussed. The degradation products are flammable gases. Then, sensitivity calculations are performed to determine if a flammable concentration could be formed from the degradation products and furnace air. The sensitivity analysis included the quantity of plastic and plastic type. Large and small quantities of plastic are considered since large quantities probably yield flammable gas concentrations above the upper flammability limit while small quantities may result in quantities of flammable gas with excessive diluent. This is generally what was found.

There are cases, however, in which a deflagration could occur after the furnace gases are cooled and if a spark source is present. The probability of this condition is addressed next, followed by the consequence. The probability range is 10^{-3} to 10^{-5} depending on the type of plastic in the oxide. Plastic type is important because some plastics degrade below the auto-ignition temperature of the flammable gases given off. In this case, normal furnace operation can provide the spark source. When the deflagration occurs, oxide is resuspended into the furnace and blown out into the glove. The glove bursts and aerosol is blown into the room. The building HEPA filters are not affected by the deflagration so the release leaves the

building filtered. As a result, the onsite and offsite doses are quite small ($<10^{-3}$ rem).

The polymeric contaminants are bounded by one of the following four materials

- polyethylene (PE) - $(CH_2)_n$

  - Where the subscript "n" indicates that the molecule is made up of repeating groups.

- polystyrene (PS) - $(RCH\text{-}CH_2)_n$

  - Where "R" denotes benzene ring

- polycarbonate (PC) - $(HO\text{-}R\text{-}C_3H_3\text{-}R\text{-}CO\text{-}Cl)_n$

- polyvinyl chloride (PVC) - $(CH_2\text{-}CHCl)_n$

From these four plastic materials are made bags, bottles, bottle caps, sample containers, wire insulation, packaging, molded items, tool handles and brush bristles (Hilado 1982). The types of polymeric compounds most likely present in non-product quality feed material are plastics used for plutonium packaging (e.g., plastic bags), or small pieces of plastic from broken equipment (e.g., tool handles, polyjars). There are a number of hydraulic oil formulations (e.g., phosphate esters, siloxane). Over the years, various formulations have likely been used at PFP. The principal sealant used at PFP is a vulcanizing silicone elastomer (RTV). Table 9-62 summarizes thermal decomposition information for hydraulic oil and RTV. The flammable constituents (e.g., methyl and ethyl groups) of these compounds are such that they can be adequately represented by an analysis of polymeric compounds. Some glovebox windows are made from polymethyl methacrylate. This polymer is similar to polyethylene except that there are side groups of acetic acid. However, the decomposition products or mechanism is not significantly different from PE. The glovebox gloves are made of Hypalon which is a chlorosulfonated polyethylene. This material is different than the four bounding polymers in that heating can give off SO_2 and CS_2 (Polymer Science 1986). Bits or pieces of glove are not expected to be in the glovebox or added to the oxide. Unattached gloves are not left in gloveboxes as are plastic bottles and tools. The failure mode of gloves is cuts or holes. Cuts or pin holes in gloves do not leave pieces within the glovebox that could be placed into oxide containers. Therefore hypalon can be left out of the bounding polymers.

Heating of oxide containing these polymers can result in products that are flammable if insufficient oxygen is present during heating. The phenomena in which polymers degrade into component pieces in inert atmospheres is called pyrolysis. The term combustion refers to the phenomena where these polymers are heated in air forming CO_2 and H_2O. Testing of the thermal degradation of these polymers in air and in argon is documented in Barney (1998). Barney shows that with air flow providing oxygen for combustion, the off-gas is primarily carbon dioxide and water. If the atmosphere is argon, the off-gas products are various hydrocarbons (Barney 1998 and Landrock 1983). However,

PVC and polystyrene (as resin beads) produced low molecular weight hydrocarbon gases during combustion in air.

The thermal degradation products of the 4 plastics are described in Landrock (1983) and are summarized below. Landrock uses the term thermal degradation which is the common term for pyrolysis.

Polyethylene - Polyethylene is a member of the category "polyolefins." Polyolefins burn readily in air and produce virtually no soot. The polyolefins pyrolyze under heating into volatile fragments by random chain scission. In a limited oxygen environment, the products of pyrolysis are carbon monoxide (CO), carbon dioxide (CO_2), ethylene, butene, hexene, propane and pentane.

Polystyrene - Polystyrene burns readily in air with the production of dense smoke. Polystyrene volatilizes rapidly at 300 °C and is completely volatilized at 450 °C. In a limited oxygen environment, the products of pyrolysis are predominantly styrene with some small amounts of toluene and benzene.

Polyvinyl chloride - Polyvinyl chloride (PVC) itself does not burn under most conditions. When exposed to heat, PVC releases HCl at relatively low temperatures. The release is highly endothermic. As a result thermal degradation slows as heat is absorbed in the liberation of HCl. However, PVC is usually compounded with large amounts of plasticizers many of which are flammable. Depending on the plasticizer used, the thermal decomposition products may include the same components as that from polyethylene in addition to benzene.

Polycarbonates - In a limited oxygen environment, the products of pyrolysis of polycarbonate include large amounts of methane and lesser amounts of benzene and toluene.

The flammable pyrolysis products of the four bounding polymers are:

benzene	toluene
carbon monoxide	alkenes (e.,g., butene, hexene, ethylene)
styrene	alkanes (e.g., methane, propane)

Barney (1998) determined the pyrolysis products to be toluene, ethylene, tetramethylammonium (he used resin beads as his PS where Landrock discussed pure PS) and phenol (chemical form is R--OH). These are similar to the list taken from Landrock.

In some cases, Barney (1998) shows that hydrogen is also a constituent of the off-gas. Hydrogen can be a pyrolysis product or as one of the products of a catalyzed reaction of water vapor with hydrocarbons over a metal oxide bed. Examples of this are from Sneed (1957) who describes a reaction of alkane (C_nH_{2n+2}) over a bed containing 25% nickel, 25% zirconium sulfate and 50% magnesium oxide which produced hydrogen and a catalytic conversion of methane (CH_4) to hydrogen over a bed of barium oxide or calcium oxide at a similar temperature.

Table 9-59 summarizes the information on ignition and decomposition from Landrock (and Barney) and the Chemical Engineers Handbook.

The operators will sieve the oxide and visually inspect the oxide in the furnace boat for contaminants. It is assumed that up to 10 g of plastic can escape the sieving and visual inspection process. To show the likelihood of that occurring, consider the following. The density of most plastics is about 1 g/cm^3. Therefore, 10 g represents a total volume of 10 cm^3. To get an idea of how much plastic this is, consider the following. A 10 g piece of a 12 mil plastic bag would have an area of 328 cm^2 (e.g., a square 7 inches on a side). A 10 g cube would be 0.85 inches on a side. However, a "4-mesh" screen has a square opening 0.185 inches on a side. A cube of this dimension weighs 0.1 g. One hundred of these very small cubes equates to 10 g. It is this material that escapes the sieving and inspection process. Failure to sieve and inspect could result in quantities greater than 10 g.

9.2.10.2.1.1 Scenario. From the discussions above, a deflagration could occur if oxide containing plastics is heated in the furnace having insufficient or no air flow to support full combustion. It is assumed that both furnaces are operational. A 2500 g (Pu weight) charge is sieved and the sieved material is placed in each furnace boat. The material in the boat is visually inspected for contaminants. One of the charges is also assumed to contain 10 g of plastics in the form of very small pieces. Both boats are placed in the furnaces and heated normally. It is assumed that there is a failure such that there is no purge air flow through either furnace. Note that the sensitivity of the analysis to both smaller (i.e., 1 g) and larger (i.e., 50 g) quantities of plastic is subsequently addressed.

Whether or not a deflagration can occur or not is dependent on many factors. The pyrolysis products are flammable gases. For flammable gases to deflagrate, an oxidizer must be present (e.g., oxygen in the air) as well as an ignition source. Likely ignition sources are the heat from the furnace coils (if the coil temperature exceeds the auto-ignition temperature) or short circuits in the electrical power circuit to the coils. If the flammable gases are not pre-mixed with air initially but mix with air as a result of the scenario, and if the ignition source is present at the beginning of air entrainment, a flash fire, not a deflagration will occur (AIChE 1994). If the air is entrained first then ignited, a deflagration will occur (AIChE 1994).

The combustion and pyrolysis of various types and quantities of plastic materials, during the heat-up and cool-down cycles of the furnace, are modelled in the following paragraphs. This allows identification of scenarios that can result in flammable gas concentrations in the furnace.

The feed material containing plastic (or contaminant that reacts like plastic on heating) is placed into a furnace boat. The furnace boat is placed into the furnace and heated. It is assumed that there is no offgas air flow through the furnace. As the temperature increases, the oxygen in the furnace atmosphere reacts with the plastic. Combustion is assumed to occur. Combustion is defined as the following:

$$C_nH_m + (n + m/4)\ O_2 + 3.8\ (n + m/4)\ N_2 \rightarrow nCO_2 + (m/2)H_2O + 3.8\ (n + m/4)\ N_2$$

where "m" ranges from "n" to "2n" for the plastics under consideration.

It is seen that there are more moles of products than gaseous reactants. Because the furnace is so small, there is only enough oxygen to combust a little of the plastic. Therefore combustion results in an oxygen deficient atmosphere and a pressurized furnace. The increased pressure results in flow of these gases out of the furnace until atmospheric pressure is reached.

The furnace interior dimensions are 5 inches by 5.5 inches by 13 inches for a volume of 0.2 ft^3 or 6 L. Initially there is 0.24 moles of air in the furnace (assuming 1 atmosphere and 300 °K). During combustion the 0.05 moles of O_2 in the air will react with 0.017 moles of plastic as ethylene. The 0.017 moles of plastic is 0.5 g. This is the quantity that is burnt (combustion) early. This initial combustion is ignored in the following calculations.

As the furnace temperature increases there is gas flow out of the furnace due to the expansion of the gases. At the decomposition temperature, the remaining plastic under goes pyrolysis and is transformed into an alkene, or benzene, etc., depending on the plastic. Since the most likely plastic found is polyethylene, ethylene (C_2H_4) is chosen to be the representative off-gas.

Ten grams of ethylene case

Ten grams of plastic equates to 0.36 moles of ethylene. The pyrolysis is complete at about 450 °C [Barney (1988) and Landrock (1983)]. At this temperature and atmospheric pressure, there are 0.1 moles of gas in the furnace. Prior to pyrolysis, the gas is mostly N_2 with a small quantity of CO_2 and H_2O from combustion. The combustion products will be ignored.

The generation of ethylene from pyrolysis, coupled with lack of air flow creates a positive pressure in the furnace which results in the flow of ethylene and N_2 out of the furnace. This occurs throughout the time of pyrolysis. If the furnace temperature exceeds the auto ignition temperature of ethylene, the gas could burn when it reaches the air exterior to the furnace (if it hasn't cooled to below the auto ignition temperature).

At 1000 °C, there are 0.057 moles of gas in the furnace in a ratio of 0.36 moles of ethylene to 0.1 moles of N_2. As a result there are 0.045 moles of ethylene and 0.012 moles of N_2.

As the furnace cools, air enters the furnace due to the contraction of the gas inside. At 485 °C, the auto ignition temperature of ethylene, the furnace can hold 0.096 moles of gas. It already has 0.045 moles of ethylene and 0.012 moles of N_2. To this will be added 0.039 moles of air of which 0.008 moles is O_2. The furnace now contains:

0.045 moles ethylene
0.039 moles air
0.012 moles N_2

Ethylene makes up about 47% of the air space by volume. The flammability limits for ethylene are 2.7% to 36% at room temperature. The lower flammability limit decreases to about 1.5% at 485 °C (Zabetakis 1965). The upper flammability limit increases but a value is not provided. It is known however that the gas will burn in air at the auto ignition temperature.

As air enters the furnace as it cools. At 1000 °C the air entering reacts with the flammable gas. The upper limits of flammability for ethylene is 36% at room temperature (Zebatikis 1965). At 1000 °C it is much greater. The air is drawn in slowly so the burn occurs slowly. A deflagration will not occur as the flammable gas is not premixed with air at this point (AIChE 1994). The addition of 0.008 moles of O_2 above the auto-ignition temperature will result in a reaction with the ethylene present. The 0.008 moles of O_2 will react with 0.003 moles of C_2H_4 to create 0.006 moles of CO_2 and 0.006 moles of H_2O.

Therefore at conditions just below the auto-ignition temperature (i.e., after all the burning is completed) there is:

(0.045 - 0.003) = 0.042 moles ethylene
(0.012 + 0.039 - 0.008) = 0.043 moles N_2
0.006 moles CO_2
0.006 moles H_2O

The moles of CO_2 and H_2O are added to the moles N_2 to simplify the math. This addition yields 0.055 moles N_2.

At 100 °C the furnace can hold 0.196 moles of air. Therefore 0.1 moles of air was drawn in resulting in a mixture of:

0.042 moles ethylene
0.055 moles N_2
0.1 mole air

<u>One gram of ethylene case</u>

If instead of 10 g there were 1.0 g of plastic (0.036 moles ethylene), there would be 0.015 moles of ethylene and 0.042 moles N_2 at 1000 °C. After cooling to 485 °C and reacting with the 0.008 moles O_2 coming in, there would be:

0.012 moles ethylene
0.084 moles N_2

After cooling to 100 °C, there is:

0.012 moles ethylene
0.084 moles N_2
0.1 moles air

Ten grams of ethylene case with partial decomposition to hydrogen

One of the decomposition products is hydrogen. Assume that there is 10 g plastic present. Since H_2 comprises 15% of the ethylene molecule assume the pyrolysis gases are 15% H_2 and 85% C_2H_4 (mole percent) (Barney 1998 shows 14% H_2). Now ten grams of plastic pyrolyzes to 0.353 moles ethylene and 0.062 moles H_2. For a total of 0.415 moles of gas. This is in the furnace with 0.1 moles N_2 at 450 °C.

At 1000 °C there is 0.057 moles of gas total in the furnace. The total is comprised of:

0.007 moles H_2
0.039 moles ethylene
0.011 moles N_2

After cooling to 485 °C and reacting the H_2 with the oxygen first, as H_2 is more reactive then C_2H_4, there is:

0.038 moles ethylene
0.058 moles N_2 (adding the 0.007 H_2O from the reaction of H_2 with O_2 and the products of the reaction with ethylene)

After cooling to 100 °C, there is:

0.038 moles ethylene
0.058 moles N_2
0.1 moles air

Ten grams of ethylene case with pyrolysis to benzene

If the plastic pyrolyzed to benzene, 10 g would equal 0.128 moles. At 1000 °C there would be 0.033 moles benzene and 0.026 moles of N_2. The auto-ignition temperature of benzene is 592 °C. The following calculation is done at 485 °C to provide a comparison to the other calculations. After cooling to 485 °C and burning some of the benzene in air, there would be:

0.032 moles of benzene
0.066 moles N_2 (adding 0.01 moles of the reaction products of benzene and air)

At 100 °C there is:

0.032 moles of benzene
0.066 moles of N_2
0.1 moles of air

One gram of ethylene case with pyrolysis to benzene

If there were 1 g of plastic and the pyrolysis product were benzene, 1.0 g would equal 0.032 moles. At 1000 °C there would be 0.007 moles of benzene and 0.050 moles of N_2. After cooling to 485 °C and reacting with the O_2, there would be:

0.006 moles of benzene
0.09 moles N_2 (including 0.01 moles of reaction products)

After cooling to 100 °C, there is:

0.006 moles of benzene
0.09 moles of N_2
0.1 moles of air

Fifty grams of ethylene case

Now assume 50 g of plastic all as ethylene. This assumption is made to determine the sensitivity of the results to the assumption of 10 g of plastic. At 450 °C there is 0.1 moles N_2 and 1.79 moles ethylene. At 1000 °C there is 0.054 moles ethylene and 0.003 moles N_2.

After cooling to 485 °C and reacting some of the ethylene with air, we have:

0.051 moles ethylene
0.044 moles N_2

After cooling to 100 °C, there is:

0.051 moles ethylene
0.044 moles N_2
0.1 moles air

The summary of the above is shown in Table 9-60.

The flammability limits for ethylene in air is 2.7 to 35 volume %. Zebatakis (1965) shows that with N_2 as a diluent, the lower flammability does not change appreciably with the addition of N_2. The upper flammability limit decreases from 37% with 0% N_2, to 20% with 20% N_2, to 10% with 35% N_2 to "non-

flammable" at about 50% N_2. The flammability limit for benzene is 1% to 9% in air.

Table 9-60 shows that the 10 g ethylene (15% H_2, 85% C_2H_4) and the 1 g cases are within the flammability limits at 100 °C, as is the 1 g benzene case. The other cases have too much N_2 as a diluent.

At 100 °C ethylene is within the flammability limits even with the N_2 diluent. Should a spark occur at this time, a deflagration in the furnace would result. Should a reheating cycle inadvertently occur, the gas could deflagrate at the auto ignition point. A deflagration during reheating will, however, only involve only a fraction of the ethylene contained in the furnace at 100 °C because the air expands as it is reheated, forcing some of the ethylene out. The air temperature when the furnace coils reach 485 °C is unknown.

Potential Gas Burn Outside of the Furnace

As pyrolysis occurs, some of the flammable gas is forced out of the furnace. The ratio of the moles of gas in the furnace at 1000 °C divided by the moles of gas at 450 °C is 0.57. This means that 43% of the flammable gas was forced out of the furnace or 4.3 g from the 10 g case. Since there is a gap all the way around the door, the gas will escape in all directions. The gas is initially hot and could burn as a flame out of the doors when the gas meets the air. Section 9.2.10.3 shows the results of a fire ball containing more than the 4.3 g of gas released through the door. Neither the panel nor the gloves are adversely affected.

If the gas does not burn, it mixes with the air in the glovebox. The glovebox ventilation flow is 30 ft^3/min. The inlet flow comes from the HC-2 conveyor, flows across the furnaces (which are quite close to the conveyor) into the open portion of the glovebox and out the top. The volume of the area in front of the furnaces is 2 ft wide, 6 ft long and 1.5 ft tall. The volume is 18 ft^3.

The gas will mix with the glovebox ventilation flow in front of the furnaces. If perfect mixing of the blown out furnace gas with the air in front of the furnace occurs, the mass of gas in this volume with time is found by the following:

$$\frac{dM}{dt} = m_{in} - \frac{M\ (30\ ft^3/min)}{18\ ft^3}$$

where: M = mass of furnace gas, g
m_{in} = flow rate of furnace gas into glovebox, g/min.

Solving for "M" when at time equal to zero, "M"equals zero yields:

$$M = \frac{m_{in}}{30/18} \quad [1\text{-exp-}(30/18)t]$$

Assume the gas comes out in 1 min, then m_{in} equals 4.3 g/min.

Solving for "M" for various values of "t" yields the following:

T, min	M
0	0
1	2.1 g of the 4.3 g total

The rest of the gas is swept into the remainder of the glovebox.

If the gas comes out over 5 min, then:

T, min	M
0	0
5	0.52 g of the 4.3 g total

The calculation shows that even with ventilation flow, most of the gas is mixed with the rest of the glovebox air.

The glovebox ventilation system inlet being very close to the furnaces and having a high flow rate removes and mixes the gas efficiently. Even if the glovebox ventilation system should fail at the point where gas is coming out, the gas flow rate and its temperature and the fact that gas is released in four directions (up, down, right and left) is judged to mix it well. In the case of no purge air or glovebox vent flow, there is likely no electricity to the building and therefore no ignition source even if the gas does not mix. Once the gas is in the glovebox (volume of 105 ft^3), the equation for removal is:

$$\frac{dM}{dt} = m_{in} - \frac{M\ (30\ ft^3/min)}{105\ ft^3}$$

Solving yields:

$$M = M_o \exp\ (-30t/105)$$

The results of solving this equation are as follows:

m/m_o	T, min
1.0	0
0.75	1
0.42	3
0.24	5
0.13	7

So the glovebox is effectively purged in about 7 to 10 minutes.

In summary there are two scenarios to be considered. All involve a loss of purge air and the presence of plastics. The two scenario's are:

- Ignition of flammable gas in the furnace after cooling,
- Flash fire if the door is opened after the furnace has reached the auto-ignition temperature.

The flash fire case is analyzed in Section 9.2.10.3 and is shown to produce minimal damage.

9.2.10.2.1.2 Mitigation. Adequate purge air flow ensures the plastic contaminant is combusted in a controlled manner during ramp up in the furnace. The purge air flow is assured by procedural controls. Purge air flow is set by the operator during the phases of furnace operation. Proper purge air flow is initiated by the operator prior to furnace heating. By procedure the operator first checks to assure that the 26-in.-Hg vacuum system is operational by reading the vacuum off a gauge. From this reading, the operator consults a chart to determine the purge air flow rotameter reading necessary to produce 1 to 1.5 standard cubic feet per minute (scfm). The operator adjusts a valve to obtain that reading. The operator logs both the rotameter reading and the purge air line differential pressure reading at 1 to 1.5 scfm. The rotameter is then valved out (i.e., bypassed). By procedure, the differential pressure gauge is read every 15-20 minutes to check that the purge air flow is at the set value.

The oxide is sieved prior to placement in the furnace boat in Glovebox HC-21A. The plastic is likely in the form of pieces of noticeable size as it was added to the pure oxide prior to packaging. Sieving is very effective for pieces of this size.

Most of the oxide to be processed will likely not contain plastics. Adding contaminants to containers of clean oxide is not performed per procedure and is not a routine occurrence. The plastics are much more likely to be found in floor sweepings which are typically kept in a separate container.

By procedure, the operator pulls the gloves out of the glovebox and secures them with a bungie cord before operating the furnaces. The operator also visually checks the glovebox interior to verify the no combustible material is in contact with the heated surfaces. The operator checks to

assure that the temperature recorder is running and periodically observes the furnace temperature. Only when the furnace temperature is below 200 °C is the operator instructed to open the furnace door. The furnace door is kept closed when the furnace is hot to preclude flash fires in the furnace.

The glovebox ventilation system sweeps away those gases that came out of the furnace door, thus precluding a deflagration outside the furnace.

9.2.10.2.1.3 Probability. The probability of the deflagration in the furnace given PE or PC as the plastic (Scenario 1) is in the middle of the Extremely Unlikely category (or about 10^{-5}) for processing "clean" oxides. This is because it requires three independent failures. The first is a failure such that purge air flow is not occurring at any time during the heating and cooling cycle. This has a probability of 10^{-2}, based on requiring an operator failing to follow procedure for setting up the most important support system in the operation, the purge air. Per Swain and Guttmann (1980), Table 20-20 and 20-27, the human error probability (HEP) for the failure to follow an established procedure is 10^{-2} and the failure to properly use written procedures under normal conditions is 10^{-2}. Failure of purge air flow could also be due to a system failure. The system failure probability is no greater than the HEP and likely less.

The second failure is having plastics in the oxide when there is not supposed to be any present. The likelihood of this is about 10^{-1} as it requires deliberately putting plastic into a "non-glovebox sweeps" container. The plastic considered here is not part of the process but debris. Debris is placed in different containers than is product.

The third failure is an ignition source when the furnace door is opened or inadvertent reheat cycle prior to opening the door. The likelihood of either of these is about 10^{-2}. The furnace door interlock is an electrical switch that very likely sparks each time it is actuated. However the spark energy is small and located away from the location of the furnace gas. The furnace gas is hydrocarbons not hydrogen. Ignition of hydrocarbons requires more energy than that of hydrogen. In addition, the hydrocarbon concentration is far from stoichiometric and nitrogen is present as the diluent. As a result, ignition requires a large spark which is judged to occur only under off-normal conditions. An inadvertent reheat has a low probability as this requires either two operator failures to pay attention to detail (failure to remove the boat after cooling and failure to insert a boat prior to starting the furnace) or a system failure.

The probability of the deflagration in the furnace given PE or PC as the plastic is 10^{-4} for non-product quality feed material. This is because it requires two independent failures (the first and third failures described above for the "clean" oxides).

The probability of the deflagration if PVC or PS is the plastic is 10^{-2}. This is because these plastics decompose at a low temperature. At this low temperature oxygen may still be present when the flammable gases appear. They are ignited when the furnace coils cycle on. Therefore, a separate failure is not required for ignition. The probabilities discussed above are per boat processed. Depending on the number of boats processed per year, the annual

probability of a deflagration could easily be in the anticipated category for either type of deflagration considered.

As an example; assume PVC decomposes into ethylene (C_2H_4) at 260 °C. At 260 °C, the number of moles of air in the furnace is 0.137. Ten grams of plastic (as C_2H_4) equates to 0.36 moles. Adding this to the air and normalizing the mole quantities back to 0.137 (equivalent to depressurizing the mixed gases to attain atmospheric pressure) yields:

C_2H_4 - 0.10 moles
air - 0.038 moles

Of this mix, C_2H_4 comprises 72% which is above the upper flammability limit. If 2 g of plastic (0.07 moles) were involved, not 10 g, the normalized quantity would be:

C_2H_4 - 0.046 moles
air - 0.091 moles

Of this mix, C_2H_4 comprises 34% which is just within the flammability limits at room temperature. The flammability limits expand as the temperature increases.

In this case, the furnace cycling on causing the furnace coils to exceed the auto-ignition temperature would result in a deflagration.

The above conditions require that the oxygen not react with the plastic prior to the flammable gas evolving and that the furnace coils remain below the auto-ignition temperature for a period of time that is long as compared to the flammable gas evolution time. Otherwise the furnace coils will burn the gas as it evolves.

In addition, almost any air flow at all will purge the furnace. Using the purge equations set up for glovebox flow above, one finds:

$$M = M_o \exp [-(cfm/V)t]$$

where: cfm = flow rate through the furnace, ft^3/min
V = furnace volume, ft^3
V = 0.2 ft^3
t = time, min.

With "cfm" equal to 1.0 ft^3/min, the furnace is purged (m/m_0 of 0.05) in 0.6 min. With "cfm" equal to 0.2 ft^3/min, the furnace is purged in 3 min. A deflagration under these conditions (i.e., no separate spark source needed) is less likely with PE and PC as the decomposition does not occur until the gas is above or at the auto-ignition temperature. This allows more time and for favorable conditions for oxygen reaction with the plastic prior to

decomposition. In addition, with the temperatures above the auto-ignition temperature and oxygen present, the gas will burn off as it is generated.

The probability of a flammable gas deflagration occurring outside the furnace due to pyrolysis gases being expelled from the furnace is much less likely than a deflagration in the furnace. This is due to the fact that the gases flow out of the furnace over time. This allows ample time for mixing and dilution afforded by the glovebox ventilation flow. There is also a lack of an ignition source in front of the furnace.

The probability of the flash fire (Scenario 2) is 10^{-4} as it requires a failure of purge air flow throughout the heating and cooling cycle, presence of the plastics and the operator opening the furnace door when the temperature is above the auto-ignition temperature. The probability discussed above is per boat processed. Depending on the number of boats processed per year, the annual probability of a deflagration could be in the anticipated category for a flash fire.

9.2.10.2.1.4 Consequences. A deflagration could occur if a flammable concentration of gas exists within the furnace in the presence of an ignition source.

It is believed that the most likely plastic is PE. The discussion to follow assumes the plastic is PE. The consequences of a deflagration with PVC are quite similar to that from PE.

A review of the gas concentration versus furnace temperature data shows that a flammable mixture could exist in the furnace after cooling is complete if the plastic contaminant pyrolyses in the furnace due to the failure of purge air flow. This mixture can be ignited if an ignition source should appear after cooling is completed. Should this occur, a deflagration would result as the gas is pre-mixed. To cause a deflagration, following are required:

- Presence of plastics in the oxide feed material,
- No purge air flow for an entire heating and cooling cycle,
- No opening of the furnace door after cooling,
- Ignition of the gas.

Ignition could be as a result of one of three possible failures. A potential ignition source is the limit switch on the door. A spark, as the door is being opened, could ignite the gas inside. A less likely ignition source is mechanical sparks when the boat is dragged across the furnace floor or static charge set up by the operator using the gloves to move the boat out of the furnace. The spark from the limit switch could ignite gas within the furnace or ignite the heavier-than-air gases (the benzene pyrolysis case) as they flow out of the glovebox as the door is opened. The static spark or mechanical spark case would ignite the gas left in the furnace after the door was opened. The gas within the furnace in this case will be to some extent diluted by the communication with air outside the furnace as well as flowing out of the furnace and being replaced by outside air.

Another unlikely source is inadvertent or spontaneous restart of a furnace heating cycle. The restart will cause the coils to go full on which will increase their temperature beyond the auto-ignition temperature of the gas in the furnace.

The 10 g, 15% hydrogen - 85% ethylene case is analyzed as the potential quantity of energy released is a little larger than that of the 10 g ethylene case. This is because the concentration is less near the upper flammability limit resulting in more gas burning. The 10 g benzene case is above the upper flammability limit.

The chemical formula for the reaction is as follows.

$$0.038\ C_2H_4 + 0.137\ N_2 + 0.021\ O_2 \rightarrow 0.014\ H_2O + 0.014\ CO_2 + 0.031\ C_2H_4 + 0.137\ N_2$$

The heat of formation for the components are:

H_2	0.0
C_2H_4	-20.2 k cal/mole
N_2	0.0
O_2	0.0
$H_2O(v)$	-57.8 k cal/mole
CO_2	-94.0 k cal/mole

The heat of reaction is 1.98 k cal. It is found by summing the product of the heats of formation of the products with the moles of each product and subtracting that from the product of the heats of formation of the reactants with the moles of each reactant.

The energy is used to heat the reactants. It is assumed that the average temperature over the reaction is 430 °C (703 °K). The specific heats are (from Perry 1951):

Product	Formula	cal/mole -C
H_2O	$6.93 + 8.3 \times 10^{-4} (T)$	7.5
CO_2	$10.34 + 2.7 \times 10^{-4} (T)$	10.5
N_2	$6.5 + 10^{-3} (T)$	7.2
H_2	4.97	4.97
C_2H_4	graph	26

The value of "cal/C" for the products is found by multiplying the number of moles of products by the specific heat. The value is 2.04 cal/C.

The temperature rise is found by:

Heat of reaction = (cal/C)(dT)

The temperature rise is found to be 970 °C. The final temperature is 1000 °C. So use of 430 °C, as the average, is reasonable.

The pressure inside the furnace is found by the ideal gas law:

$$PV = nRT$$

where: V = 6 L
N = 0.194 g-moles of gas in the furnace after reaction
R = 0.082 L-atm/g-mole-K
T = 970 °C + 273 + 30 °C
= 1273 K

Solving for "P" yields 3.4 atm, absolute or 2.4 atm, gauge (35 psig).

The gas comes out of the furnace as a turbulent free jet for a very short period of time. Turbulent free jets entrain air and expand which lessens the center line velocity. Daily (1966) shows that for a jet coming from a slot of width "2b" or a circular jet of diameter "d", the velocity does not decrease significantly until:

$$x/2b \quad \text{or} \quad x/d > 8 \text{ to } 10$$

where "x" is the downwind distance.

In our case the value of "d" or "2b" is the furnace width or 5 inches. The gloves are located about 24 inches away (i.e., "x" equals 24 inches). Since "x/d" is not greater than 8 to 10, the jet velocity remains the same. As a result, the gas from the furnace does not lose much energy due to entrainment before impacting the gloves and plastic panel.

The effect of the jet on the panel is assessed first. The energy of the reaction is 1.98 kcal or 1980 cal. The energy of explosion of TNT is 1050 cal/g (AIChE 1994). Therefore the reaction is equivalent to 1.9 g TNT or 0.004 lb. AIChE (1994) discusses using equivalency factors for vapor cloud explosions. The factors range from 1% to 30% depending on the study. In all of these studies, the exploding gas was largely unconfined. In this case the gas is fully confined or mostly confined within the furnace if the scenario is the "door opening" case or the "spontaneous reheat" case. An efficiency of 100% will be used because of the confinement.

The effect on the panel comes from Baker (1983), Figure 4-31. First, the TNT curves are used to determine impulse and pressure at the location of the panel. The TNT curves require a value for:

$$Z = R/W^{1/3}$$

where: Z = scaled distance, $ft/lb^{1/3}$
R = distance to panel, ft
= 2 ft
W = weight of TNT, lb
= 0.004

Solving for "Z" yields 12.6. From the TNT curves, the value of Z equal to 12.6 gives the following values of "P" and "$i_r/W^{1/3}$".

$$P_r = 17 \text{ psig}$$

$$i_r/W^{1/3} = 20 \text{ psi-ms/lb}^{1/3}$$

where: P_r = peak positive normal refected pressure

$i_r/W^{1/3}$ = scaled unit positive normal reflected impluse

Multiplying $i_r/W^{1/3}$ by the cube root of the TNT weight ($W^{1/3}$) yields a value for i_r of 0.003 psi-s.

Baker (1983), Figure 4-31, is a graphical solution to the question of whether a plate deforms. Deformation occurs in all cases if the value of the following parameter exceeds 1.0:

$$(E^{0.5}\ i_r)/(A\ \sigma_y\ \rho^{0.5}\ h)$$

where: E = modulus of Elasticity, psi
= 5×10^5 for poly-methyl methacrylate (Avallone 1978, pg 13-4)
i_r = 0.003 psi -s
A = a shape factor
= 0.25 for brittle clamped plates
σ_y = yield stress, psi
= 9000 psi (Avallone 1978)
ρ = density in lb/in^3 divided by acceleration due to gravity in in/sec^2.
= 8.9×10^{-5} based on a specific gravity of 0.95 for methyl methacrylate
h = thickness, in.
= 0.375

Solving yields 0.27. Since this value is less than 1.0, the panel will not deform. In Baker's terminology deform means deform to the point of yield. In addition, the furnaces are oriented at a 45 degree angle to the panels. This will lessen the effect of the pressure pulse.

Now consider the gloves. The gloves fail at an over pressure of 0.6 psi (Walden 1980). The gloves are a little more than twice the volume of the furnace. The furnace pressure was 35 psig. It is assumed that the entire furnace volume (at 35 psig and 1273 K) enters the glove and expands to fill

the volume of the glove. The instantaneous glove pressure will be about half that of the furnace or 17 psig. Rhude (1962) describes a test in which a 17.7 ft^3 glovebox was filled so that it contained a 10% by volume hydrogen - air mixture. The peak pressure in this burn is found by using the same methods as above. The volume of H_2 is 1.77 ft^3 which equates to 2 moles at 30 °C. The air volume is 15.9 ft^3 or 451 L. This equates to 18.1 moles of air. The balanced equation is as follows:

$$H_2 + 3.8O_2 + 14.3\ N_2 \rightarrow 2H_2O + 2.8\ O_2 + 14.3\ N_2.$$

The heat of this H_2-air reaction is 115,400 cal. The temperature increase is found using a specific heat for oxygen of 8.27 cal/mole -C. This value, like nitrogen, is relatively insensitive to temperature. The temperature increase is 748 °C. The final temperature is 778 °C or 1051 °K. The final pressure is 51 psia or 36 psig. Rhude showed that under these conditions one glove was blown off intact and the other three were completely shattered. In our case, the glove pressure is initially 17 psig with no back pressure (i.e., glovebox pressure of 0.0 psig allowing expansion back into the glovebox). In Rhude's case, the back pressure was also 36 psig. Since the pressure in this case is close to that of Rhude's and since the gloves in his test failed catastrophically, the gloves in this case are assumed to fail as well.

Plutonium Release - The amount of plutonium suspended is determined next. For the case of a deflagration in the furnace, DOE (1994), Section 4.4.2.3, is applicable. The volume of flammable gas in the furnace is 24% of the total (at 100 C), however, only about 1/4 of the gas is burnt. Therefore the situation is covered by Section 4.4.2.3 ("vapor < 25% of container volume"). Given these conditions, DOE (1994) suggests that the pressurized venting experiments bound the release. Given the peak pressure of 35 psig (0.24 MPa), DOE (1994), Table 4-12, gives a value for ARF*RF of 0.0064 for UO_2 powder vented from 0.34 MPa and 7 x 10^{-4} for powder vented at 0.17 MPa. A value of 2 x 10^{-3} is used (the logarithmic average).

Applying this to the furnace boat within the furnace yields a respirable quantity (RQ) of

$$RQ = 2 \times 10^{-3}(2500\ g) = 5\ g.$$

In the discussion on jets above, it was argued that there is little air entrainment in the jet coming from the furnace. As a result, the jet is approximated by the furnace length and cross-section. The furnace volume is 6 L or 0.006 m^3. The aerosol loading in this volume is 5/0.006 or 833g/m^3.

The jet is more accurately modelled as a fast moving puff. The puff will slow and expand as it travels due to air entrainment and expansion due to energy dissipation. The release will be into the room. The concentration in the puff will still be large as the puff leaves the glovebox but very likely not as large due to agglomeration and settling. The puff goes into the glove. The glove either breaks loose or shatters (Rhude 1962). If it shatters, the

powder is dispersed throughout the room. If the glove breaks loose, the puff travels to the wall across from the glovebox where it stops. Much of the material will rebound back into the room and disperse in a much more quiescent manner (ignoring capture of the powder within the glove). The net effect of both cases is judged to be aerosol loading within the entire room of 10 mg/m^3. This is a conservative value for the following reasons. The "glove breaks loose" case is considered first. The dimensions of the room volume in front of the HC-21C glovebox is 16 ft long, 20 ft wide and 16 ft tall. Considering the room layout of which glovebox HA-21I is a part, the nearby glovebox HA-23S would act as wall similar to the discussion above related to a glove breaking loose from HC-21C hitting the wall across from the glovebox. Thus the room volume in front of the HA-21I glovebox is considered to be similar to the volume related to the HC-21C glovebox and the remainder of the release calculations are representative of the releases for the HA-21I glovebox. The puff from the furnace expands only to about 2 ft in radius (Daily and Harleman 1966). The effect of the rebound off the wall will be felt in a much smaller volume than the entire room. Sutter (1982), Section 2.4.9 shows that the airborne aerosol concentration is less than 33 mg/m^3 a few minutes after an accident. The initial aerosol loading was much larger. The concentration decreased due to settling, impaction and agglomeration which enhances settling. It is judged that use of 10 mg/m^3 over the entire portion of the room in front of the glovebox envelopes 33 mg/m^3 over a smaller volume. Using 10 mg/m^3 over this volume results in a respirable quantity of 1.5 g. For the situation in which the powder disperses (glove "shatters"), the release is spread over the entire volume in front of the glovebox. The concentration is 34 mg/m^3 initially. Some of this release will settle out over time. While 5 g respirable are carried over, there are larger particles carried over as well. This will settle much faster. As they settle, they will intercept (i.e., agglomerate) smaller particles and remove them. It is judged that the 10 mg/m^3 value used in the "glove blown out" case is a reasonable value here as well. The consideration that two furnaces (in HC-21C) or three furnaces (in HA-21I) might have deflagrations within a short time period of one another due to common cause events, leads to tripling (for HA-21I) the respirable quantity to 4.5 g (1.5 g per furnace times 3 deflagrations separated by a short period of time = 4.5 g respirable release to the room).

The Criticality Specifications state that only 5 kg of Pu can be in the HC-21C glovebox at one time and that there must be 10 inches separation between containers. The Criticality Specifications state that only 8 kg of Pu can be in the HA-21I glovebox at one time. Since each boat is to contain 2500 g and Glovebox HA-21I could have three boats in its three furnaces, then this leaves 500 g of Pu that could be in Glovebox HA-21I either fixed on the furnace or in cracks or crevices.

Both furnaces in HC-21C and all three furnaces in HA-21I could be operating and in fact that may be the preferred mode of operation. It is unlikely that more than one furnace boat in either glovebox (HC-21C or HA-21I) will contain 10 g of plastic. It is possible that air flow could be lost to all furnaces at the same time but not likely that the door interlock for each will spark at the same time. It is therefore not likely that more than one furnace will deflagrate at the same time. If this occurs, the release out of the room of Pu from the furnace deflagrations will be by the conservative release of the 4.5 g Pu in Glovebox HA-21I that was in the furnaces. For the releases from the 500 g plutonium fixed on the furnace or located in cracks or

crevices, a value for ARF*RF of 4×10^{-5}/hr for aerodynamic entrainment and resuspension (DOE 1994) is used. Based on a conservative 1 hour release from the glovebox for pressurized venting, 0.02 grams plutonium (500 g x 4×10^{-5}/hr) would be released. Thus 4.52 g of respirable Pu (4.5 g from within the furnaces and 0.02 g from outside the furnaces but within the glovebox) will be assumed to be released to the room.

There is unburned ethylene as one of the products of the deflagration. It is assumed that the ethylene is heated as it is part of the hot deflagration gases. The jet models show that there is little air entrained during the time that the gas travels from the furnace to the gloves. This means that a second, but now unconfined, deflagration will not occur as the product ethylene does not mix with air. However, the ethylene could burn as a flash fire or a flame. Flash fires are discussed in Section 9.2.10.3. The consequences of this flash fire are insignificant as compared to the deflagration. The flash fire, while in the glovebox, could further heat the deflagration gas but this effect would be small as the time spent in the glovebox is quite short. The flash fire, if it occurs at all, will occur in the room where there will be little effect.

The dose consequence of a 4.52 g release into the room uses the methodology in Section 9.3. The release will be filtered by at least one stage of HEPA filtration. The quantity remaining after filtration is:

$$RQ = 4.5\ g\ (5 \times 10^{-4}) = 2.3 \times 10^{-3}\ g$$

The release will be elevated. The dose is determined by:

$$D(rem) = Q(g) \times X/Q'(s/m^3) \times R(m^3/s) \times C(rem/g)$$

Where: D = dose
Q = respirable quantity released, g
= 2.3×10^{-3}
X/Q' = atmospheric dispersion factor for elevated releases, s/m^3
= 1.62×10^{-5} onsite (Table 9-39)
= 5.7×10^{-6} offsite (Table 9-40)
R = breathing rate, m^3/s
= 3.3×10^{-4} (Table 9-48)
C = dose conversion factor, rem/g inhaled
= for EDE the value is 1.7×10^{8} per Table 9-46, ">10% ^{240}Pu, Class Y".
= for Bone Surface Dose the value is 2.7×10^{9} per table 9-47, ">10% ^{240}Pu, Class Y."

Solving for "Dose" yields:

Onsite = 2.1×10^{-3} rem EDE, 0.03 rem Bone Surface
Offsite = 7.4×10^{-4} rem EDE, 0.01 rem Bone Surface

9.2.10.2.1.5 Conclusions. These doses are well below the Guidelines for any frequency category. The reason for this is the ability of the HEPA filters to remain functional after the deflagration. Thus a deflagration in either Glovebox HC-21C or HA-21I due to thermal decomposition of polymeric contaminants would result in doses below the Guidelines for any frequency category.

9.2.10.2.2 Deflagration in Glovebox HC-21C or Glovebox HA-21I Due to TBP in PRF Sludges. PRF sludges are non-thermal stabilized plutonium-bearing material that appears wet. The wet appearance is due to the presence of nitric acid and possibly TBP. When thermally stabilized, sludges can give off oxides of nitrogen (NO_x), butene, and butanol. The butene evolution rates are documented in a report by Barney and Cooper (1994). Table 3 of that reference is reproduced in Table 9-63.

9.2.10.2.2.1 Scenario. PRF sludges are usually processed in an inert environment. This is because flammable gas is evolved from the TBP in the sludge. Flammable gas may also evolve from contaminants potentially present in the sludge (e.g., plastics), but the quantity of gas would be less than evolved from the TBP in the sludge. A 2,500 g (Pu weight) charge is placed in a furnace boat. The material in the boat is visually inspected for contaminants. The charge is assumed to contain 10 g of TBP.

TBP is an organic compound that was used in the solvent extraction process. Upon heating, TBP releases butene gas. When sludges are processed, the vacuum is set so that 2-3 ft^3/min of air and CO_2 are drawn through the furnace. The CO_2 purge flow is set at 0.5 ft^3/min. The controller on the furnace allows the temperature to rise slowly to 175 °C. The temperature is held there for two hours. Over that time the butene is completely released. The release rate is 0.0084 g of butene/min-g of TBP at 172 °C (Table 9-63). Given 10 g of TBP in the charge, the release rate is 0.084 g of butene/min at 172 °C (Table 9-64). The 10 g of TBP (0.038 moles) releases over time 0.113 moles of butene (6.3 g of C_4H_8). At 0.084 g/min, the butene will be completely released in 75 minutes. During this time the furnace atmosphere is purged with CO_2.

If the CO_2 purge fails, air will be drawn by the vacuum system. The volumetric flow rate of butene is 0.055 L/min. at 175 °C. The CO_2 flow is 0.5 ft^3/min (14.2 L/min). If the CO_2 fails, the vacuum will cause air to be drawn through the doors. It is assumed that the airflow is drawn in at a flow rate equal to the CO_2 purge rate, as the furnace doors are not air tight. Under these conditions, the butene concentration is 0.4%. This is well below the lower flammability limit. The vacuum is typically adjusted to draw in 2-3 ft^3/min. (with the CO_2 flow included). There is additional air flow not accounted for in the butene concentration calculation above and results in even lower concentrations.

If there were no vacuum or CO_2 flow, butene would accumulate in the furnace. The furnace volume is 6 L. The volumetric flow rate of butene at 175 °C is 0.055 L/min. The flammability limits of butene at room conditions are 2% to 13% (Kanury 1975).

If the vacuum fails, the furnace will be purged of air as more and more butene is evolved and butene-air mixtures are pushed out of the furnace.

Assume that the furnace temperature is held at 175 °C with no purge flow. The butene generation rate is 0.1 g/min by interpolation to 175 °C of Table 9-64 values. The furnace volume is 6 L. At 175 °C, the furnace contains 0.16 moles of air. The butene generation rate is 0.1 g/min or 0.0018 moles/min. The amount of butene in the furnace at any time is found by the following equation:

$$(dM/dt) = m_{in} - M(V_{in}/V) \quad (1)$$

where

M = mass of butene in the furnace, g
m_{in} = butene mass generation rate
m_{in} = 0.1 g/min per Table 9-64 with 10 g TBP
V_{in} = butene volumetric generation rate
V_{in} = 0.066 L/min per the ideal gas law with T=448 K
V = volume of furnace, L = 6 L
V_{in}/V = 0.011
$m_{in}/(V_{in}/V)$ = 9.09, g

Solving yields

$$M = [m_{in}/(V_{in}/V)][1 - \exp(-V_{in}\, t/V)] \quad (2)$$

The mass and volume of butene in the furnace at various times is found in Table 9-65. Table 9-65 shows that the concentration is above the lower flammability limit within a few minutes and above the upper flammability limit at about 20 minutes. The auto-ignition temperature for butene is 443 °C (Kanury 1975). The air temperature is 175 °C but the furnace coil temperature is much greater. The furnace coils ignite the gas. If the upper flammability expands to 20% by volume, the flammable condition exists for about 20 minutes at a temperature below the auto-ignition temperature. If the furnace coils cycle off and on during this period the gas may ignite. Since the butene flow rate is small, the gas will not have time to adequately mix with the furnace air. As a result, a small flash fire will occur. There will likely be a continuing small fire as the butene evolves and burns. It is assumed that air can be drawn in fast enough to support combustion. The combustion reaction is

$$C_4H_8 + 6\ O_2 \rightarrow 4\ CO_2 + 4\ H_2O \quad (3)$$

The butene flow rate is 0.0015 moles/min (using 0.055 L/min at 175 °C). The air flow needed is 0.043 moles/min. The heat of combustion for butene is 10.8 kcal/g (Perry 1963, page 3-143). The heat rate is 907 cal/min (0.06 kw). The heat of combustion will heat the air and pressurize the furnace. This will force burning gases out the door and could potentially blow the door open. The heat rate is small enough that no damage should occur.

The temperature controller could fail or not be set on the correct program. Under these conditions, the furnace temperature could ramp up at 300 °C/hr until a temperature of 500 °C is reached. Butene begins to evolve at 112 °C and evolves at an ever increasing rate up to 268 °C. Table 9-64 shows

the butene evolution rate and total evolved assuming 10 g TBP initially. Table 9-64 shows that the last portion of the butene comes out at 3.3 g/min. at 252 °C (525 K). Using the ideal gas law, the volumetric flow rate is 2.5 L/min. At a purge flow of 0.5 ft^3/min, (14 L/min) the butene concentration is 18% by volume. At 3 ft^3/min (84.9 L/min) the concentration is 3%. So the mixture is within the flammability range even with purge flow and CO_2 for a short time when the temperature is below the auto-ignition temperature. So even under conditions, in which there is both air and CO_2 flow, a flammable concentration of gas exists for about 5 minutes (time during which the furnace temperature is between 232 °C and 252 °C).

A volumetric flow rate of 2.5 L butene/min will result in a well mixed volume during the time the furnace coils are off. When the furnace coils come back on a deflagration may occur. The deflagration will pressurize the furnace and blow open the door. The rest of the butene given off will likely burn in and outside the furnace as the expanding furnace air will transport the butene out. The heat rate of the burn is found from the following equation:

$$\text{Heat Rate} = (3.3 \text{ g/min})(10.8 \text{ kcal/g}) = 35.6 \text{ kcal/min}$$

$$= 2.5 \text{ kw}$$

The heat will continue for 2 minutes when the butene is fully evolved.

Now consider the case with no air or CO_2 flow and the temperature controller does not stop the heating ramp rate at 175 °C (i.e, furnace heats at 300 °C/hr), assume the quantity of TBP as 10 g, and that the butene generation rate is 0.5 g/min. Using equation 2 above with a temperature of 222 °C (495 °K), an approximate average generation rate over the last 12 minutes, per Table 9-64, results in the following:

- M = 1.66 g
- M_{in} = 0.5 g/min
- V_{in} = 0.36 L/min with T = 495 °K
- V_{in}/V = 0.06
- $M_{in}/(V_{in}/V)$ = 8.33
- time to reach the lower flammability limit - very short
- time to reach a volume fraction of 0.2 the assumed upper flammability limit at 250 °C - 3.7 min.

The accident analysis will be performed assuming a stoichiometric quantity of butene in the furnace and assuming no purge or CO_2 flow. At the auto-ignition point of 443 °C, the stoichiometric quantity of butene is 0.22 g. The air-butene mixture expands as it is heated, removing some of each out the door. It is interesting to note that to be left with 0.22 g of butene in the furnace at 443 °C only requires 0.35 g TBP to be present initially for the case where the controller holds heating at 175 °C.

A summary of flammability conditions for sludges are as follows:

1. Purge air or CO_2 at 0.5 ft^3/min, furnace temperature remains at 175 °C - concentration never within the flammable range

2. Purge air alone or with CO_2 at 0.5 ft^3/min, furnace temperature increases at 300 °C/hr, 10 g TBP - concentration within the flammable range for 5 minutes - deflagration occurs.

3. No purge air or CO_2, 10 g TBP, temperature controller stops increase at 175 °C- concentration is within flammable range for 20 minutes. Then it is above the upper flammability limit - flash fire occurs followed by burn.

4. No purge air or CO_2, 10 g TBP, furnace temperature increases at 300 °C/hr, flammable concentration for about 4 min - deflagration occurs.

5. No purge air or CO_2, 0.35 g TBP - stoichiometric conditions at the auto-ignition temperature. Larger quantities would also be within the flammability limits.

9.2.10.2.2.2 Mitigation. Important features to preventing fires and deflagrations include:

- Purge air (prevents flammable concentrations)
- CO_2 purge (prevents flammable concentrations at high butene release rates should the temperature program be incorrect if the flow rate is at least 25 volume percent CO_2 in air flow - present flow rate is 16 volume percent)
- Temperature controller (if CO_2 purge is too unreliable or as a secondary safety feature).

Adequate purge air and CO_2 flow ensures that the contaminant is exhausted during ramp up in the furnace such that conditions in which deflagrations or fires could occur do not exist. In addition the operator pulls the gloves out of the glovebox before operating the furnace. This is discussed in Section 9.2.10.2.1.2.

Glovebox ventilation is discussed in Section 9.2.10.2.1.2.

The feed is sampled for TBP content. Any feeds with greater than 10 g TBP will not be stabilized in this manner.

9.2.10.2.2.3 Probability. The accident scenario in Section 9.2.10.2.2.1 is based on a CO_2 flow rate of 0.5 ft^3/min. At this flow rate, a deflagration could occur with TBP if both the vacuum offgas and temperature controller fail. If the CO_2 is set at a flow rate that yields at least 25% CO_2 in the furnace, then an additional failure, i.e., loss of CO_2, is required.

For this analysis, it is assumed that the CO_2 flow rate is set such that there is at least 25% CO_2 in the furnace. Using the rationale developed for plastic contaminants, the annual probability is 10^{-3} to 10^{-4}. Both the CO_2 and vacuum offgas flowrates could be erroneously set by a single operator. This is a more likely failure mode than the concurrent failure of both systems.

Another consideration is the operator error of sending boats with PRF sludge to HA-21I, which does not have the CO_2 cover gas, by mistake. Thus the additional error of sending boats to HA-21I with PRF sludge, which lowers the

chance of a deflagration, is approximately offset by the probability of deflagration in HA-21I with PRF sludge and no CO_2 cover gas. The probabilities discussed above are per boat processed. Depending on the number of boats processed per year, the annual probability of a deflagration could easily be in the anticipated category for a deflagration while processing PRF sludge.

9.2.10.2.2.4 Accident Analysis and Dose. To develop a flammable concentration of butene in the furnace requires 0.35 g of TBP. This results in the presence of 0.0039 moles (0.22 g) of butene at the auto-ignition temperature. The reaction is

$$0.0039\ C_4H_8 + 0.023\ O_2 \rightarrow 0.016\ CO_2 + 0.016\ H_2O \qquad (4)$$

The heats of formation are

CO_2 -94.0 kcal/mole, at 25 °C (Perry 1963, page 3-135)
H_2O -57.8 kcal/mole, at 25 °C (Perry 1963, page 3-137)
C_4H_8 0.3 kcal/mole, at 25 °C (Perry 1963, page 3-135)

The heat of reaction is 2.4 kcal.

The temperature increase is found by using the reaction products above and 0.075 moles N_2 present initially. The average temperature is taken to be 1,500 °C. The specific heat is found in the same way it was for plastics. The specific heat is found to be 0.9 cal/C. The temperature rise is found to be 2,666 °C. The final temperature is 3,110 °C. So use of 1,500 °C is a reasonable average. The pressure is found to be 4.9 atm, using a total of 0.107 moles and a temperature of 3,110 °C (3,383 K). The peak pressure 4.9 atm and the energy of reaction of 2,400 cal are similar to the peak pressure for plastics of 3.4 atm and energy of reaction of 1,980 cal. Given all of the uncertainties, the structural results for butene deflagration will be similar if not slightly more severe then those for plastics described in Section 9.2.10.2.1.4.

Since sludge containing TBP is guaranteed to contain organics (from the TBP), it is very likely that more than one furnace could have the flammability conditions necessary for a deflagration. Thus deflagrations could occur in three furnaces (in HA-21I by operator error) and it is assumed that deflagrations will be separated by a short period of time such that 4.5 g of respirable material from the furnaces and 500 g of respirable material from outside the furnaces but inside the glovebox will be assumed to be released to the glovebox room.

As a result the dose consequences will be similar to those calculated in Section 9.2.10.2.1.4.

9.2.10.2.2.5 Conclusion. These doses are well below the risk guidelines for any frequency category. The reason for this is the ability of the HEPA filters to remain functional after the deflagration.

9.2.10.3 Seismically Induced Deflagration in Glovebox HC-21C or HA-21I. Section 9.2.10.2 provides a discussion of the conditions necessary to result in a deflagration as a result of Glovebox HC-21C or HA-21I operation. It is shown in this section that a seismically induced deflagration is not credible. However, a flash fire scenario is shown to be credible and is analyzed in detail.

9.2.10.3.1 Scenario. Section 9.2.10.2 showed that a deflagration could only occur if the following conditions were met:

1. Organic contaminants in the feed material.
2. The air purge is off prior to the point where the assumed organic contaminants within the oxide pyrolyzes.
3. The door remains closed allowing flammable gases to remain relatively undiluted.
4. A spark source occurs after the point when sufficient air has been drawn in during cooling to result in a flammable mixture.

Barney (1998) showed that plastic will pyrolyze at 260 °C to 450 °C, depending on the plastic, if no air is present. With a furnace heat-up rate of 5 °C/min, these temperatures are reached at between 46 and 84 minutes. In the analysis that follows, a heat-up time to pyrolysis of about 90 minutes is used for conservatism.

Therefore in order for a deflagration to occur as a result of a seismic event, one of the following condition sets is necessary.

Condition Set 1

Organic contaminants in the feed material being heated.

Seismic event occurs prior to the time that the organic contaminants have combusted resulting in loss of purge air flow only. Glovebox and equipment remain in-place. The duration of this condition is just under 1.5 hours twice per day as the furnace is heated from room temperature to 450 °C in just under 1.5 hours.

Power remains on and temperature controller functions normally or fails so as not to result in power loss.

Operator fails to shut power off as he/she evacuates. A seismic event mild enough that evacuation is not necessary is not considered a seismic event for this analysis.

Spark occurs when door opens either due to aftershock or when operator opens door on return to the building. A deflagration will not occur if the door opens prior to cooldown as a flammable concentration does not exist per Section 9.2.10.2. A flash fire will occur under these conditions.

Condition Set 2

Organic contaminants in the feed material being heated.

Operator error in starting furnaces with no purge air flow. Airflow loss is either due to operator error during pre-heating activities or system failure. The furnace operates as normal.

Seismic event occurs after cooling is complete. Seismic event results in door opening and spark but not glovebox toppling or significant equipment movement. Seismic event before cooling is complete does not result in a deflagration but a flash fire. The window is about 2 hours twice per day at the end of the cool down time.

9.2.10.3.2 Probability. The seismic deflagration is not considered credible because the four following situations must occur:

1. A seismic event capable of causing damage must occur (10^{-3} to 10^{-4} event),
2. Organic contaminants must be present in the oxide being heated (10^{-1}),
3. The window during which the seismic event can satisfy the pyrolysis condition is about 10-15% of the time,
4. Either a pre-existing failure must be present prior to the seismic event (Condition Set 2) or the seismic event must fail specific equipment yet allow certain equipment to survive (10^{-1} to 10^{-3}).

The failures above describe the conditions necessary for a seismically induced deflagration for polyethylene (the most likely plastic contaminant) or polycarbonate. As was discussed in Section 9.2.10.2, the spark source may not be needed if the plastic is polyvinyl chloride. This results in Condition Set 1 requiring the first three failures, not all four. The event is still not considered to be credible for the reasons given.

If the plastic is PVC, Condition Set 2 is not applicable as the gas will deflagrate prior to the seismic event that occurs at cool conditions.

The phenomena that could occur in a seismic event is a flash fire. A flash fire occurs when air and an ignition source are brought together with a flammable gas at a concentration that is above its flammability limit. Fireballs are a type of flash fire. This can occur from Condition Set 1 or 2 conditions if the door opens prior to the furnace being cool. The annual probability of this event is still quite low (on the order of 10^{-5} or 10^{-6}) as it requires a seismic event, and either specific seismically induced failures but survival of other components or pre-existing failures. The window for this event is 20 hours/day if the furnaces are operated on a 12 hours/boat cycle.

9.2.10.3.3 Consequences. The flash fire can result in radiant heat applied to the panels and glovebox air. The first calculation shows the

effect of radiant heat. The conservatisms are chosen to maximize the radiant heat. The second calculation shows the effects of heating the air.

SFPE (1988), pg 2-78, provides a method for calculating the damage due to a fireball (or flash fire). The diameter of the fireball as a function of time is given by:

$$D = 0.81n^{1.12}V^{1/3} + d_o$$

where: V = vapor volume, m^3
= $6 \times 10^{-3} m^3$ (6L) in our case
$n = 3.13t/V^{1/6}$
D = diameter of fireball, m
t = time after ignition, s
d_o = initial diameter based on fuel volume, m, $(6V/\pi)^{1/3}$

The maximum duration of the fireball is given by:

$$t = 2.8\ V^{1/6}\ \text{sec.} = 1.2\ \text{sec.}$$

The thermal flux generated by the fireball varies with time. The variance is shown in Fig 2-4.35 of SFPE 1988. A number of points of that figure are shown below.

Normalized Heat Transfer rate, v	Nondimensional Time, n	Actual Time, (from nondimensional time) sec (Note 1)
		0
0.01	0	0.27
0.07	2	0.54
0.10	4	0.68
0.16(peak)	5	1.09
0.10	8	1.36
0.04	10	1.91
0.01	14	3.00
0.0	22	

Note 1 - actual time = (nondimensional time)$(V^{(1/6)})/(g^{0.5})$

The actual heat flux in kW/m^2 is given by:

$$q = vf\tau g^{0.5}\rho h_f V^{5/6}/4\pi r^2$$

where: r = distance from the center of the fireball at the time of interest.

What is assumed is that the seismic event causes the door to open, and fresh air to rush in. This is assumed to displace the flammable gas in the furnace. The gas, air and spark meet in front of the furnace at the door creating a fireball. It is assumed that the furnace is filled with the flammable gas at room temperature and that there is no air mixed in. This maximizes the amount of gas.

The table above shows that the normalized heat flux is a maximum of 0.16 at a nondimensional time, n, of 5. The fireball diameter as a function of V and nondimensional time is given by:

$$D = 0.81n^{1.12}V^{1/3} + d_o$$

At a value of "n" of 5 and "V" of 0.006 m^3, "D" is found to be 1.12 m. Therefore, the value of 0.56 m will be used for "r" above.

To solve for "q" the following is needed:

v = 0.16
f = fraction of heat that is radiated to the environment assumed to be 1.0
τ = atmospheric transmissivity
Taken to be 1.0 per Fig 2-4.20 of SFPE 1988 which show values of 0.95 at low relative humidity and small fireballs.
g = 9.8 m/s^2
ρ = density of flammable gas at ambient conditions, kg/m^3
= 1.13 for ethylene
h = heat of combustion, kJ/kg
= 51500 for ethylene

Solving for "q" yields 105 kW/m^2.

Glovebox windows are made out of either polycarbonate or PMMA. Polycarbonate windows are more heat resistant than PMMA. The Fire Hazards Analysis (McKinnis 1998) shows that at a heat flux of 40 kW/m^2 it takes 182 s to ignite polycarbonate and at 70 kW/m^2 it takes 75 s (see also Section 9.2.10.4.1). Extrapolating (using a log-log graph) to 105 kW/m^2 shows the duration must be 40 s. The maximum duration of the fireball was found to be 1.2 s. It is also noted that from Figure 2-4.35 of SFPE (1988) the time of significant heat transfer is only about 1/4 to 1/3 of the duration or 0.4 s in this case. As a result the windows do not fail. Even with PMMA windows the duration must be 2.5 s (log-log extrapolation) for failure to occur. The FHA states that even small fires result in failure of PMMA panels. The hypalon glovebox gloves are judged to be no more readily ignitable than PMMA panels. It is therefore concluded that the gloves will also survive the fireball. Since the glovebox is not breached as a result of the fireball, there is no

release out of the glovebox for this condition. Release due to toppling is found in Section 9.2.4.

If the seismic event fails the panel, the fireball might be able to carry the resuspended material out of the glovebox.

The fireball travels across the powder pan and could resuspend some of the powder. Mishima (1973) describes a test in which a 15 inch diameter, 2 inch deep stainless steel pan was placed in a wind tunnel. Twenty-five grams of ball milled UO_2 powder was sprinkled on the horizontal surface of the pan. Wind was blown over the pan and the amount of powder suspended was measured. The results for a 1 m/s wind was that 0.09 wt% of the powder was suspended over 4.8 hrs. Of this, 83% was respirable. The release rate vs time is an inverse exponential function; large at the start of the experiment and small at the end. Data on the release rate was not provided for the "1m/s wind over stainless steel" case. So the rate will be inferred from other cases discussed in Mishima (1973). For the "9 m/s wind over stainless steel" case, 50% of the release occurred over the first 30 minutes with the remainder occurring over the next 23 hours. The "1 m/s wind over sandy soil" case showed 50% of the release occurred over 2 hours for a 1m/s wind. It will be assumed that 50% of the release occurs over 1 hour. The vertical flux is therefore:

$$\text{Flux} = \frac{Q(0.09/100)(0.83)}{2(dt)(A)}$$

where: Q = initial quantity in the pan
= 25 g
dt = duration of 50% release
= 1 hour
A = area, m^2
= 0.114 m^2 based on 15 in. diameter
Flux = g/m^2 -hr

Solving for "Flux" yields 0.08 $g/hr\text{-}m^2$. Applying this to the fireball case:

$$RQ = (0.08\ g/hr\text{-}m^2)(1.2\ s/3600)(A)$$

where: A = area of boat, m^2
= $(5.5)(13)/144\ (3.28\ ft/m)^2$
= 0.046 m^2
RQ = respirable quantity released

Solving for "RQ" yields 1.2×10^{-6}g.

Iverson (1984) was used as a check. Iverson placed various heavy powders in pans distributed along a bed. Wind was blown over the top of the pans. The bed was 183 cm long (72 in) and 14 cm wide (5.5 in). The amount resuspended was measured. He calculated resuspension fluxes (g/cm^2-s) from 2×10^{-7} to 6×10^{-6}. The wind speeds used were 7 to 10 m/s. Using these values

for the fireball case (duration of 1.2 s, area of 461 cm^2) yields 1 x 10^{-4} to 3 x 10^{-3} g. These resuspension values are greater than those calculated from Mishima, of 1.2 x 10^{-6}, because of the greater wind speed.

Iverson also presents the results of suspension off of a coal pile. The empirical relationship is

$$Q = \frac{336\ u^3\ \rho^2\ A^{0.345}}{(PE)^2}$$

where: u = wind speed, m/s
= use 1 m/s
ρ = bulk density, g/cm^3
= 5 g/cm^3 for PuO_2
A = area m^2
= 0.046 m^2 for this boat
PE = moisture index which ranges from 7 to 180. Use 10 as 7 is extremely dry coal.
Q = resuspension rate mg/s.

Solving for "Q" yields 29 mg/s. Over 1.2 s the release is 0.035 g. If a value of 50 had been used for "PE", the release would have been 10^{-3} g. The release is therefore insignificant.

The ignition of the flammable gas could increase the glovebox temperature and cause pressurization. Section 9.2.10.2 shows the glovebox volume to be 105 ft^3. The total quantity of flammable gas in the furnace is taken from the 10 g benzene case as the energy release is greatest. There is 0.032 moles of benzene in the glovebox or 2.5 g. The heat of combustion for benzene is 9.56 kcal/gm. The energy release from combustion is 23,900 cal. The amount of air in the glovebox at room temperature (30 C) is found by the ideal gas law to be 119.6 g-moles or 3470 g. The specific heat of air is 0.24 cal/g-C. The temperature rise from this energy release assuming all of it goes into heating only the air is 28.7 °C. The glovebox pressure after burning assuming no air flow out of the glovebox is 1.4 psi. To maintain the pressure at atmospheric conditions at this greater temperature means that 10 ft^3 must be removed from the glovebox. The duration of the burn is 1.2 s, so the flow rate must be greater than 10 ft^3/s at pressures much less than 1.4 psig to maintain the glovebox pressure near atmospheric.

There will be flow-out of the glovebox into the conveyor as the glovebox pressure increases. The opening to the conveyor is taken to be 1.5 ft wide (distance from edge of glovebox to the center of the furnace door) and 1.5 ft. high (from the floor of the glovebox to the top of the conveyor).

The gas flow rate under subsonic conditions comes from AIChE (1989). The gas flow rate at a pressure equal to 0.4 psig and 8.2 C increase (the approximate conditions of Section 9.2.10.1) is found by:

$$G = \frac{C\ A\ P\ B}{a}$$

where: G = gas flow rate, kg/s
C = discharge coefficient, taken to be 1.0
A = area of opening, m^2
= $1.5(1.5)/3.28^2$ = 0.21 m^2
P = upstream pressure N/m^2
= 101320 [(14.7 + 0.4)/14.7]
= 104100 N/m^2
a = sonic velocity of gas at T
= $(s\ RT/M)^{0.5}$
s = ratio of specific heats = 1.3 for air
R = gas constant = 8310 J/kg-mole-K
T = upstream temperature, K = 311.2
M = molecular wt of gas = 29 for air
a = 340.5
B = flow factor
= $[(b)(c)(d)]^{0.5}$
b = $2s^2/(s-1)$ = 11.3
c = $(Pa/P)^{2/s}$ = 0.96
Pa = atmospheric pressure, N/m^2
= 101320
d = $[1-(Pa/P)^{(s-1/s)}]$
B = 0.26

Solving for "G" yields 16.7 kg/s.

The density of air at 311.2 and 15.1 psi is 0.04 moles/L or 1.167 g/L. The volumetric flow rate out is 14300 L/s or 505 ft^3/s. This flow rate easily maintains the glovebox pressure below that in Section 9.2.10.1 of 0.4 psi with the indication of high gas flow rates at even lower pressures, the peak glovebox pressure will likely be much less than 0.4 psi.

9.2.10.3.4 Conclusions. The releases are insignificant. As a result, the consequences due to a seismically induced deflagration are very much less than those of a seismic event (Section 9.2.4).

9.2.10.4 Glovebox HC-21C or HA-21I Fire. Reactive-material stabilization operations are conducted in gloveboxes HC-21A, HA-21I, and HC-21C (See Chapter 6.0). Glovebox HC-21C is located in room 230A of the 234-5Z Building. Glovebox HA-21I is located in room 235B of the 234-5Z Building. Glovebox HC-21C uses two muffle furnaces and glovebox HA-21I uses three muffle furnaces to stabilize the reactive plutonium-bearing materials. A fire in either Glovebox HC-21C or HA-21I is possible as either glovebox contains intense heat sources (the muffle furnaces and their exhaust), the potential for electrical sparks and combustible material (e.g. the tape and plastic from the container plus polycarbonate windows).

9.2.10.4.1 Scenario. The potential for a fire exists whenever combustible materials coexist with a source of ignition. The high temperatures associated with operation of the furnaces represent a credible ignition source. Therefore, to reduce the probability and magnitude of potential fires, administrative controls are established to minimize the quantities of combustible materials present in the glovebox. These materials

consist primarily of packaging materials (plastic bags and tape) used for sealing items into or out of the glovebox.

A fire could be initiated if the insulation fails while the furnace is operational or the furnace door is opened when the furnace is at a high temperature. The polycarbonate windows will burn if a heat source of 40 kW/m^2 for 182s (about 3 minutes) or 70 kW/m^2 for 75s (a little more than 1 minute) or the equivalent is applied to the window (McKinnis 1998). A fire involving glovebox windows can also be initiated if trash accumulates and is ignited so as to result in the above heat fluxes and duration. It is assumed that one of these scenarios occurs.

For this analysis, it is assumed that a fire of sufficient magnitude and duration to breach the glovebox via burned-out gloves or failed windows occurs, releasing material to the surrounding room.

9.2.10.4.2 Mitigation. The mitigating factors are as follows:

1. Administrative controls help to minimize the amount of combustible waste kept within the glovebox and keep it located away from hot surfaces.

2. The operation of the Halon system for Glovebox HC-21C and the operation of the dry-chemical fire protection system for HA-21I.

3. The wet-pipe sprinkler system.
4. The response of the Hanford Fire Department.

9.2.10.4.3 Probability. The muffle furnaces are used to thermally stabilize reactive plutonium-bearing compounds. The glovebox has polycarbonate panels (see Hanford drawing H-2-97289 and H-2-95707). The polycarbonate panels were installed in 1985 and 1986. The polycarbonate panels are covered by lead glass panels. To burn through polycarbonate panels requires a heat flux of 30 kW/m^2 (McKinnis 1998). McKinnis 1998 states that in a separate experiment a fire having a heat rate of 18 kW causes ignition of PMMA in 2 minutes. Table 7-1 of McKinnis shows that in general the heat needed to ignite polycarbonate is about double that needed to ignite PMMA. Therefore a 36 kW fire is needed to cause polycarbonate to burn. An example of a heat source of this magnitude is a pile of paper or trash about 1 ft. in diameter containing about 3 kg of trash (McKinnis 1998). It is unlikely that this amount of trash would accumulate, if allowed, as a result of stabilization activities. The ignition source is also unlikely. Possible ignition sources are:

- failure of insulation on exhaust line. The exhaust line insulation touches the plastic panel. This may also require simultaneous prolonged operation of the furnace or a process upset within the furnace in order to deliver the required energy to the window.

- failure of electrical leads into the furnace. This is a very unlikely ignition source as the trash is likely in the front of the glovebox and the power is in the rear.

- prolonged operation with the door open (radiant heating of the front panel). This is unlikely because an interlock on the furnace door interrupts power if the door is opened.

- failure such that the glove contacts a hot furnace surface.

The probability of allowing trash to accumulate is taken to be 10^{-2} (Swain and Guttmann, 1980, Table 20-22, entry on "failure to carryout a plant policy," and "use of written procedures under normal operating conditions).The probability of igniting the trash creating a fire large enough to breach the windows is judged to be on the order of 10^{-2} based on the above. The probability of a propagating fire involving glovebox panels is therefore 10^{-4}.

Should administrative controls fail such that a large quantity of combustible material accumulates and ignites in the gloveboxes, redundant fire suppression measures are in place. Operators are present in rooms 230A and 235B and are trained to extinguish fires in accordance with *Respond to Plutonium Metal/Scrap Fires*, Procedure ZO-200-010. An automatic Halon system is provided in Glovebox HC-21C and an automatic dry-chemical system is provided in Glovebox HA-21I. The wet-pipe sprinkler system servicing rooms 230A and 235B would activate if the magnitude of the fire was large. In addition to these in-plant measures, the HFD is available to respond to onsite emergencies. Section 9.2.2A estimates the annual probability of the failure of fire suppression measures to be about 10^{-4} (i.e., the combined "failure to act" of the Halon system, wet pipe sprinkler system, and HFD response probabilities). The annual probability of a fire that will breach this glovebox and not be extinguished rapidly is less than 10^{-6}. The consequences of this fire is evaluated as a bounding event.

9.2.10.4.4 Accident Analysis and Dose. Criticality Prevention Specifications (CPS) limit the plutonium inventory in Glovebox HC-21C to 5 kg (see Table 9-25). The Criticality Prevention Specifications (CPS) limit the plutonium inventory in Glovebox HA-21I to 8 kg (see Table 9-25). Therefore, the inventory of plutonium available for a bounding, postulated suspension and release in this analysis is limited to 8 kg.

For a given inventory at risk, the amount of plutonium aerosolized by a fire is dependent upon many variables such as the chemical and physical form of the plutonium, the matrix in which it is held, and the direction and velocity of entraining gases. Recommended values of ARF and RF for solids undergoing thermal stress are documented in DOE (1994). The ARF is defined as the coefficient used to estimate the amount of radioactive material that can be suspended in air and available for transport. The RF is defined as the fraction of the airborne radionuclides present as particles that can be transported through air and inhaled into the human respiratory system (commonly assumed to be particles 10-μm AED and less in size).

DOE (1994) presents the recommended bounding ARF*RF for various plutonium compounds (as powders) subjected to thermal stress (temperature <1000 °C; natural convection). It is conservatively assumed that the plutonium inventory involved in this scenario is in the form of a non-reactive oxide compound in open furnace boats.

For this analysis, the ARF*RF per DOE (1994) for non-reactive compounds (i.e, plutonium dioxide) is 6 x 10^{-5} (ARF of 6 x 10^{-3}, RF of 10^{-2}). The quantity of respirable PuO_2 made airborne is therefore:

8000 g x 0.006 x 0.01 = 0.48 g

DOE (1994) stated that the respirable fraction was 0.01. Figure 9-28 shows a respirable fraction of 0.04 for plutonium fluoride as prepared by PFP. It could be argued that the RF for heating is 0.04, not 0.01 making the assumption that oxide powder would have a similar size distribution. DOE (1994) recognizes this question and stated that it was difficult to obtain process powders with RF greater than 1%. DOE (1994) further stated that even if this were possible, the particle size distribution changes with the time over which the container sits. The respirable fraction gets less and less (see Figure 1-41 of DOE 1994). Therefore DOE (1994) believes the value of RF 0.01 to be reasonable and conservative.

For the purpose of this analysis, it is assumed that one-half of the plutonium aerosols generated are exhausted via the E-4 ventilation system servicing Glovebox HA-21I, and one-half is exhausted via the E-3 system that services room 235B. Both the E-3 and E-4 pathways were given credit for one stage of HEPA filtration. The minimum acceptable collection efficiency, as indicated by testing, is 99.95%. Since both paths lead to the stack through HEPA filtration, the flow split between the two paths does not affect the consequences. Applying this value to the 0.48 g of plutonium assumed to be released via the E-3 and E-4 pathways, results in the discharge of 2.40 x 10^{-4} g from the 291-Z-1 stack, all of which is respirable.

The doses due to the release of 2.40 x 10^{-4} g of plutonium can be calculated by using the methodology from Section 9.5.

$$D(rem) = Q(g) \times \chi/Q'(sec/m^3) \times R(m^3/s) \times C(rem/gram)$$

where: D = Dose
Q = Quantity of plutonium released = 2.40 x 10^{-4} grams.
χ/Q = Atmospheric dispersion coefficient for elevated release = 1.62 x 10^{-5} s/m^3 for onsite receptor and 5.73 x 10^{-6} s/m^3 for offsite receptor from Table 9-39 and 9-40 respectively.
R = Breathing rate = 3.3 x 10^{-4} m^3/s.
C = Gram plutonium to dose conversion factor for Class Y >10% ^{240}Pu, 90th percentile = 1.7 x 10^8 rem/gram (EDE) and 2.7 x 10^9 rem/gram (Bone Surface) from Table 9-46 and 9-47, respectively.

Therefore, the EDE doses are:

- onsite = 2.2 x 10^{-4} rem
- offsite = 7.7 x 10^{-5} rem

The bone surface doses are:

- onsite = 3.5×10^{-3} rem
- offsite = 1.2×10^{-3} rem

9.2.10.4.5 Conclusions. The results of the preceding analysis show that the consequences of a bounding release from a large-scale fire are several orders of magnitude below these Risk Acceptance Guidelines (Table 9-49) for even an anticipated event. The reason the doses are so small is the functioning of the HEPA filters during and after the fire.

9.2.10.5 Seismically Induced Fires in Gloveboxes HC-21C and HA-21I.

9.2.10.5.1 Scenario. Fires in these gloveboxes are addressed in Section 9.2.10.4. Fires require an accumulation of flammable material and for this flammable material to come in contact with an ignition source. Administrative controls prevent accumulation of large quantities of flammable material. To produce a fire therefore, a heated surface must contact the glovebox window. This can occur if the glovebox topples. When the glovebox topples, it is likely that the furnace will impact the front window when it hits the floor (i.e., the glovebox, the window and the furnace strike the floor and each other at the same time). Even if the glovebox remains partially upright, the vibratory motions along with the tipping is assumed to cause impact of the furnace and the plastic panel. The impact is assumed to result in a hot surface touching the panel for sufficient duration that the panel begins to burn. It is also possible that the seismic event causes the furnace door to open and causes failure of the vacuum and glovebox ventilation system. It is assumed that radiant heat from the furnace can result in ignition of the panels. The effects of seismically induced fires in these gloveboxes are discussed in Section 9.2.4.2.12.F.

9.2.10.6 Changes to the RMC/RMA Lines Fire Analysis from Gloveboxes HC-21A, HC-21C, and HA-21I. Section 9.2.2A analyzes a worst case glovebox fire which includes gloveboxes HC-21A, HC-21C, and HA-21I. Therefore all changes due to these gloveboxes have been incorporated in the analysis discussed in Section 9.2.2A.

9.2.11 Accidents for the Laboratory Prototype Calciner

The Laboratory Prototype Calciner is not currently authorized for operation. However, the previous accidents analyzed for the laboratory calciner are retained in the FSAR for future evaluation if the calciner is reauthorized for operation in the future.

Accidents which have been postulated to potentially result from operation of the Laboratory Prototype Calciner are as follows:

- Hydrogen deflagration in Room 188 from opening drum
- Hydrogen deflagration in Glovebox 188-1 from opening bagged polybottle

- Flammable gas deflagration in the Laboratory Prototype Calciner
- Glovebox 188-1 fire
- Glovebox 188-1 seismic event.

Each of these accidents is discussed in detail in the Laboratory Prototype Calciner addendum to this FSAR. The accident analysis provides a description of the accident scenario, mitigation, probability, consequences and conclusions for each event analyzed.

9.2.12 Accidents for the Magnesium Hydroxide Precipitation Process.

Accidents associated with operation of the Magnesium Hydroxide Precipitation Process are identified and analyzed in the related addendum (Carson 2000) to this FSAR.

9.2.13 Accidents for the Bagless Transfer System (BTS).

Accidents associated with the operation of the BTS are identified and analyzed in the related calculation notes (FH 2000).

9.3 DOSIMETRY CALCULATIONS

Radiation dose is proportional to the quantity of energy deposited per unit mass of irradiated tissue. The total "absorbed dose" is reported in units of rad (100 ergs/g) or gray (1 J/kg). This is normalized to relative biological effect, depending on the type of radiation, in dose equivalent units of "rem" or "sievert."

All radiological dose calculations for this study were made using the GXQ code in combination with the plutonium inventory appropriate to a specific accident. The following sections summarize the models used in the GXQ code, the primary accident scenarios for which $\overline{\chi}/Q'$ values are calculated, the dose conversion factors for various plutonium isotopic distributions, and provide a sample calculation for a 1 g release from the 61 m stack.

9.3.1 Material Release

The dosimetry calculation begins when the radioactive material is released from the facility into the environment via discharge into the air, a body of water, or the ground. For the PFP analysis all releases were assumed to be into the air. A discharge may be characterized as a total release in Curies, a release rate, or as a concentration in stack effluent. In any case, the specification is made in terms of a detailed radionuclide inventory at the moment of release. In order to be transported for any distance the material must be either gaseous or a fine aerosol. Aerosols are assumed to be in the form of a particulate distribution in the respirable size range (less than 10 μm).

9.3.2 Material Transport Methodology

This section briefly discusses the methodology and models used to estimate $\overline{\chi}/Q'$ in this report. Implementation is performed with the aid of a computer program called GXQ. For more detailed information on the models used and their applicability, refer to the GXQ documentation (Hey 1993a, 1993b).

The atmospheric dispersion coefficient $\overline{\chi}/Q'$ represents the dilution of an airborne contaminant due to atmospheric mixing and turbulence. It is the ratio of the average contaminant air concentration $\overline{\chi}$ at the receptor to the contaminant release rate Q' at the release point. Since atmospheric conditions fluctuate, a bounding atmospheric condition is determined to be that condition that causes a downwind concentration of airborne contaminants that is exceeded only a small fraction of time due to weather fluctuations. The NRC defines this fraction as 0.5% for each sector or 5% for the overall Site, whichever is greater (NRC 1982).

9.3.2.1 Atmospheric Dispersion Coefficient Calculation - $\overline{\chi}/Q'$. The Gaussian straight-line model is employed by GXQ for calculating atmospheric dispersion.

The time integrated atmospheric dispersion coefficient $\overline{\chi}/Q'$ for a continuous point source is given by:

$$\frac{\overline{\chi}}{Q'} = \frac{f(y)g(z)}{2\pi\sigma_y\sigma_z\overline{u}}$$

where: σ_y = Horizontal diffusion coefficient (m)
σ_z = Vertical diffusion coefficient (m)
$f(y)$ = Horizontal correction term
$g(z)$ = Vertical correction term
$\overline{u}$ = Mean wind speed (m/s).

The horizontal correction term is given by:

$$f(y) = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where: y = Horizontal offset from plume centerline (m).

If the mixing height is large compared to the release height and the vertical diffusion coefficient, then the vertical correction term is given by:

$$g(z) = F_{ref}\exp\left[-\frac{1}{2}\left(\frac{h_e - z}{\sigma_z}\right)^2\right]$$

where: F_{ref} = Reflection factor[1]
h_e = Effective release height (m)
z = Receptor height (m).

Mathematical approximations are used to evaluate the atmospheric diffusion coefficients σ_y & σ_z which are based on the Pasquill-Gifford-Turner curves. These approximations are identical to those used in the GENII Code (Napier 1988).

[1]The reflection factor is based on the virtual image source and assumes 100% ground and mixing layer reflection. The mathematical expression is given in Hey (1993a).

9.3.2.2 Additional Dispersion Models. When appropriate, certain additional effects may be considered in the calculation of $\overline{\chi}/Q'$. The models for these effects are summarized below and are utilized to varying degrees in the consequence calculations discussed in Section 9.2.

9.3.2.2.1 Building Wake Effect. The building wake model is a simple alteration of the Gaussian plume model. It assumes the release point to be at the ground level and in the middle of the downwind face of the building. The plume horizontal and vertical dimensions are initialized such that the plume concentrations at the sides and roofline of the building from which the release occurs are assumed to be 10% of plume centerline concentrations (i.e., building edges are 2.15 σ from the plume centerline). The formulae below were taken from Equation 2.2 of the *MELCOR Accident Consequence Code System (MACCS) Model Description*, NUREG/CR-4691 (NRC 1990).

$$\sigma_y(x=0) = \frac{W_b}{4.3}$$

where: W_b = Building width (m).

$$\sigma_z(x=0) = \frac{H_b}{2.15}$$

where: H_b = Building height (m).

The above adjustment is made using the virtual distance method. The virtual distance method involves calculating the distances corresponding to $\sigma_y(x = 0)$ and $\sigma_z(x = 0)$ and adding these distances to the distance from the release point to receptor (x). These adjusted "virtual distances" are then used to calculate subsequent diffusion coefficients.

9.3.2.2.2 Exhaust Flow Rate Effect. As the release point to receptor distance, x, approaches zero, the values for σ approach zero as well. Thus, the calculated atmospheric dispersion coefficient ($\overline{\chi}/Q'$) using the Gaussian model approaches infinity. In reality, the $\overline{\chi}$ should not exceed the initial effluent concentration at the release point.

To correct this deficiency in the mathematical model, the diffusion coefficients at the point of release are chosen to represent the initial plume dimensions (Rittmann 1984). The initial lateral plume spread, $\sigma_y(x = 0)$, is based on the stack diameter or initial plume width. The initial vertical plume spread, $\sigma_z(x = 0)$, is based on the exhaust flow rate in such a way that the effluent concentration is obtained at $x = 0$. This dimension is essentially the vertical rise of the plume in the time it takes the plume to travel downwind one stack diameter.

This model is applicable to releases having an initial vertical velocity. The above adjustment is accomplished through the following equations.

$$\sigma_y(x=0) = \frac{d}{\sqrt{2\pi}}$$

where: d = Stack diameter (m).

$$\sigma_z(x=0) = \frac{F_{ref}(z=hs)V_0}{\sqrt{2\pi}\,\bar{u}d}$$

where: V_0 = Plume volumetric flow rate (m^3/s)
$F_{ref}(z=hs)$ = Reflection factor evaluated at stack height.

As in the building wake model, the virtual distance method also is used in the exhaust flow rate adjustment. If both the building wake and exhaust flow rate models are selected, then the larger diffusion coefficient of the two is used to calculate $\bar{\chi}/Q'$.

9.3.2.2.3 Plume Meander Effect. The plume meander model (as follows) is based on the fifth power law formula (Hanna 1982, eq. 4.15). When selected, it is applied to the horizontal diffusion coefficient based on the release duration t_A.

$$\frac{\sigma_{yA}}{\sigma_{yB}} = \left[\frac{t_A}{t_B}\right]^{\alpha}$$

where: σ_{yA} = Horizontal diffusion coefficient averaged over time t_A
σ_{yB} = Measured horizontal diffusion coefficient
α = 0.2, when 10 min $\leq t_A <$ 1 h
α = 0.25 when 1 h $\leq t_A \leq$ 100 h
t_A = Release duration
t_B = Measurement averaging time (10 min).[1]

9.3.2.2.4 Plume Rise Effect. The momentum/buoyancy plume rise model used in GXQ is taken from Equations 8.35, 8.36, and 8.57 of *Atmospheric Science and Power Production*, DOE/TIC-27601 (Randerson 1984) for plume rise in a crosswind. Assumptions made are that the effluent is a heated gas with a heat capacity and mean molecular weight close to that of air, and that initial effluent density and vertical velocity within the plume are constant.

[1]The standard Pasquill-Gifford curves represent a sampling time of approximately 10 min (Hanna 1982).

$$z_c' = \left[\frac{3}{\beta_m^2} \frac{F_m}{\bar{u}^2} x + \frac{3}{2\beta_b^2} \frac{F_b}{\bar{u}^3} x^2 \right]^{1/3}$$

where:

z_c' = Centerline rise of plume (m)

$\beta_b = 0.6$

$\beta_m = 0.4 \frac{1.2}{R}$

$\bar{u}$ = Mean ambient wind speed (m/s)

x = Distance downwind (m)

R = Velocity ratio = $\frac{w_0}{\bar{u}}$

w_0 = Initial plume vertical velocity (m/s) = $\frac{4V_0}{\pi d^2}$

d = Stack diameter (m)

F_b = Buoyancy flux

$= 3.7 \times 10^{-5} q_h (m^4/s^3)$

g = Gravitational acceleration (9.82 m/s^2)

q_h = sensible heat emmission rate (cal/s)

$F_m = \frac{\rho_0 w_0 V_0}{\pi \rho_a}$

ρ_0 = Initial plume density (g/cm^3)

V_0 = Initial plume volume flow rate (m^3/s)

ρ_a = Ambient air density (0.00122 g/cm^3 assumed).

The above equation provides a transition from the $x^{1/3}$ law for bent-over jets to the $x^{2/3}$ law for bent-over buoyancy-dominated plumes.

For Pasquill stability conditions E, F, and G, the buoyant rise of the plume is assumed to be limited by

$$\Delta h = 2.6 \left[\frac{F_b}{\bar{u} S} \right]^{1/3}$$

where: S = Stability parameter
$= 5.04 \times 10^{-4}$ for stability class E
$= 1.27 \times 10^{-3}$ for stability class F
$= 1.75 \times 10^{-3}$ for stability class G.

This equation can be found in the MELCOR/Accident Consequence Code System (NRC 1990).

For Pasquill stability conditions A through D, buoyant rise is terminated when any of the following conditions are met (NRC 1990):

- $\Delta h = 300\ (F_b/u^3)$.
- The plume centerline reaches the height of the mixing layer.
- The plume has travelled downwind for 1 h.

Near-surface wind speeds increase with altitude. Because plume rise is a function of wind speed and wind speed is a function of effective release height, iteration is necessary to converge on an effective release height and corresponding wind speed. As the plume experiences a change in elevation, the average of the wind speeds at the release point elevation (assumed to correspond to the meteorological wind data) and the effective release height at the receptor is used. Iteration on effective release height and average wind speed continues until the difference between the last two calculated effective release heights becomes less than 1 m or until five iterations are completed. This procedure is used in GXQ any time an elevation-corrected wind speed is selected and a non-zero stack height or plume height model (i.e., plume rise, stack downwash, or gravitational settling) results in an elevation different than the height corresponding to the wind speed data.

9.3.2.2.5 Liftoff Criterion. When wind speeds are high, a buoyant plume that is released into a strong building wake will be unable to escape from the wake. Escape of a buoyant plume from a building wake is governed by a lift-off criterion. The criterion states that plume rise occurs only when the stack-level wind speed is less than a critical wind speed, u_c, that is calculated using the following formula.

$$u_c = \left[\frac{9.09F_b}{H_b}\right]^{1/3}$$

where: H_b = Building height (m)
F_b = Buoyancy flux (m^4/s^3).

9.3.2.2.6 Wind Speed Variation with Height. The measurement height for meteorological data is provided in the joint frequency file. If the measurement height differs from the effective release height, the wind speed at the effective release height is corrected using a power law function given in Equation 4.9 of the *Handbook on Atmospheric Diffusion*, DOE/TIC-11223 (Hanna et al. 1982).

$$u = u_m\left[\frac{h_e}{h_m}\right]^p$$

where: u = Corrected wind speed for elevated release (m/s)
u_m = Measured wind speed (m/s)
p = Power coefficient for rural roughness
h_m = Height of measured wind speed
h_e = Effective release height.

The corrected wind speed remains constant below 10 m and above 200 m in height. Power coefficients for rural areas also were taken from Hanna (1982). Rural coefficients were chosen to represent Hanford Site surface roughness.

9.3.2.3 Model Integration. The above discussions center on the individual models and approaches used. Control of model application is divided between the user of the code and the code itself. The user specifies which models to implement. The choice is based on the scenario under consideration. The code determines how those models interact with each other. This subsection describes how the various models are combined in GXQ to provide a single calculated $\overline{\chi}/Q'$.

For a release scenario involving a long-duration release from a building with a short stack, application of the plume meander, building wake, and flow correction models may be appropriate. These models, described above, are applied to the Gaussian plume model as an adjustment to the lateral and vertical diffusion coefficients (σ_y,σ_z) to account for the additional dispersion phenomena. The code calculates a corrected coefficient for the process that dominates the initial spreading of the effluent. The code does not attempt to combine the effects of all three models simultaneously.

For a release scenario involving a buoyant plume or vertical jet, application of a momentum buoyancy rise model may be appropriate. The plume rise model described in Section 9.3.2.2.4 raises the centerline of the Gaussian plume to model a vertical offset from the receptor to the plume centerline. If a stack or building is also involved, then stack downwash phenomena and plume trapping can be modeled through application of the downwash model and lift-off criterion. The effective release height, h_e, is determined using the following formula:

$$h_e = h_s + z_c'$$

where: h_s = Stack height (m)
z_c' = Centerline rise of plume (m)

To model the general increase in wind-speed with vertical distance from ground level, the wind speed correction model can be applied. Since wind speed is a function of plume rise and visa versa, GXQ iterates on the two until a converged value is reached.

When calculating a frequency-based $\overline{\chi}/Q'$, GXQ factors in the frequency of the combination of atmospheric stability class, wind speed, and wind

direction. These data are stored in a joint-frequency file. The procedure involves the calculation of a $\overline{\chi}/Q'$ and the selection, through interpolation, of a value that is exceeded only 0.5% of the time (i.e., for a 99.5% $\overline{\chi}/Q'$).

9.3.3 Release Point to Receptor Distances

Both onsite and site-boundary receptors are considered. These are chosen to yield the worst exposure to airborne contaminants. The receptor is assumed to remain at a given location for the duration of the plume passage. A map of the Hanford Site showing the irregular boundary and a map of the 200 West Area showing the location of nearby facilities are presented in Chapter 5.0. Onsite and site-boundary distances are given in Tables 9-37 and 9-38.

Onsite receptors are defined as workers at facilities that are occupied at least 5 d/week. Workers involved in sporadic activity that may occur at lesser distances are not considered. Only five sectors are identified for onsite receptors, since the remaining sectors either do not contain a facility or the nearest facility is several kilometers away (i.e., in the 200 East Area) and so the associated χ/Q would be much lower than for the facilities identified in Table 9-37.

Ground-level distances are from the edge of the 234-5Z Building. Distances from the PFP perimeter fence to the onsite receptor are approximated by subtracting 100 m from the ground-level distances.

9.3.4 Scenario Descriptions and $\overline{\chi}/Q'$ Results

Each of the accident scenarios for which $\overline{\chi}/Q'$ calculations are performed are briefly discussed below. Pertinent parameters for the models discussed above are also stated. Calculated $\overline{\chi}/Q'$s are provided at the end of this section.

9.3.4.1 Elevated Release. This release scenario is applied to postulated glovebox releases into rooms within the PFP that assume that all of the release occurs through the 200-ft (61-m) PFP stack. Scenarios postulated for gloveboxes HC-21C and MT-5 are characteristic of when this scenario is applicable. The stack flow rate is 260,000 std ft^3/min (123 m^3/s). The stack ID is 13.5 ft (4.1 m) (Section 1.2.2). Effluent is assumed to be at ambient temperature. The release occurs over approximately 6 min and is, therefore, essentially instantaneous.

The distance to the onsite receptor is taken to be the stack distance shown in the second column of Table 9-37.

9.3.4.2 Ground Level Release with Building Wake and Plume Meander. This release scenario is applied to a postulated event that assumes a release occurs through openings in the 234-5Z Building structure (i.e., doors, cracks). The release is assumed to occur at ground level with no rise in plume centerline. Building wake is modeled as described in Equations 4 and 5 for a building height and width of 14 m and 46 m, respectively. Additionally,

plume meander is also modeled for a 1-h duration release using the fifth power law model described in Hey (1993a).

The distance to the onsite receptor is taken to be the ground-level distance shown in the third column of Table 9-37.

9.3.4.3 Buoyant Plume Rise. This release scenario is applied to a postulated ground-level fire, such as that from stored combustible waste that assumes an attendant plume rise. The buoyancy of the plume depends upon the sensible heat generated.

A 3-m-dia pan fire of gasoline is assumed with a small fire being conservative. This assumption is based on the premise that combustion of the contaminated solids contained in an array of several sealed drums does not occur unless externally heated, and the most likely means for this to occur is by ignition of spilled fuel. The assumed fuel is gasoline, which has a heat of combustion of 43.7 MJ/kg and a burn rate of 0.055 kg/m^2 s (DiNenno 1988). The radiative heat loss is assumed to be 30%, a conservatively high value. Under these conditions, 60 gal of gasoline would burn in approximately 10 min (a little more considering fire growth and burn-out periods).

Due to the short duration of the fire, no credit is taken for plume meander. Additionally, plume trapping due to building turbulence is invoked using the liftoff criterion. The buildings near enough to cause this effect are single-story structures. A building height and width of 6.1 m (20 ft.) and 10 m (33 ft.) are used, respectively. Credit for building wake is taken if conditions prevent buoyant plume rise (i.e., plume trapping).

The distance to the onsite receptor is measured from the PFP perimeter fence to the nearest occupied onsite facility (see the fourth column of Table 9-37). It is assumed that such a fire occurs in waste drums stored in the southwest corner of the PFP fenced perimeter.

9.3.4.4 Point Source Ground Level Release. This release scenario is described as a point-source release of short duration. It may be applied to a postulated storage drum rupture involving a single drum that is assumed to rupture and release some portion of its contents. Additionally, it may be applied to the release from 232-Z, which is also assumed to release its contents instantaneously. No credit is taken for any plume rise, wake effects, or plume meander. It is modeled as a point-source ground-level release.

For the drum-rupture scenario, the distance to the onsite receptor is measured from the PFP perimeter fence to the nearest occupied onsite facility, as it was for the storage drum fire. For the 232-Z release, the distance to the onsite receptor is taken to be the ground-level distance shown in the third column of Table 9-37.

9.3.4.5 $\overline{\chi}/Q'$ Results. Tables 9-39 and 9-40 list the calculated $\overline{\chi}/Q'$ for each of the accident scenarios described above. The distance and direction listed under the column heading "Release scenario" refers to the location of the maximum receptor. That is, all other receptor locations had a calculated $\overline{\chi}/Q'$ that was smaller and less conservative. It might be observed that the

direction of the maximum onsite boundary does not coincide with the direction of the maximum site-boundary receptor. This is a direct result of the irregular site boundary and wind rose frequency.

9.3.5 Plutonium Inventory Characterization

9.3.5.1 Plutonium Isotopic Composition. Plutonium produced in nuclear reactors is a mixture of plutonium isotopes. The potential radiological hazard of plutonium depends significantly on the abundance of particular isotopes present. Each isotope represents a different hazard due to its specific activity and decay mechanism. Therefore, establishing a source term for the PFP requires appreciating and understanding the variation in plutonium isotopic ratios found in the stored materials. Table 9-41 shows the half-life and specific activity of major plutonium isotopes.

The principal exposure pathway in PFP-postulated accidents is via dispersion in air and subsequent inhalation by individuals. Differences in the magnitude of this radiological hazard for selected plutonium isotopes can be seen by examining doses incurred through inhalation of a given mass of each isotope. The term 'unit dose' describes the dose a person would receive over the next 50 yr if they inhaled 1 g of an isotope. Table 9-42 presents the EDE and bone-surface unit doses for plutonium compounds with two different lung-clearance classes. Plutonium compounds other than oxides, such as plutonium nitrate, that have relatively short clearance times in the lungs are considered Class W compounds (Eckerman et al. 1988). Oxides of plutonium are considered Class Y compounds (Eckerman et al. 1988). Although the differences are significant in dose consequences, they do not affect the determination of the plutonium inventory and isotopic composition. Only Class W material EDE values will be used for illustrative purposes through the remainder of this section until the final section where tables presented summarize the calculations for both Class W and Class Y materials.

Plutonium production in a nuclear reactor begins with a neutron-capture in ^{238}U and subsequent beta decays to form ^{239}Pu, which in turn is followed by successive neutron capture reactions as shown in Figure 9-31 (Wick 1967). Plutonium isotopes 240, 241, 242, and 243 are formed by these successive neutron captures. The sequence of isotopes thus produced ends with ^{242}Pu because of the short half-life of ^{243}Pu (4.95 h). ^{238}Pu is created by (n, 2n) reactions in ^{239}Pu and through decay chains from ^{238}U and ^{236}U.

The isotopic composition of plutonium from a reactor depends on the reactor power level, length of fuel exposure, neutron flux energy spectrum, and other factors that influence the production and removal rates of individual plutonium isotopes. The effective neutron cross sections of the various plutonium isotopes are dependent on the neutron flux energy spectrum. The ratio of fissions to captures in plutonium is expected to be greater in a fast spectrum than in a thermal spectrum. Consequently, the plutonium created in a thermal reactor has a greater percentage of the higher isotopes of plutonium than that produced in a fast reactor. Because the production of the higher isotopes requires multiple neutron captures, the isotopic ratios (relative amounts of higher isotopes) also depend on the length of time the fuel is left in the reactor and on the neutron flux level.

Radioactive decay decreases the quantity of each isotope at different rates because of the different half-lives of each isotope. Table 9-41 presented half-life data for plutonium isotopes. In the case of ^{241}Pu, the decay is principally beta decay that results in a daughter product, ^{241}Am. Alpha decay from this americium isotope contributes to the inhalation doses from plutonium and thus represents a personnel exposure concern. The processing of plutonium removes the americium and lowers the dose from the plutonium on a per gram basis. The production, decay, and processing history of each particular lot of plutonium significantly affects its isotopic composition, and therefore its potential radiological hazard.

9.3.5.2 PFP Plutonium Inventory. The current plutonium inventory is a collection of individual items and not a continuous spectrum of a single product line. The plutonium in each inventory container is unique because of its creation in a particular reactor environment and its chronological history of processing and storage. Individual containers may have similar plutonium isotopic distributions because they have a common history, were a part of a common process blend lot, or purely from coincidence.

Nondestructive analysis of shipments and periodic vault-inventory verifications have been performed at the PFP for more than a decade using gamma spectroscopy to determine isotopic concentrations of plutonium. The vault-verification program includes randomly selecting a number of items from the inventory and nondestructively verifying container contents. The shipping NDA measurements verify the composition of material shipped into and out of the PFP. Additional measurements are made for items created during PFP operations. In all, more than 4,700 items have been measured since 1985. The results of these measurements have been maintained by PFP laboratory analysts in a historical database.

This database, referred to as the NDA Verification Database, assessed the distribution of individual isotopes and their net effect on calculated potential doses in safety analyses. However, because the database is a record of "all" measurements, it includes duplicate measurements and counts of standards made for quality control purposes. These data were deleted from the database before use in this evaluation because they do not represent items in the inventory. Some of the database items were analyzed when shipped in, and again when shipped out. Counting these items in the estimate is not appropriate because these items no longer are in the inventory; therefore they were deleted from the database. Table 9-43 shows the plutonium isotopic distribution of the NDA database. The remaining mass of plutonium and number of items measured are also shown in Table 9-43, columns 2 and 3.

9.3.5.3 Dose Consequences of Current Inventory. Figure 9-32 depicts the plutonium inventory in terms of Class W EDE inhalation dose, based on 2,722 sample points from the NDA verification activity using the conversion factors from Table 9-42. The data points within each column show the range of inhalation doses within the corresponding ^{240}Pu bin. The dramatic difference in the scatter of data points for material with less than 10% ^{240}Pu, compared with that having more than 10% ^{240}Pu can be seen.

The description of the PFP inventory was continued one step further. The seven bins were collapsed into two ranges, one for items with greater than 10% ^{240}Pu and the other for items with <10% ^{240}Pu in Table 9-44.

These ranges are represented by three values each for the inhalation doses, the mass-weighted average, maximum value, and the 90th percentile as seen in Table 9-45. The inhalation dose varies because different isotopic compositions and different ages are presented in these tables. An item in the inventory need only be described as having more or less than 10% ^{240}Pu to have a maximum rem/g inhalation dose specified. The 90th percentile for each bin represents an inhalation-dose value greater than 90% of the inventory in each range. Because each range represents about half of the inventory, the 90th percentile for the upper range is approximately the 95th percentile for the total inventory. Table 9-45 gives the mass-weighted average, the minimum, the maximum, and the 90th percentile value for the two ranges.

The worst case class (Class W) for lung clearance is presented in the above table. This class is generally applicable to all plutonium compounds except for PuO_2. For PuO_2, the unit doses reported above would generally be lower by approximately 25%. The exact difference is a function of the americium content, which has only one lung-clearance class. The next section provides values for both lung-clearance classes.

9.3.5.4 Summary and Conclusions. Enough information has been presented for safety analysts to characterize the PFP inventory on a mass-weighted average basis by the ^{240}Pu content. Table 9-44 gives the plutonium isotopic composition for each of these bins based on the NDA verification sampling for the past 8.5 yr. Table 9-45 provides the maximum consequences as a function of age (Crowe and Szempruch 1994). Any specific isotopic composition concern addressed in a safety analysis can use this information to define a source term.

In addition, the description of the PFP inventory was continued one step further. The seven bins were collapsed into two ranges, one for items with greater than 10% ^{240}Pu and the other for items with less than 10%. These ranges are represented by three values each for the inhalation doses, the mass-weighted average, maximum value and the 90th percentile as seen in Table 9-45. An item in the inventory need only be described as having more or less than 10% ^{240}Pu to have a maximum rem/gram inhalation dose specified.

Tables 9-46 and 9-47 summarize the considerations for various plutonium compounds. These table values are adjusted to account for aging, so from a time standpoint, these computed doses are always conservative (Crowe and Szempruch 1994).

Single items should be described by the appropriate 90th percentile value depending on the ^{240}Pu content (less than or greater than 10% ^{240}Pu) and the plutonium compound (Class W or Class Y). Because the > 10% 90th percentile unit dose is greater than the mass-weighted average from the > 19% bin (by approximately 40%), even the selection of items from the highest exposure bin should not, on the average, exceed the 90th percentile unit dose values.

It can be seen that it is appropriate to use of the 90th percentile data for individual items by examining the Radiological Risk Acceptance Guideline curve (The radiological Risk Acceptance Guideline curve is shown with additional annotation as Figure 9-33). Because only 10%, by mass, of the items have a dose consequence greater than the 90th percentile value, the probability of getting an item with a greater dose consequence than the 90th

percentile is by definition 1/10. When the greatest possible dose consequences are represented by the maximum values shown in Tables 9-46 and 9-47, the largest maximum to 90th percentile ratio is 2.1, coming from the bone-surface Class Y material in the less than 10% ^{240}Pu range. Point A in Figure 9-33 is a hypothetical calculated consequence using a 90th percentile dose value, Point B represents a consequence of 2.1 greater than Point A occurring at 1/10 the probability. Even in this extreme example, the slope of line A-B is not greater than the slope of the Radiological Risk Acceptance Guidelines curve at any point. Thus, the risk stays within the acceptable risk region at all times.

For situations in which multiple inventory items are needed to accumulate sufficient mass for use in a safety analyses (e.g., loading a glovebox to capacity), the weighted-average values are appropriate to use. The Central Limit Theorem in the field of statistics describes mathematically that the distribution of the average of a series of random samples from a given population, no matter what the original probability distribution, tends to be normally distributed with the mean of the averages equal to the mean of the parent population.

Given that the current inventory at PFP is the majority of reprocessed plutonium with > 10% ^{240}Pu in the United States, the data presented in tables have wide applicability and are universally valid within the following context:

- The values account for all plutonium compositions from the DOE ^{239}Pu production programs and for all commercially reprocessed power reactor plutonium to-date. Plutonium from the DOE ^{238}Pu-production programs are not covered by these values. There is significant confidence, based on the several thousand isotopic distributions examined, that any given item of plutonium would exhibit the statistical characteristics used to create the unit doses reported.

- The unit dose values account for current and potential future inventories of plutonium at the PFP, provided there is no concerted effort to selectively transfer large amounts (hundreds of thousands of grams) out of the inventory based on a criterion that results in lower dose materials being moved. This would result in shifting the 90th percentile numbers slightly upward. Transfers of such materials into the inventory would lower the values, which is conservative from a safety analysis perspective.

- The values are valid for plutonium of any age.

9.3.6 Dose Calculation

This section describes how $\overline{\chi}/Q'$ is used to estimate the dose from a release of radioactive materials.

The $\overline{\chi}/Q'$ refers to the concentration of airborne contamination. It is the ratio of contaminant concentration at a specific receptor location to contaminant release rate. The receptor of concern is normally defined as a

human having a standard breathing rate and metabolism. The standard man breathing rates are typically taken from ICRP (1975). Values are provided in Table 9-48.

The product of $\overline{\chi}/Q'$ and breathing rate is a unitless number representing the fraction of contaminant inhaled to contaminant released. Inhalation is by far the most significant, unavoidable, and likely pathway to human exposure. Although ingestion represents an additional theoretical pathway, the ingestion pathway can be avoided through interdiction of food products, if necessary, in the event of an accident. The ground-shine and plume-submersion pathways can, for all practical purposes, be ignored for releases of plutonium.

The dose from the inhalation of radioactive materials, plutonium in particular, can be calculated using the following formula:

$$D\ (rem) = Q\ (g) \times \frac{\overline{\chi}}{Q'}\ (s/m^3) \times R\ (m^3/s) \times C\ (rem/g)$$

where: Q = Quantity plutonium released
$\overline{\chi}/Q'$ = Atmospheric dispersion coefficient
R = Breathing rate
C = Gram plutonium to dose conversion factor.

The quantity released, Q, is specific to the accident scenario. It is a function of several factors, including the inventory at risk, dispersing energy available, release fraction, RF, and mitigation. It is essentially a source term represented in grams. The grams plutonium to dose conversion factor, C, is specific to the isotopic mixture and chemical compound under consideration. Conversion factors for both oxides (Class Y) and non-oxides (Class W) are provided in Section 9.3.5 for both the committed EDE and the maximum-organ committed dose. Thus, to calculate the 50-yrcommitted dose for a given release, one must determine the appropriate isotopic mixture of the plutonium, select the proper breathing rate, and apply the appropriate $\overline{\chi}/Q'$ from Section 9.3.4.

9.3.7 Dose Calculations - Highway 240

Report HNF-6493, *Additional Air Transport Factors of PFP*, documents calculations done to evaluate the impacts to receptors at Highway 240. These impacts are shown in Table 9-1 and in accordance with Hanford procedures are provided for information only. The same accident conditions and modeling assumptions were used to ensure consistency with the FSAR. The consequences were originally evaluated using GXQ Version 3.1D (WHC-SD-GN-SWD-30002, Rev. 0); however, this version is no longer available and, therefore, Version 3.1C of GXQ was used in these calculations. As can be seen in HNF-6493, with the exception of the fire release, Version 3.1C calculated X/Q's are the same as version 3.1D. The calculated X/Q' for the fire using Version 3.1C is approximately 3% greater (1.19×10^{-6} s/m^3 versus 1.16×10^{-6} s/m^3) than the X/Q' calculated using Version 3.1D. It can be concluded that Version 3.1C is

suitable to calculate X/Q's to determine consequences to a receptor located on Highway 240.

The nearest individual on Highway 240 is located 4,210 m in the WSW direction. For the purposes of these dose calculations, the highest X/Q for each scenario was selected. In all instances this X/Q corresponds to a different direction. Four release scenarios are evaluated; 1) elevated stack release, 2) fire or buoyant plume release, 3) seismic ground level release with building wake, and 4) seismic ground level release with no building wake.

The glovebox releases from the 291-Z stack were modeled as a simple elevated stack release. As in the PFP FSAR, no credit was taken for momentum rise or the large flow rate out the stack. The stack flow rate is 123 m3/s, the stack diameter is 4.1 m, and the receptor height is 2 m. The calculated X/Q determining offsite consequences is 5.73×10^{-6} s/m^3 and the calculated X/Q for determining consequences to the nearest individual located on Highway 240 is 1.35×10^{-5} s/m^3. Thus the calculated offsite dose consequences are multiplied by 2.36 to determine consequences to the individual located on Highway 240.

The seismic release was modeled differently for 234-5Z and 232-Z. The 234-5Z building is assumed to have numerous penetrations so that the MACCS building wake model applies. Building 234-5Z width is 46 m and height is 14 m. In addition, the effect of plume meander was included through the fifth power law with a duration of 1 hour. In contrast, the 232-Z building is assumed to be a point source at ground level with no building wake.

The calculated X/Q for a ground level release with building wake (234-5Z Building modeled consequences), is 1.01×10^{-5} s/m^3 and the calculated X/Q for determining consequences to the nearest individual located on Highway 240 is 3.93×10^{-5} s/m^3. Thus the calculated offsite dose consequences, for a ground level release with building wake, are multiplied by 3.89 to determine consequences to the individual located on Highway 240. The calculated X/Q for a ground level release with no building wake (232-Z Building modeled consequences), is 1.62×10^{-5} s/m^3 and the calculated X/Q for determining consequences to the nearest individual located on Highway 240 is 6.58×10^{-5} s/m^3. Thus the calculated offsite dose consequences, for a ground level release with no building wake, are multiplied by 4.06 to determine consequences to the individual located on Highway 240.

The fire release uses a buoyant plume model. In Version 3.1 of GXQ, plume rise was computed using the MACCS formulas and user input was simply the thermal emission rate of the stack, namely, 2.80×10^{6} cal/s. As before, the volumetric flow rate is 7.07 m3/s with a fire diameter of 3 m. Building wake was included with a building width of 10 m and a building height of 6.1 m. The calculated X/Q for a buoyant plume release (fire), is 1.16×10^{-6} s/m^3 and the calculated X/Q for determining consequences to the nearest individual located on Highway 240 is 1.74×10^{-6} s/m^3. Thus the calculated offsite dose consequences, for a buoyant plume release, are multiplied by 1.50 to determine consequences to the individual located on Highway 240.

9.4 RISK ACCEPTANCE GUIDELINES AND EVALUATION

9.4.1 Risk Acceptance Guidelines

The radiological and toxicological Risk Acceptance Guidelines are shown in Tables 9-49 and 9-50, respectively. These guidelines are to be applied as curves, as shown in Figures 9-34 and 9-35. For example, an event with a likelihood of 9×10^{-3}/yr that produces a potential EDE of 1 rem to the maximum offsite individual is not acceptable because it falls above the guideline in Figure 9-34, even though it lies within the stated range in Table 9-49.

The radiological Risk Acceptance Guidelines represents EDEs and corresponding organ dose equivalents from all pathways (inhalation, air submersion, ingestion, and direct exposure). Radiological doses reported in safety analyses should include the contributions from each pathway, and consideration should be given to the fact that action could be taken to control doses from ground contamination, ingestion, and water immersion if necessary. The Environmental Release Analysis Manual provides further guidance on this subject.

9.4.2 Bases for Risk Acceptance Guidelines

Tables 9-49 and 9-50 are based on the philosophy that higher probability events, because they theoretically could occur more often, should have more restrictive consequences guidelines than lower probability events. They are also based on the philosophy that offsite guidelines should be more restrictive than onsite guidelines. This philosophy is consistent with common practice within the nuclear industry (e.g., annual dose limits and radionuclide concentration guides).

ERPG values do not exist for all chemicals. In the event that there is no ERPG-1 concentration, and one cannot be developed by the Hanford Environmental Health Foundation(HEHF), the chemicals Threshold Limit Value - Time Weighted Average (TLV-TWA) should be used in the comparison. When comparing calculated concentrations to a TLV-TWA or ERPG, normalize the average concentration over a period of 8 h and 1 h, respectively, for comparison purposes.

9.4.2.1 Specific Basis for Radiological Guidelines. The 25 rem EDE ceiling for offsite individuals is well established in the nuclear industry as a siting criterion (DOE Order 6430.1A; Elder et al. 1986). The ceiling is also suggested as an offsite risk acceptance criterion for low probability events (Elder et al. 1986).

A 25-rem EDE has been applied as a Risk Acceptance Guideline for offsite consequences. It is recognized that consequences of any given accident may be higher onsite than offsite and the onsite Risk Acceptance Guideline has been set to four times the offsite guideline, or 100 rem EDE. The endpoint for the offsite guidelines is thus established at the point corresponding to an annual probability of 10^{-6} and a dose consequence of 25 rem EDE, or corresponding organ-dose equivalents (i.e., 75 rem to the lens of the eye and 250 rem to all

other organs, in accordance with DOE Order 5480.11, *Radiation Protection for Occupational Workers*, EDE, and organ-dose equivalent limit relationships). The endpoint for the onsite guidelines is similarly established at the point corresponding to an annual probability of 10^{-6} and a dose consequence of 100 rem EDE, or corresponding organ dose equivalents (i.e., 300 rem to the lens of the eye and 1,000 rem to all other organs).

The DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, also specifies an annual limit of 0.1 EDE for continuous exposure of the public. Limits for events with an annual probability approaching one are set an order of magnitude lower, which provides an endpoint for the offsite guideline at an annual probability of one and 0.01 rem EDE, or corresponding organ dose equivalents.

The DOE Order 5480.11 specifies an annual limit of 5 rem EDE for occupational exposure. It is therefore conservative to apply this criterion to events with an annual probability of 10^{-2}. This provides a midpoint for the onsite guideline at an annual probability of 10^{-2} and 5 rem EDE, or corresponding organ dose equivalents. A limit of 1 rem EDE is established for events with an annual probability of occurrence of 0.1. The 1-rem-EDE limit is also applied to events with annual probabilities between 0.1 and 1.

All other dose guidelines are defined by lines on log-log graphs whose endpoints are the onsite or offsite dose guidelines addressed above.

9.4.2.2 Specific Basis for Toxicological Guidelines. The ERPGs (ERPG-1, -2, -3) values are intended as estimates of concentration ranges where there is a reasonable probability of adverse effects from exposure to the specific chemical. The adverse effects are described in the definitions for ERPG-1, ERPG-2 and ERPG-3 below:

> "The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up the 1 h without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
>
> The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 h without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
>
> The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 h without experiencing or developing life-threatening health effects." (AIHA 1990)

A TLV-TWA is the TWA concentration for a normal 8-h workday and a 40-h workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. It is considered conservative to use the TLV-TWA as an acceptable offsite guideline for higher probability events.

9.4.3 Gram Equivalent of Dose Guidelines

This section converts dose guidelines to grams released. During the PHA the analyst needed to understand the significance of an event in order to know whether or not it should be forwarded for more complete analysis. The gram-equivalents were determined from the ratio between the unit doses given in Tables 9-46 and 47 and the Risk Acceptance Guidelines from Table 9-49 follows:

$$\frac{\text{Guide rem}}{\text{Dose rem}} = \text{Equivalent g}$$

The following example shows how the amount of plutonium that would just meet the criterion for EDE following a ground-level release to an onsite individual at a probability of 0.1 is calculated. From Table 9-49, note that the guide dose is 1 rem. From Table 9-46 the maximum unit inhalation dose for Class Y (2.3×10^{8} rem/g) is multiplied by the acute breathing rate from Table 9-48 (3.3×10^{-4} m^3/s) and by the onsite atmospheric dispersion coefficient for a point source ground level release from 232-Z from Table 9-39 (8.72×10^{-4} s/m^3). This result, the acute EDE to an onsite individual from a ground-level release of 1 g, Class Y, gives a dose of 66 rem. Therefore,

$$\frac{1.0 \text{ rem}}{66 \text{ rem}} \times 1 \text{ g} = 0.015 \text{ g}$$

The elements of Table 9-51 and 9-52 were constructed using this procedure.

9.4.4 Gram Release at Stack Alarm Level

The number of grams PuO_2 released at just the stack alarm level at a maximum stack flow for 1 h is calculated for comparison to the stack-release equivalents presented in Tables 9-51 and 9-52. The maximum stack flow recorded between 1979 and 1989 was 270,000 ft^3/min. The stack alarm limit is set at 2×10^{-12} Ci/m^3 of alpha-emitting isotope. From Tables 9-41 and 9-44 the total activity for 1 g of weighted-average, >10% ^{240}Pu inventory is 1.61 Ci. This information is combined as follows:

$$\frac{2 \times 10^{-12} \text{ Ci/m}^3}{1.61 \text{ Ci/g}} = 1.24 \times 10^{-12} \text{ g/m}^3$$

$$1.24 \times 10^{-12} \text{ g/m}^3 \times 2.83 \times 10^{-2} \text{ m}^3/\text{ft}^3 \times 2.7 \times 10^{5} \text{ ft}^3/\text{min} \times 60 \text{ min/h}$$

$$= 5.7 \times 10^{-7} \text{ g/h}$$

Therefore, the amount released during 1 h at the stack-alarm set point is a factor of 3.5×10^{4} lower than the limit value for the most limiting

stack-release event shown in Table 9-51, and a factor of 2.6×10^4 lower than the most limiting stack release event shown in Table 9-52.

9.4.5 Toxicological Risk Acceptance Guidelines for HNO_3.

The Risk Acceptance Guidelines are defined by the accepted ERPGs as provided by the HEHF. The specific concentration limits for the various frequency ranges are presented in Table 9-53 for HNO_3. The ERGP values define the endpoints and the interior points were calculated by interpolation.

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Table 9-1. Summary of Accident Analysis Consequences. (4 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
9.2.1F	Flammable gas deflagration	Flammable gas deflagration resulting from: 1) slow leak of propane gas or 2) catastrophic failure of propane cylinder	Slow leak: 1.0 assumed Catastrophic Failure: Incredible (<1.0 E-06)	The slow leak event was found to have acceptable consequences even with an assumed probability of 1.0. For the event with a <1 E-06 probability, no consequence was calculated since the event is incredible.	The overpressure resulting from the deflagration is not large enough to breach any PFP wall panels.	N/A
9.2.2A	RMC/RMA Lines Fire	Fire in trash igniting RMC/RMA Lines and Adjacent rooms	10^{-4} to 10^{-6}	Onsite EDE = 1.2 E-02 Offsite EDE = 4.3 E-03 Onsite bone = 2.0 E-01 Offsite bone = 7.4 E-02	Onsite EDE: 25 Offsite EDE: 4 Onsite Bone: 250 Offsite Bone: 40	0.01
9.2.2B	Hydraulic oil fire, Room 231 234-52	Roof collapse due to failed structural members	Incredible (<1.0 E-06)	None calculated as probability <1.0 E-06 and low source term	Not applicable	N/A
9.2.2C	Not Used					
9.2.2D	Waste Drum Events	Vehicle crash with ensuing fire	<<1.0 E-02	Onsite EDE = 2.2 Offsite EDE = 0.04 Onsite Bone = 32.8 Offsite Bone = 0.64	(Probability = 1.0 E-02) Onsite EDE: 5 Offsite EDE: 0.5 Onsite Bone: 50 Offsite Bone: 5	0.06
		Mechanical Release	1.0 E-01	Onsite EDE = 0.12 Offsite EDE = 2 E-03 Onsite Bone = 2.2 Offsite Bone = 0.03	Onsite EDE: 1 Offsite EDE: 0.1 Onsite Bone: 10 Offsite Bone: 1.0	8 E-3
		Drum Explosion	<<1.0 E-02	Onsite EDE = 1.65 Offsite EDE = 0.02 Onsite Bone = 28.7 Offsite Bone = 0.38	(Probability = 1.0 E-02) Onsite EDE: 5 Offsite EDE: 0.5 Onsite Bone: 50 Offsite Bone: 5	0.08
9.2.3	Criticality	The generic criticality from Regulatory Guide 3.35 used	2.5 E-02	Ground release: Onsite EDE total = 0.73 Offsite EDE total = 0.053 Onsite thyroid = 2.4 Offsite thyroid = 1.6 Stack release: Onsite EDE total = 0.16 Offsite EDE total = 0.032 Onsite thyroid = 0.27 Offsite thyroid = 0.97	Onsite EDE: 2 Offsite EDE: 0.2 Onsite Thyroid: 20 Offsite Thyroid: 2 Onsite EDE: 2 Offsite EDE: 0.2 Onsite Thyroid: 20 Offsite Thyroid: 2	2.15 E-1 7.55 E-2

Table 9-1. Summary of Accident Analysis Consequences. (4 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
9.2.4[1]	Seismic Event[1]	no ventilation case	1.0 E-04	Onsite EDE = 17.71 Offsite EDE = 0.37 Onsite Bone = 256 Offsite Bone = 5.26	Onsite EDE: 25 Offsite EDE: 4 Onsite Bone: 250 Offsite Bone: 40	1.44
		ventilation case	1.0 E-04	Onsite EDE = 11.49 Offsite EDE = 2.53 Onsite Bone = 178 Offsite Bone = 38	Onsite EDE: 25 Offsite EDE: 4 Onsite Bone: 250 Offsite Bone: 40	5.97
		Small earthquake with release from Building 232-Z only	2.0 E-03	Onsite EDE = 4.57 Offsite EDE = 0.09 Onsite Bone = 73 Offsite Bone = 1.36	Onsite EDE: 8.5 Offsite EDE: 1.0 Onsite Bone: 85 Offsite Bone: 10	0.37
9.2.5	Strong wind and missile strike	Wind driven missile breaches transfer line at the bottom of the outside HNO_3 storage tank causing a large pool and release of HNO_3 vapors	<1.0 E-02	HNO_3 Onsite = 18 ppm HNO_3 Offsite = 0.29 ppm	HNO_3 Onsite: 19 ppm HNO_3 Offsite: 3.9 ppm	0.92 ppm
9.2.7	Aircraft accident	Airplane crash into building	Incredible (<1.0 E-06)	Not calculated; probability <1.0 E-06	N/A	N/A
9.2.8	Toxic chemical release	7000 gal outside HNO_3 storage tank failure caused by seismic event; HNO_3 vapor release from spilled solution surface	1.0 E-04	Onsite: 1.8 ppm Offsite: 0.032 ppm	Onsite 24 ppm Offsite 7.7 ppm	0.13 ppm
9.2.9	Accidents for the Plutonium-Bearing Solution Stabilization Process using the Production VDC					
9.2.9.1	Flammable Gas Deflagration in the VDC	Injection of organic material into the VDC	To be developed before authorization of Production VDC operations			
9.2.9.2	Glovebox HC-230C-2 Fire	Fire due to failure to control combustibles in glovebox which contact hot surfaces of the calciner	To be developed before authorization of Production VDC operations			

Table 9-1. Summary of Accident Analysis Consequences. (4 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
9.2.9.3	Compressed Air Cylinder Failure	Hnadling accident results in supply valve being sheared off	1.0 E-2 to 1.0 E-4	Negligible	(Probability = 1.0 E-2) Onsite EDE = 5 Offsite EDE = 0.5 Onsite Bone = 50 Offsite Bone = 5	N/A
9.2.9.4	Glovebox HC-230C-2 Seismic Release	Seismic event	1.0 E-04	Onsite EDE = 0.67 rem Offsite EDE = 0.24 rem Onsite Bone = 10.5 rem Offsite Bone = 3.7 rem	See 9.2.4	0.57
9.2.9.5	Changes to RMC/RMA Lines Fire Analysis from Glovebox HC-230C-2	Spread of RMC Line fire down HC-2 and HC-3 conveyors to Glovebox HC-230C-2	NA Airlock between HC-2 and HC-3 prevents spread of fire	NA Airlock prevents spread of fire to Glovebox HC-230C-2	----	N/A
9.2.10	Accidents for Reactive Plutonium-Bearing Material Stabilization Operations in Gloveboxes HC-21C and HA-21I.					
9.2.10.1	Hydrogen Deflagration in Glovebox HC-21A from Opening Pressurized Containers	Deflagration	1.0 E-02 to 1.0 E-04	Negligible	NA	N/A
9.2.10.2	Deflagration in Glovebox HC-21C or HA-21I	Deflagration	1.0 E-04 to 1.0 E-06 for PE or PC 1.0 E-02 to 1.0 E-04 for PVC and PS	Onsite EDE 2.1 x 10^{-3} Offsite EDE 7.4 x 10^{-4} Onsite Bone 0.03 Offsite Bone 0.01	(Probability 1.0 E-02) Onsite EDE = 5.0 Offsite EDE = 0.5 Onsite Bone = 50 Offsite Bone = 5	1.7 E-03
9.2.10.3	Seismically Induced Deflagration in Glovebox HC-21C or HA-21I	Deflagration Flash Fire	Not credible 1.0 E-04 to 1.0 E-06	NA Negligible	NA	N/A
9.2.10.4	Glovebox HC-21C or HA-21I Fire	Fire	Not credible	Onsite EDE 2.2 E-04 Offsite EDE 7.7 E-05 Onsite Bone 3.5 E-03 Offsite Bone 1.2 E-03 Also included in Section 9.2.2A.	See 9.2.2A	1.82 E-4
9.2.10.5	Seismically Induced Fire in Glovebox HC-21C and HA-21I	Fire	1.0 E-04	See Section 9.2.4.2.12.F Included in total for seismic event, Section 9.2.4.	See Section 9.2.4	0.31

Table 9-1. Summary of Accident Analysis Consequences. (4 sheets)

Section	Scenario	Postulated event	Calculated annual probability	Postulated dose consequences (rem)	Risk acceptance guidelines (rem)	Highway 240 Dose (rem)
9.2.10.6	Changes to the RMC/RMA Lines Fire Analysis from Gloveboxes HC-21A, HC-21C, and HA-21I	All changes have been incorporated into the RMC/RMA Lines fire analysis in Section 9.2.2A.				
9.2.11	Accidents for the Laboratory Prototype Calciner	Refer to the Laboratory Prototype Calciner addendum to this FSAR for information on analyzed accidents (This process is not currently authorized.)				
9.2.12	Accidents for the Magnesium Hydroxide Precipitation Process	Refer to the Magnesium Hydroxide Precipitation Process addendum (Carson 2000) to this FSAR for information on analyzed accidents				
9.2.13	Accidents for the Bagless Transfer System	Refer to the calculation notes for the Bagless Transfer System (FH 2000) for information on analyzed accidents				

EDE = Effective dose equivalent.
LPG = Liquid propane gas.
PFP = Plutonium Finishing Plant.
RMC = Remote Mechanical C.

Note: 1. The consequences for the seismic event exclude the seismic analysis related to the laboratory Prototype Calciner shown in the Laboratory Prototype Calciner addendum to this FSAR since the calciner is not authorized for operation. Similarly, the seismic event consequences do not include the seismic releases associated with the Production Vertical Denitration Calciner since it is not authorized for operation.

Table 9-2. Functions Excluded from Analysis.

Function	Building/glovebox, or room
Electrolytic metal dissolution (Discontinued Operation)	236-Z/MT-3
Incinerator ash calcination (Discontinued Operation)	234-5Z/HA-40F
Incinerator ash dissolution (Discontinued Operation)	234-5Z/HC-46F
Polycube calcination (Future Operation)	236-Z/MT-4
RMA Line button and oxide production gloveboxes	234-5Z/Rooms 235-A1, 2, and 3 (Included for Seismic)
Hydrogen Fluorination (Discontinued Operation)	234-5Z
Laboratory Concentration (Discontinued Operation)	234-5Z
Product Concentration (Discontinued Operation)	236-Z
Filtrate Evaporation (Discontinued Operation)	236-Z
Slag and Crucible Operation (Discontinued Operation)	236-Z

Table 9-3. Synopsis, Abnormal Events. (2 sheets)

Number	Title	Synopsis
9.1.1	Radioisotope-Bearing Liquid Spills	A spill involving a 10-L bottle of plutonium solution is used as a bounding event. Other spills with lower combinations of volume, energy, and concentration give a smaller release. The event is shown to release 0.16 g Pu into the building. Such a release is well below the criteria for a probability one event with the presence of HEPA filters (9.4.3).
9.1.2	Radioisotope-Bearing Pressurized Liquid Container	A pressurized 10-L container is assumed to release half the contents to a room. The airborne release is 0.08 g Pu. Such a release is well below the criteria for a probability one event with HEPA filters (9.4.3).
9.1.3	Radioisotope-Bearing Powder Spills	A powder spill is assumed that requires an incredible number of errors to achieve. The resulting 3 g airborne release is just slightly greater than needed to just equal the limit amount for a probability one stack release event even without HEPA filters (9.4.3).
9.1.4	Radioisotope-Bearing Pressurized Powder Container	Plutonium, when stored in closed containers, has the potential for release to a room when driven by internal gas pressure. Chemical reactions or radiolysis of hydrogenous material can develop such gases. The analysis shows storage room air concentrations to be on the order of 2.5×10^{-10} µCi/mL. This is far lower than would be significant as a stack release.
9.1.5	Stack Release Resulting from Filter Changes	During exchange of final-stage HEPA filters there is a potential for release of plutonium if a filter is handled roughly. This section shows that such an event would have a low consequence.
9.1.7	Ventilation System Upsets (introduction)	Properly functioning ventilation systems provide a vital part of the equipment that makes it possible to handle plutonium safely. The following subsections detail the most important of the failure modes. In no case does upset directly result in a release of radioactive materials. Such events, in conjunction with loss of containment events, could, however, exacerbate the spread of contamination within a building. In most events within Buildings 234-5Z, 242-Z, and 236-Z, no automatic recovery systems would be available. However, the normal operator response in difficult situations is to automatically shut off the electric supply fans, place all dampers in their fail positions, activate either emergency exhaust fan EM-1 or EM-2, and evacuate zone 3 ventilation areas.
9.1.7A	Excessive Building Pressurization-234-5Z	Excessive building pressurization can occur from failure of control dampers. Supply dampers B, C, D, and E each feed air to rooms and corridors within the radiation zones of the 234-5Z Building. A number of separate scenarios are presented under this heading. Pressure differentials of up to 1 in. w.g. between adjacent rooms will occur but gloveboxes remain negative to room atmospheres.
9.1.7B	Excessive Pressurization of 236-Z Building	The 236-Z Building receives air from 234-5Z Building through Supply Damper F. Failure to the open position can cause pressurization of up to 0.5 in. w.g. over normal. As with the damper failures within the 234-5Z Building, the process cell and gloveboxes remain negative to the rooms. No radioactive materials escape from the building.
9.1.7C	Excessive Building Pressurization, 2736-ZB Building	A ventilation control failure could lead to a pressurization of ~2 in. w.g. Such a pressurization is not expected to cause a breach of the building or release of material from the single glovebox located in the building.
9.1.7D	Excessive Building Pressurization, 2736-Z Building	A pressurization of the 2736-Z Building is not expected to cause any release of radioactive material into the building or to the outside as all materials stored in this facility are double or triple canned in metal cans or drums. The building could be pressurized to 2 in. w.g.
9.1.7E	Excessive Building Pressurization, 241-Z Building	No building pressurization would happen as there are no supply fans.

Table 9-3. Synopsis, Abnormal Events. (2 sheets)

9.1.7F	Excessive Building Depressurization, 234-5Z Building	Significant depressurization of the 234-5Z Building is prevented by a pair of gravity-operated supply relief dampers on the supply plenum and by control on the exhaust fans.
	236-Z Building	Accidental closure of Supply Damper F could result in depressurization to -15.2 cm (-6 in.) w.g. Such a depressurization is approximately equal to the 14.7 cm (5.8 in.) w.g. live load of the roof. During such an event the pressure inside and outside gloveboxes would be the same but there would be no force to release radioactive materials to the rooms. There would, of course, be no release to the environment.
	2736-ZB Building	No credible scenario was found.
	2736-Z Building	An actual event once depressurized the building to ≈7.6 cm (≈3 in.) w.g. with no adverse effect.
	241-Z Building	There is no way to significantly depressurize this building.
9.1.8	Loss of Ventilation	This section contains a number of events that result from loss of ventilation--none of which result in a significant spread of plutonium. The topics include air reversals due to convection and weather changes, radiolytic hydrogen accumulation, and spread of contamination in vaults due to container rupture from heat rise.
9.1.9	Glovebox Glove Breach	The most vulnerable part of the plutonium confinement system is the glove system. This section discusses various release mechanisms and concludes that the hazard to operating personnel is not great.
9.1.10.1	Pressurized Production Vertical Denitration Calciner	The VDC is assumed to pressurize due to a loss of vacuum. The pressurized calciner is estimated to release 127 mg of Pu to the HC-230C-2 glovebox atmosphere. Two testable stages of HEPA filtration within the E-4 ventilation system limit the release out the exhaust stack to an insignificant value. (A third testable stage of HEPA filters exists in the exhaust system but was not credited in the analysis).
9.1.11	Reactive Material Thermal Stabilization Process	No unique abnormal operations were identified that were associated with operation of the thermal stabilization process.
9.1.12	Laboratory Prototype Calciner	No unique abnormal operations were identified that were associated with operation of the Laboratory Prototype Calciner.
9.1.13	Loss of Filtration	Loss of filtration events were analyzed for Buildings 232-Z and 241-Z to determine impacts. Based on annual stack emission data, Loss of filtration is at or near current emissions.
9.1.14	Magnesium Hydroxide Precipitation Process	See the Magnesium Hydroxide Precipitation Process addendum (Carson 2000) to this FSAR for identification and evaluation of abnormal operations.
9.1.15	Bagless Transfer System (BTS)	See the calculation notes (FH 2000) for the BTS for identification and evaluation of abnormal operations.

Table 9-4. Room Ventilation Zones.

Zone	Ventilation system	Damper	Set pressure (in. w.g.)
1	S-1	A	+0.14 to +0.16
3*	S-3*	B	-0.14 to -0.17
3	S-3	C	-0.14 to -0.17
3A	S-3A	D	-0.11 to -0.14
3B	S-3B	E	-0.03 to -0.10

*Note that zone 3 includes those rooms formerly balanced as zone 2.

Table 9-5. Listing of Zone 3 Rooms and Their Source of Ventilation.

From damper B	From damper C				From dampers B and C		From dampers C and D
210	135	150-A	228-C	264	221-A	230	146
211	136	151	230-A	308-1	221-B	232	308
212	137	159	232-A	320	228-E	235	
225	145	159-A	235-A	327	228-W	235-B	
229	148	162	236	328			
233	149	224	244	329			
249	150	227	245	330			
	Corridor 3		263				

Table 9-6. Listing of Zone 3A Rooms Supplied from Damper D.

113	139	154	167-A	179-D	239-A	Corridor 3	Corridor 8A
116	140-A	155	168	180	242	Corridor 4	Corridor 9
121	140-B	156	169	182 to 183	242-A	Corridor 4A	Men's Changeroom
124	140-C	157	170	183-A	242-B	Corridor 4B	Tunnel 14
126	141	158	171	184	242-C	Corridor 4C	Tunnel 15
127	142	161	172 to 179-A	185	242-D	Corridor 4D	
128	143	163	173	186 to 187	246	Corridor 5	
131	144	164	174	188	247	Corridor 6	
132	145-A	165	175	189	262	Corridor 7	
133	152	166	179-B	190	242-Z	Corridor 7A	
134	153	167	179-C	191	Corridor 10	Corridor 8	

Table 9-7. Plutonium Characteristics, Fractions, Activities, Energies, and Calculations.

Nuclide	Weight fraction	Activity Ci/g (of isotope)	Energy MeV/dis	Ci-MeV/g-dis
^{238}Pu	0.0029	17.1	5.6	0.28
^{239}Pu	0.70	0.0621	5.3	0.23
^{240}Pu	0.22	0.228	5.2	0.26
^{241}Pu	0.018	103.0	0.021β	0.039
^{242}Pu	0.017	--	--	0.0
^{241}Am	0.039	3.43	5.6	0.75
Total				1.56

Table 9-8. Not Used

Table 9-9. Not Used

Table 9-10. Not Used

Table 9-11. Not Used

Table 9-12. Not Used

Table 9-13. Not Used

Table 9-14. Not Used

Table 9-15. Not Used

Table 9-16. Not Used

Table 9-17. Not Used

Table 9-18. Plutonium Finishing Plant TRU Mixed Waste Drum Summary.

Time span	Waste drums (55 gal)		
	1978 to 1981*	1982 to 1985*	1986 to 1988*
Total number of containers	4,945	5,258	1,212
Average TRU (g)	21.0	10.6	28.2
Average % combustible	79	85	81

*Based on data presented in Table 4-37 in Anderson et al. (1990) covering production from 1985 to 1988. Historically, the average weight of a 55-gal TRU waste drum was 175 lb (79.4 kg) (Anderson et al. 1990). Currently the maximum weight, without prior approval of PFP management, for a CH-TRU waste package is 1,000 lb (454 kg)/drum (WHC 1993).

Table 9-19. Atmospheric Dispersion Coefficients for Onsite and Site Boundary Maximum Individuals.

Accident Scenario		$\bar{\chi}/Q'_3$ (s/m^3)	Atmospheric Condition
Onsite	Waste Drum Fire (950 m ESE)	5.98×10^{-5}	D @ 9.80 m/s
	Waste Drum Rupture (450 m WNW)	1.22×10^{-3}	G @ 4.70 m/s
Site Boundary	Waste Drum Fire (17,400 m NNW)	1.16×10^{-6}	G @ 2.65 m/s
	Waste Drum Rupture (12,500 m W)	1.62×10^{-5}	G @ 2.65 m/s

Table 9-20. Risk Factors for Potential Accidents for Plutonium Storage Outside Plutonium Finishing Plant.

Accident	Annual frequency	Onsite (rem)		Offsite (rem)	
		EDE * (limit)*	Bone * (limit)*	EDE * (limit)*	Bone * (limit)*
Fire	Much less than 10^{-2}	2.2 (5)	32.8 (50)	0.04 (0.5)	0.64 (5)
Mechanical	10^{-1}	0.12 (1)	2.2 (10)	0.002 (0.1)	0.03 (1.0)
Explosion	Much less than 10^{-2}	1.65 (5)	28.7 (50)	0.02 (0.5)	0.38 (5)

*limits based on annual frequency as described in Section 9.4.

Table 9-21. Criticality Accident Committed, Effective Dose Equivalent, and Organ Doses in rem (Onsite and Offsite Receptors, 200-ft 291-Z-1, Stack).

Location	Direction	Distance (km)	n-gamma	EDE (rem)	Thyroid (rem)
Onsite 272-WA	WNW	0.63	5.4 E-02	1.6 E-01	2.7 E-01
Offsite (resident)	WNW	13.2	N/A	3.2 E-02	9.7 E-01

Table 9-22. Criticality Accident Committed, Effective Dose Equivalent, and Organ Doses in rem (Onsite and Offsite Receptors, Low Stack).

Location	Direction	Distance (km)	n-gamma	EDE (rem)	Thyroid (rem)
Onsite 272-WA	WNW	0.63	5.4 E-02	7.3 E-01	2.4 E+00
Offsite (resident)	WNW	13.2	N/A	5.3 E-02	1.6 E+00

Table 9-23. Plutonium Metal Phases with Stability Temperature Ranges and Densities.

Phase	Stability range (°C)	Density (g/cm^3)
Alpha	<~115	19.86
Beta	~115 to ~200	17.70
Gamma	200 to 310	17.14
Delta	310 to 452	15.92
Delta'	452 to 480	16.00
Epsilon	480 to 640	16.51

Table 9-24. Amount (Ci) and Room Typical Concentration (Ci/m^3) of Important Nuclides Released from a Criticality (Regulatory Guide 3.35, NRC 1979b).

Nuclide	Radioactivity			Room (Ci/m^3)
	0 to 0.5 h	0.5 to 8 h	Total	
^{83m}Kr	1.5 E+01	9.5 E+01	1.1 E+02	1.1 E-02
^{85m}Kr	9.9 E+00	6.1 E+01	7.1 E+01	7.3 E-03
^{85}Kr	1.2 E-04	7.2 E-04	8.1 E-04	8.6 E-08
^{87}Kr	6.0 E+01	3.7 E+02	4.3 E+02	4.4 E-02
^{88}Kr	3.2 E+01	2.0 E+02	2.3 E+02	2.4 E-02
^{89}Kr	1.8 E+03	1.1 E+04	1.3 E+04	1.3 E+00
^{131m}Xe	1.4 E-02	8.6 E-02	1.0 E-01	1.0 E-05
^{133m}Xe	3.1 E-01	1.9 E+00	2.2 E+00	2.3 E-04
^{133}Xe	3.8 E+00	2.3 E+01	2.7 E+01	2.8 E-03
^{135m}Xe	4.6 E+02	2.8 +03	3.3 E+03	3.4 E-01
^{135}Xe	5.7 E+01	3.5 E+02	4.1 E+02	4.2 E-02
^{137}Xe	6.9 E+03	4.2 E+04	4.9 E+04	5.0 E+00
^{138}Xe	1.5 E+03	9.5 E+03	1.1 E+04	1.1 E+00
^{131}I	1.5 E+00	9.5 E+00	1.1 E+01	4.6 E-03
^{132}I	1.7 E+02	1.0 E+03	1.2 E+03	4.8 E-01
^{133}I	2.2 E+01	1.4 E+02	1.6 E+02	6.7 E-02
^{134}I	6.0 E+02	3.7 E+03	4.3 E+03	1.8 E+00
^{135}I	6.3 E+01	3.9 E+02	4.5 E+02	1.9 E-01
^{238a}Pu			5.9 E-04	
^{239}Pu			2.7 E-05	
^{240}Pu			5.8 E-05	
^{241}Pu			1.8 E-02	
^{242}Pu			4.3 E-07	
^{241}Am			2.4 E-05	
Alpha total			1.87 E-02	

[a]Total radioactivity assumes the isotopic mix to be the equilibrium mix for fuel cycle plutonium and 1 mg of PuO_2 released.

Table 9-25. Criticality Prevention Specification (CPS) Total Plutonium Limits and Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets) (See Note 3)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS	Seismic Qualification
Hood 1	148	234-5Z	150[1]	no
Hood 2	148	234-5Z	150[1]	no
Hood 1	149	234-5Z	150[1]	no
Hood 2	149	234-5Z	150[1]	no
Glovebox 522	152	234-5Z	3,400[1]	no
Hood 521	152	234-5Z	250[1]	no
Glovebox 5	153	234-5Z	250[1]	no
Hood 1	153	234-5Z	250[1]	no
Hood 2	153	234-5Z	250[1]	no
Hood 3	153	234-5Z	250[1]	no
Hood 4	153	234-5Z	250[1]	no
Glovebox 1	154	234-5Z	Inactive[1]	no
Glovebox 2+3	154	234-5Z	150[1]	no
Hood 1	155	234-5Z	400[1]	no
Hood 2	155	234-5Z	150[1]	no
Hood 3	155	234-5Z	150[1]	no
Hood 4	155	234-5Z	150[1]	no
Glovebox 1+2	156	234-5Z	150[1]	no
Hood 3	156	234-5Z	150[1]	no
Hood 4	156	234-5Z	150[1]	no
Glovebox 1+2	157	234-5Z	150[1]	no
Glovebox 3+4	157	234-5Z	2,500[1]	no
Glovebox HC-4	166	234-5Z	52,800	YES
Glovebox HC-6	166	234-5Z	3,000 inactive[1]	no
South hood	166	234-5Z	400	no
Glovebox HA-40F	169	234-5Z	12,000 inactive[1]	no
Glovebox HC-46F	170	234-5Z	12,000 inactive[1]	no
Hood	170	234-5Z	inactive[1]	no
Glovebox 1	179	234-5Z	2,500[1]	no
Glovebox 10	179	234-5Z	2,500[1]	no
Glovebox 12	179	234-5Z	2,500[1]	no
Glovebox 4	179	234-5Z	2,500[1]	no
Glovebox 6	179	234-5Z	2,500[1]	no
Glovebox 9	179	234-5Z	2,500[1]	no
Glovebox 11	179	234-5Z	400 inactive[1]	no
Hood 2	179	234-5Z	400 inactive[1]	no
Hood 3	179	234-5Z	400 inactive[1]	no
Hood 1	180	234-5Z	15[1]	no
Glovebox 5	183	234-5Z	Inactive[1]	no
Hood 1	187	234-5Z	150[1]	no
Hood 2	187	234-5Z	150[1]	no
Hood 3	187	234-5Z	150[1]	no
Hood 4	187	234-5Z	150[1]	no

Table 9-25. Criticality Prevention Specification (CPS) Total Plutonium Limits and Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets) (See Note 3)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS	Seismic Qualification
Hood 5	187	234-5Z	150[1]	no
Glovebox 1	188	234-5Z	7,000[1]	yes
Glovebox 3	221-C	234-5Z	2,500[1]	no
Hood 1	221-C	234-5Z	150[1]	no
Hood 2	221-C	234-5Z	150[1]	no
Storage Cabinet SC-221C	221-C	234-5Z	250[1]	no
Hood 1	221-D	234-5Z	150[1]	no
Hood 2	221-D	234-5Z	150[1]	no
Hood 3	221-D	234-5Z	150[1]	no
Hood 4	221-D	234-5Z	250[1]	no
Glovebox 5	221-D	234-5Z	400[1]	no
Hood 1	221-E	234-5Z	150[1]	no
Hood 2	221-E	234-5Z	250[1]	no
Hood 3	221-E	234-5Z	150[1]	no
Glovebox HC-227S	227	234-5Z	20,000	Yes (seismic qualification does not mitigate analyzed seismic release scenario)
Hood HC-227T	227	234-5Z	4,500	YES
Glovebox HC-1, conveyor	228-A, B,C	234-5Z	Normally empty[2]	no
Glovebox HC-2, conveyor	228-A, B,C 230-A, B,C	234-5Z	Normally empty[2]	no
Glovebox HC-7	228-A	234-5Z	3,000	YES
Glovebox HC-9B	228-A	234-5Z	32,700	YES
Glovebox HC-10	228-A	234-5Z	2,500 inactive[1]	no
Glovebox HC-11	228-A	234-5Z	30,000	YES
Glovebox HC-12S	228-A	234-5Z	4,000 inactive[1]	no
Glovebox HC-13MD	228-B	234-5Z	2,500	no
Glovebox HC-15A,-B,-C	228-B	234-5Z	12,000 inactive[1]	YES
Glovebox HC-16CC	228-B	234-5Z	4,000 inactive[1]	no
Glovebox HC-17-SBB	228-C	234-5Z	5,500 inactive[1]	no
Glovebox HC-17DC	228-C	234-5Z	4,000 inactive[1]	no
Glovebox HC-17P	228-C	234-5Z	1,500 inactive[1]	no
Glovebox HC-18BS	228-C	234-5Z	50,000	YES
Glovebox HC-18M	228-C	234-5Z	10,000	no
Glovebox HC-21C	230-A	234-5Z	5,000	no
Glovebox HC-21A	230-B	234-5Z	7,100	no
Glovebox HC-3, conveyor	230-C	234-5Z	1,500 normally empty[2]	no
Glovebox HC-4, conveyor	230-C 235-B	234-5Z	2,500 normally empty[2] 1 unit mass allowed	no
Glovebox HC-5, conveyor	228-C	234-5Z	1,500 normally empty[2]	no
Glovebox HC-60	230-C	234-5Z	3,000 inactive[1]	no
Glovebox HA-46	232	234-5Z	150 Inactive[1]	no

Table 9-25. Criticality Prevention Specification (CPS) Total Plutonium Limits and Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets) (See Note 3)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS	Seismic Qualification
Glovebox H-8, conveyor	235-A	234-5Z	Inactive[1]	no
Glovebox H-9A conveyor	235-A	234-5Z	Inactive[1]	no
Glovebox H-9D, conveyor	235-A	234-5Z	Inactive[1]	YES
Glovebox H-9E, conveyor	235-A	234-5Z	20,000 inactive[1]	YES
Glovebox HA-7A	235-A	234-5Z	Inactive[1]	YES
Glovebox HA-9C	235-A	234-5Z	Inactive[1]	no
Glovebox HA-10, conveyor	235-A	234-5Z	Inactive[1]	no
Glovebox HA-19	235-B	234-5Z	2,500[1]	no
Glovebox HA-20MB	235-B	234-5Z	10,000	YES
Glovebox HA-21I	235-B	234-5Z	8,000	no
Glovebox HA-23S	235-B	234-5Z	44,000	YES
Glovebox HA-28, conveyor	235-B	234-5Z	2,500	no
Glovebox 235-B-2	235-C	234-5Z	2,500[1]	no
Glovebox HA-16BS	235-A1	234-5Z	2,500 inactive[1]	no
Glovebox HA-16CS	235-A1	234-5Z	2,500 inactive[1]	no
Glovebox HA-22B	235-B	234-5Z	2,500	YES
Gloveboxes (1st floor) - east	East corridor	236-Z	3000 g in containers plus 2500 g/ft^2 in each section	YES
Gloveboxes (1st floor) - west	West corridor	236-Z	3000 g in containers plus 2500 g/ft^2 in each section	YES
Gloveboxes (2nd floor) - east	East corridor	236-Z	3000 g in containers plus 2500 g/ft^2 in each section	YES
Gloveboxes (2nd floor) - west	West corridor	236-Z	3000 g in containers plus 2500 g/ft^2 in each section	YES
Glovebox (2nd floor pH and maintenance room)	27	236-Z	5500 (total glovebox and room limit) (1000 g glovebox 17, 5500 g total room 27 limit) inactive[1]	no
Glovebox (MT-conveyor)	41	236-Z	1,500 inactive	no
Glovebox MT-1	41	236-Z	6,000 inactive[1]	no
Glovebox MT-3	41	236-Z	Inactive[1]	no
Glovebox MT-4	41	236-Z	inactive[1]	no
Glovebox MT-5	41	236-Z	29,000 inactive[1]	no
Glovebox MT-6	41	236-Z	9,000 inactive[1]	no
Glovebox (4th floor column)	42	236-Z	4,500	no
Glovebox (S&C canning and loading)	43	236-Z	3,200	no
Glovebox (S&C charging glovebox)	43	236-Z	1,200	YES
Glovebox (5th floor column)	50	236-Z	4,500	no
Glovebox (6th floor column)	60	236-Z	4,500	no

Table 9-25. Criticality Prevention Specification (CPS) Total Plutonium Limits and Seismic Qualification Status of Plutonium Finishing Plant Facilities. (4 sheets) (See Note 3)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS	Seismic Qualification
Glovebox (repackaging glovebox)	636	2736-ZB	20,000	YES

NOTES: 1. See Table 9-26 for additional limits.

2. This limit does not include containers that may be on the conveyer. Assumed time spent on conveyer is negligible.

3. Does not include the gloveboxes that comprise the Magnesium Hydroxide Precipitation Process or Bagless Transfer System. The inventories are in Carson (2000) and FH (2000), respectively.

Table 9-26. Maximum Dispersible Plutonium Quantities Considered in Accident Analysis.

ROOM/GLOVEBOX	TOTAL DISPERSIBLE PU ALLOWED	COMMENTS
Analytical Laboratory All Gloveboxes and Hoods in Rooms 131, 134, 135, 136, 137, 139, 143, 144, 145, 146, 148, 152, 153, 154, 155, 156, and 157, and Plutonium Process Support Laboratory (PPSL) All Gloveboxes and Hoods in Rooms 179, 180, 183, 187, and 188, and Standards Laboratory All Gloveboxes, Hoods and Storage Cabinets in Rooms 221-C, 221-D, and 221-E	12,450 g Total for all rooms, of which no more than 5,250 g has ^{240}Pu greater than 10%.	The limit applies to the sum of all DISPERSIBLE plutonium quantities in the three laboratory areas combined.
INACTIVE Gloveboxes (in any room)	Introduction of Plutonium containers is prohibited. Residual quantities are allowed. See Criticality Prevention Specification CPS-Z-165-80010 for general limits for inactive gloveboxes and hoods.	Residual quantities have been included in the accident analyses.
Room 235B: Glovebox HA-19	0 g	Only polystyrene cube storage permitted.

Table 9-27. Plutonium Reclamation Facility Solvent Extraction--List of Potential Seismically Induced Accidents. (2 sheets)

Accident	Comment
Criticality	Considered in the bottom of the north end of the W glovebox (location of the criticality drain) as a result of the mixing of concentrated plutonium solution from concentrator failure with other solutions coupled with the assumed pre-existing failure of the 4-in.-dia. criticality drain screen resulting in a plugging of the drain.
$Na2CO_3$ and HNO_3 Reaction	The Na2CO3 is used in the CX column. If this line fails and the valve spuriously opens and HNO_3 lines fail, then the Na2CO3 can mix with the HNO_3 resulting in mass and energy release into the glovebox.
Hydroxylamine and HNO^3 Reaction	If hydroxylamine and HNO_3 are mixed and boiled, when the acid reaches about 6M the hydroxylamine decomposes rapidly. This is not seismically induced as there is no continuous heat source in Solvent Extraction. It is not considered credible for the heat from the criticality or the $Na2CO3$-HNO_3 reaction to boil this mixture down to the point where it will vigorously react.
Red oil explosion	This accident is not possible in solvent extraction due to a seismic event as it requires too many very specific equipment failures as a result of the seismic event.
Pipe or tank failure in canyon	Possible.
Pipe or tank failure in glovebox	Possible.
Overflow of various solution to tanks 51 and 52	Overflows are possible as a result of line breaks or the failure of pumps to shut off.
NaOH to tank may cause a backflow	The TK-17 and TK-18 provide the feed stream CAF. If the chemical addition valve opens (seismically induced valve circuit, etc.), NaOH will be added to the tank and react with the HNO_3. This reaction could also occur in the glovebox.
Red oil explosion in non-heat tanks	Not possible. It is possible to get an organic and HNO_3 mixture in these tanks but since the tanks are open any heat source (like a fire) will either burn off the organic or boil the solution.
Failure of cooling water jackets	While this is possible the consequences are quite small. The cooling water is recirculated in a closed-loop system. Components of the system are geometrically favorable for criticality safety. The cooling water jackets are outside the tank (Gibson 1989).
Failure of the air pulser	Failure of the air pulser can result in a blowback of aerosol if an instrument line is broken as well. The flow may not be very large as the total airflow will be split between the ruptured line and the vent.
Failure of the lines in the "Pipe Chase" outside the CA and CC column glovebox	A number of piping lines are in an enclosed vertical pipe chase outside the CA and CC column glovebox. These lines include column pulse legs, CCP stream, CAIS stream, CAX stream, CCDP stream, and CUX stream. The CCDP, CCP, and CAIS streams are moderately concentrated aqueous plutonium. The CAW stream is an aqueous waste stream, the CUX and CAX contain no plutonium. Failure of these lines could result in the pumping of plutonium solution into the atmosphere of the fourth floor.
Failure of CAS or CCX stream (no flow)	There are a number of these streams within the Solvent Extraction system whose failure may result in plutonium carryover, or column flood, or precipitation. The tanks are geometrically favorable with respect to criticality. There are no energetic chemical reactions which may occur under these conditions. There is only "gummed up" columns. There is no red oil explosion because the pump in the storage tank upstream of the concentrator must be manually actuated and the valves manually aligned to direct solution to the concentrator, the stream line must also become unregulated.

Table 9-27. Plutonium Reclamation Facility Solvent Extraction--List of Potential Seismically Induced Accidents. (2 sheets)

Accident	Comment
Transfer line failure outside of the column glovebox	None.
Failure of drain lines or pipes between the second floor glovebox and the first floor glovebox or between the first floor glovebox and the floor	None.
Reaction of Hydroxylamine nitrate with HNO_3	If the CCX flowrate increases, there is excessive carryover of HN to the CAIS pump tank (same is true if there is low plutonium inventory in the CC column). Concentrated HNO_3 is added to the CAIS tank to keep the molarity high. The reaction between HN and HNO_3 is exothermic and produces NO_2 gas. The CAIS tank is cooled to prevent pressurization. If the cooling fails, the process is upset so CCX flow is increased and CCF flow is decreased then there could be a reaction in TK-36.
Pump MOP-120 discharge line fails or pump MOP-26 CAM pump CAIS out PPCW if line in cooling jacket fails	None.
Pu-HNO_3 solutions generate H_2 which can accumulate if not swept away by ventilation	None.

Table 9-28. Plexiglas™ Panels in Gloveboxes.

Glovebox	Location of Plexiglas™ panels	Approximate percentage of boxes that are Plexiglas™
HC-9B	North side--Bottom third and one-half of top third	15
HC-10	All	100
HC-11	All	100
HC-12S	None	0
HC-13MD	West side (covered by leaded glass)	25
HC-15A, -B, -C	East and west side (covered by leaded glass)	25
HC-16	None	0
HC-17	One-third of south, east, and west side	40
HC-18BS	None	0
HC-1	Sections of small panel interspersed between exam panels on north and south side in room 228-A, on south side only in room 228-B, and on the south side only in room 228-C	20
HC-7	Middle third of south side, all of north side	25

*Most of the top panels (except for HC-9B) are Plexiglas™; this percentage is not included. Plexiglas™ is flammable; its replacement, polycarbonate (Lexan™), is not.

Table 9-29. Best Estimate Values and Uncertainties of Return Period for Earthquake Levels.

"g" Value	Best estimate (yr)	Span of the standard deviations (yr)
0.10	500	300 to 1,700
0.15	3,000	900 to 10,000
0.20	10,000	2,500 to 50,000*
0.25	30,000	6,000 to 120,000*

Source: Coats (1984).
*Values over 10,000 are extrapolated.

Table 9-30. Chemical Storage, 234-5Z, 2nd Floor Chemicals, Amounts and Rooms.

Material	Amount	Room
Activated charcoal	150 lbs	338
Portland cement	100 lbs	338
Sodium carbonate	30 lbs	338

Table 9-31. Releases into Plutonium Finishing Plant Facilities For Seismic Event: 1 x 10^{-4} Probability.

Facility	Room, Glovebox (or Hood)	Release into Facility (g Pu)	% ^{240}Pu	Reference Subsection
234-5Z[3]	131-157, (Analytical Lab) 179-188, (PPSL) 221-C, D, and E (Standards Lab)	1.08[1] 0.79	< 10 > 10	9.2.4.6.3.1.A
	166, South Hood	0.01[2]	> 10	9.2.4.6.3.1.H
	227, HC-227S/T	0.96[2]	> 10	9.2.4.6.3.1.M
	228-B, HC-13MD	0.38	> 10	9.2.4.6.3.1.O
	228-C, HC-18M	1.5	> 10	9.2.4.6.3.1.P
	230-A, HC-21C	0.75	> 10	9.2.4.6.3.1.Q
	230-B, HC-21A	1.07	> 10	9.2.4.6.3.1.R
	235-B, HA-20MB	0.0	> 10	9.2.4.6.3.1.U
	235-B, HA-21I	1.20	>10	9.2.4.6.3.1.U
	235-B, HA-23S	3.30	> 10	9.2.4.6.3.1.U
	235-B, HA-28	0.38	> 10	9.2.4.6.3.1.U
	235-C, 235-B-2	0.38	> 10	9.2.4.6.3.1.V
	Duct Level: E-4 Ducting	1.15	< 10	9.2.4.6.3.1.W
	Duct Level: Filterbox 7A and 9A	0.83	< 10	9.2.4.6.3.1.W
	Filter Rooms	0.07	< 10	9.2.4.6.3.1.X
236-Z	Canyon	0.40[2]	> 10	9.2.4.6.3.2.A.c
	Pipe Chase	0.15[2]	> 10	9.2.4.6.3.2.A.g
	Transfer Line	0.02[2]	> 10	9.2.4.6.3.2.A.h
	27, PH and maintenance	0.83	> 10	9.2.4.6.3.2.C.d
2736-Z, -ZA, -ZB	--	Negligible	--	9.2.4.6.3.6
241-Z	--	0.10[2]	> 10	9.2.4.6.3.8
242-Z	--	Negligible	--	9.2.4.6.3.7
291-Z	--	0.01	< 10	9.2.4.6.3.9
232-Z	--	0.20	< 10	9.2.4.6.3.10
Total into Facilities		15.56[1]		

Notes: 1. The release values for the laboratoriesexclude the Laboratory Prototype Calciner in Room 188 of the PPSL since the calciner is not currently authorized for operation.

2. Denotes solution.

3. The releases from the Magnesium Hydroxide Precipitation Process gloveboxes, HC-230C-3 and HC-230C-4, and the Bagless Transfer System glovebox, HA-53BTS, are not shown in this table. See Sections 9.2.4.10 and 9.2.4.11 for releases from these gloveboxes.

Table 9-32. "No Ventilation Case" Radiological Consequences For Seismic Event: 1×10^{-4} Annual Probability

Facility	Release (g Pu)	Onsite dose (rem)		Offsite dose (rem)	
		EDE	Organ	EDE	Organ
PFP[1]	1.05	7.36	98	0.16	2.08
Building 232-Z	0.20	1.61	18	0.03	0.34
Building 241-Z	0.10	2.96	55	0.06	1.02
Bagless Transfer System Glovebox HA-53BTS	0	0	0	0	0
Magnesium Hydroxide Precipitation Process Gloveboxes HC-230C-3 and HC-230C-4	0	0	0	0	0
Seismic Initiated Fire in Gloveboxes HA-21I and HC-21C	0.42	5.78	85	0.12	1.82
Total	1.77	17.71	256	0.37	5.26
Risk Acceptance Guidelines		25	250	4	40

Note: 1. Includes releases originating from 234-5Z, 2736-Z, 2736-ZA, 2736-ZB, 242-Z, and 291-Z.

2. Values shown represent additional dose contributions resulting from a seismically initiated fire in Gloveboxes HA-21I and HC-21C as shown in Sections 9.2.4.10 and 9.2.4.11, respectively. Releases from Gloveboxes HA-21I and HC-21C due to seismic vibratory motion and assumed glovebox collapse are included in the row labeled "PFP". In the "no ventilation case", the value in row "PFP" is 0 since there are no releases from the RMC and RMA areas where these gloveboxes are located.

Table 9-33. "Ventilation Case" Radiological Consequences For Seismic Event: 1×10^{-4} Annual Probability.

Facility	Release (g Pu)	Onsite dose (rem)		Offsite dose (rem)	
		EDE	Organ	EDE	Organ
PFP[1]	12.84	5.30	80	1.87	28
Building 232-Z	0.20	1.61	18	0.03	0.34
Building 241-Z	0.10	2.96	55	0.06	1.02
Bagless Transfer System Glovebox HA-53BTS	0.63	0.57	9.1	0.20	3.22
Magnesium Hydroxide Precipitation Process Gloveboxes HC-230C-3 and HC-230C-4	0.14	0.15	2.7	0.05	0.96
Seismic Initiated Fire in Gloveboxes HA-21I and HC-21C[2]	1.92	0.90	13.3	0.32	4.72
Total[2]	15.83	11.49	178	2.53	38
Risk Acceptance Guidelines		25	250	4	40

Notes: 1. Includes releases originating from 234-5Z, 236-Z, 2736-Z, 2736-ZA, 2736-ZB, 242-Z, and 291-Z.

2. Values shown represent additional dose contributions resulting from a seismically initiated fire in Gloveboxes HA-21I and HC-21C as shown in Section 9.2.4.2.12.F. Releases from these gloveboxes due to seismic vibratory motion and assumed glovebox collapse are included in the row labeled "PFP" .

Table 9-34. Not Used.

Table 9-35. Not Used

Table 9-36. Radiological Consequences For Seismic Event: 2×10^{-3} Annual Probability.

Facility	Release (g Pu)	Onsite dose (rem)		Offsite dose (rem)	
		EDE	Organ	EDE	Organ
PFP	negligible	--	--	--	--
Building 241-Z	0.10	2.96	55	0.06	1.02
Building 232-Z	0.20	1.61	18	0.03	0.34
Total	0.30	4.57	73	0.09	1.36
Risk Acceptance Guidelines		8.5	85	1.0	10

Table 9-37. Onsite Distances for Various Plutonium Finishing Plant Release Points.

Nearest occupied onsite facility*	Stack (m)	Ground (m)	Fence (m)
272-WA (WNW)	630	550	450
T-Plant (NE)	1,580	1,540	1440
2713-W (ENE)	830	750	650
U-Plant (ESE)	1,060	1,050	950
242-S (SSE)	930	930	830

*For a facility to be qualified as an occupied facility, it must be manned at least five days a week. Activities do occur at lesser distances, but they are sporadic in nature.

Table 9-38. Site Boundary Distances for Plutonium Finishing Plant.

Transport direction	Distance (km)	Transport direction	Distance (km)
S	15.0	N	19.2
SSW	15.4	NNE	26.0
SW	16.1	NE	28.9
WSW	13.2	ENE	25.6
W	12.5	E	25.2
WNW	13.2	ESE	30.0
NW	16.5	SE	25.2
NNW	17.4	SSE	22.9

Table 9-39. Atmospheric Dispersion Coefficients for Onsite Maximum Individuals.

Release scenario	$\overline{\chi}/Q'$ (s/m^3)
Elevated release (930 m SSE)	1.62 E-5
Ground level release with building wake and plume meander (550 m WNW)	4.74 E-4
Buoyant plume rise (950 m ESE)	5.98 E-5
Point source ground level release from fence (450 m WNW)	1.22 E-3
Point source ground level release from 232-Z (550 m WNW)	8.72 E-4

Table 9-40. Atmospheric Dispersion Coefficients for Site Boundary Maximum Individuals.

Release scenario	$\overline{\chi}/Q'$ (s/m^3)
Elevated release (12,500 m W)	5.73 E-6
Ground level release with building wake and plume meander (12,500 m W)	1.01 E-5
Buoyant plume rise (17,400 m NNW)	1.16 E-6
Point source ground level release (12,500 m W)	1.62 E-5

Table 9-41. Constants for Relevant Plutonium and Americium Isotopes (Eckerman and Jeffrey 1993).

Isotope	Half-life (yr)	Specific activity (Ci/g)
^{238}Pu	87.4	17.1
^{239}Pu	24,065	0.0621
^{240}Pu	6,537	0.228
^{241}Pu	14.4	103.
^{242}Pu	376,300	0.00392
^{241}Am	432.2	3.43

Table 9-42. Unit Doses for Inhalation of Relevant Plutonium and Americium Isotopes (Eckerman et al. 1988).

Isotope	Effective Dose Equivalent Unit Inhalation Dose			
	Class W[1]		Class Y[1]	
	(Sv/Bq)	(rem/g)	(Sv/Bq)	(rem/g)
^{238}Pu	1.06 E-4	6.71 E+9	7.79 E-5	4.93 E+9
^{239}Pu	1.16 E-4	2.66 E+7	8.33 E-5	1.91 E+7
^{240}Pu	1.16 E-4	9.73 E+7	8.33 E-5	6.99 E+7
^{241}Pu	2.23 E-6	8.50 E+8	1.34 E-6	5.11 E+8
^{242}Pu	1.11 E-4	1.61 E+6	7.92 E-5	1.15 E+6
^{241}Am	1.20 E-4	1.52 E+9	--[1]	--[1]
Isotope	Bone Surface Unit Inhalation Dose			
	Class W[1]		Class Y[1]	
	(Sv/Bq)	(rem/g)	(Sv/Bq)	(rem/g)
^{238}Pu	1.90 E-3	1.20 E+11	7.25 E-4	4.59 E+10
^{239}Pu	2.11 E-3	4.84 E+8	8.21 E-4	1.88 E+8
^{240}Pu	2.11 E-3	1.77 E+9	8.21 E-4	6.89 E+8
^{241}Pu	4.20 E-5	1.60 E+10	1.78 E-5	6.78 E+9
^{242}Pu	2.01 E-3	2.92 E+7	7.81 E-4	1.14 E+7
^{241}Am	2.17 E-3	2.76 E+10	--(2)	--(2)

Notes: 1. Class Y lung retention applies to oxide forms of Pu.
Class W lung retention applies to nitrates, hydroxides and all other forms.

2. There are only Class W values for ^{241}Am. Therefore, Class W ^{241}Am values are used in the calculations for Class Y doses.

rem/g = Sv/Bq x Specific Activity x 3.7 E+12

Table 9-43. Isotopic Distribution of Plutonium at the Plutonium Finishing Plant Based on Non-Destructive Analysis (NDA) Verification Database.

Range (% ^{240}Pu)	Mass (g)	Number of Items	$^{238}Pu_*$ (% Pu)	$^{239}Pu_*$ (% Pu)	$^{240}Pu_*$ (% Pu)	$^{241}Pu_*$ (% Pu)	$^{242}Pu_*$ (% Pu)	$^{241}Am_*$ (% Pu)	Age
< 3.99	3,515	13	0.00	97.04	2.91	0.05	0.00	0.09	23
4.00 to 6.99	1,135,919	1,784	0.01	93.77	6.00	0.20	0.03	0.14	11
7.00 to 9.99	32,825	123	0.03	91.75	7.78	0.39	0.05	0.45	16
10.00 to 12.99	223,577	489	0.09	86.94	11.81	1.00	0.17	0.86	13
13.00 to 15.99	83,225	83	0.22	83.35	14.44	1.61	0.38	2.26	18
16.00 to 18.99	115,983	143	0.24	80.66	16.98	1.44	0.69	2.80	23
> 19.00	56,568	87	0.30	72.87	23.14	1.90	1.79	4.05	24
Total	1,651,613	2,722							

*The percent Pu (% Pu) is calculated on a per gram plutonium basis. The total for a row is greater than 100% because of the contribution of the ^{241}Am mass.

Table 9-44. Mass-Weighted Isotopic Values of the Material at Plutonium Finishing Plant for Two Ranges.

Range (% ^{240}Pu)	$^{238}Pu_*$ (% Pu)	$^{239}Pu_*$ (% Pu)	$^{240}Pu_*$ (% Pu)	$^{241}Pu_*$ (% Pu)	$^{242}Pu_*$ (% Pu)	$^{241}Am_*$ (% Pu)	Age (yr)
< 10%	0.01	93.70	6.05	0.20	0.03	0.15	11.7
> 10%	0.21	81.39	16.34	1.40	0.67	2.47	21.4
Both	0.13	86.59	11.99	0.89	0.40	1.49	20.6

*The percent Pu (% Pu) is calculated on a per-gram plutonium basis. The total for a row is greater than 100% because of the contribution of the ^{241}Am mass.

Table 9-45. Plutonium Inventory Evaluated by Range of Percent ^{240}Pu.

Range % ^{240}Pu	Present PFP Inventory	Inhalation doses (rem/g)				
		Mass weighted average*	Range		Percentile	
			Minimum	Maximum		
< 10%	1,542,620	3.59 E+7	2.96 E+7	6.42 E+7	90th	3.92 E+7
> 10%	2,106,611	1.01 E+8	4.68 E+7	2.46 E+8	90th	1.96 E+8
Both	3,649,230	7.36 E+7	2.96 E+8	2.46 E+8	95th	1.99 E+8

Table 9-46. Effective Dose Equivalent Unit Inhalation Doses (rem/g).

Range % ^{240}Pu	Mass Weighted Average	90th percentile	Maximum
Class W[1]			
< 10%	3.7 E+7	4.0 E+7	6.6 E+7
> 10%	1.03 E+8	2.0 E+8	2.5 E+8
Class Y[1]			
< 10%	2.8 E+7	3.1 E+7	5.5 E+7
> 10%	8.8 E+7	1.7 E+8	2.3 E+8

Note: 1. Class Y lung retention applies to oxide forms of Pu. Class W lung retention applies to nitrates, hydroxides and all other forms.

Table 9-47. Bone Surface Unit Inhalation Doses (rem/g).

Range % ^{240}Pu	Mass weighted average	90th percentile	Maximum
Class W[1]			
< 10%	6.7 E+8	7.3 E+8	1.2 E+9
> 10%	1.9 E+9	3.6 E+9	4.6 E+9
Class Y[1]			
< 10%	3.2 E+8	3.6 E+8	7.8 E+8
> 10%	1.3 E+9	2.7 E+9	3.8 E+9

Note: 1. Class Y lung retention applies to oxide forms of Pu. Class W lung retention applies to nitrates, hydroxides and all other forms.

Table 9-48. ICRP 23 Standard Man Breathing Rates.

Release scenario	Breathing rate
Acute release (i.e., <24 h)	3.3 E-4 m^3/s
Chronic release (i.e., >24 h)	2.7 E-4 m^3/s

Table 9-49. Radiological Risk Acceptance Guidelines.[a]

Probability category[b]	Nominal range of probability (per year)	Effective dose equivalent (rem)	Organ dose equivalent for lens of eye (rem)	Organ dose equivalent for all other organs (rem)
Offsite guidelines				
Anticipated	1 to E-02	0.01 to 0.5	0.03 to 1.5	0.1 to 5
Unlikely	E-02 to E-04	0.5 to 4	1.5 to 12	5 to 40
Extremely unlikely	E-04 to E-06	4 to 25	12 to 75	40 to 250
Onsite Guidelines				
Anticipated	0.1 to E-02	1 to 5	3 to 15	10 to 50
Unlikely	E-02 to E-04	5 to 25	15 to 75	50 to 250
Extremely unlikely	E-04 to E-06	25 to 100	75 to 300	250 to 1000

[a]These guidelines are to be applied as curves as shown in Figure 9-34. The dose guidelines represent EDEs and organ dose equivalents from all pathways and should be used for comparison only to doses calculated with a methodology consistent with that recommended by the International Commission on Radiological Protection (ICRP) in ICRP 26 and ICRP 30.
[b]See Table 9-51 for additional definitions of the probability categories used here.

Table 9-50. Toxicological Risk Acceptance Guidelines.*

Nominal range of probability (yr)	Concentration	
	Onsite	Offsite
1 to E-06	ERPG-2 to ERPG-3	ERPG-1 to ERPG-2

*These guidelines are to be applied as curves as shown in Figure 9-35.

Table 9-51. Grams of 90th Percentile, >10% ^{240}Pu Class Y (PuO_2) Material Released to Reach Dose Guidelines.

Receptor location	Type of release	Probability (annual)	EDE Equivalent (g)	Organ (Bone surface) equivalent (g)
Onsite	Ground	0.1	0.015	0.009
	Stack	0.1	1.1	0.69
	Ground	1 E-02	0.073	0.05
	Stack	1 E-02	5.5	3.5
	Ground	1 E-04	0.36	0.23
	Stack	1 E-04	28	17
	Ground	1 E-06	1.5	0.92
	Stack	1 E-06	110.0	69
Offsite	Ground	1	0.011	0.007[a]
	Stack	1	0.031	0.02[b]
	Ground	1 E-02	0.55	0.35
	Stack	1 E-02	1.6	0.98
	Ground	1 E-04	4.4	2.8
	Stack	1 E-04	12	7.8
	Ground	1 E-06	28	17
	Stack	1 E-06	78	49

[a]Most limiting ground-level release.
[b]Most limiting stack-level release.

Table 9-52. Grams of 90th Percentile, >10% ^{240}Pu Class W $Pu(NO_3)_4$ Material Released to Reach Dose Guidelines.

Receptor location	Type of release	Probability (annual)	EDE Equivalent (g)	Organ (Bone surface) Equivalent (g)
Onsite	Ground	0.1	0.012	0.007
	Stack	0.1	0.94	0.52
	Ground	1 E-02	0.062	0.034
	Stack	1 E-02	4.7	2.6
	Ground	1 E-04	0.31	0.17
	Stack	1 E-04	23	13
	Ground	1 E-06	1.3	0.69
	Stack	1 E-06	94	52
Offsite	Ground	1	0.009	0.005[a]
	Stack	1	0.026	0.015[b]
	Ground	1 E-02	0.47	0.26
	Stack	1 E-02	1.3	0.74
	Ground	1 E-04	3.7	2.1
	Stack	1 E-04	11	5.9
	Ground	1 E-06	23	13
	Stack	1 E-06	66	36

[a] Most limiting ground level release.
[b] Most limiting stack release.

Table 9-53. Toxicological Risk Acceptance Guidelines for HNO_3.

Annual frequency	Basis	HNO_3 concentration in ppm
Onsite		
1	ERPG-2	15
E-02	--	19
E-04	--	24
E-06	ERPG-3	30
Offsite		
1	ERPG-1	2
E-02	--	3.9
E-04	--	7.7
E-06	ERPG-2	15

Table 9-54. Effect of Production Vertical Denitration Calciner Operations on Prior PFP Abnormal Occurrence and Accident Analyses (4 sheets)

PFP FSAR Section	PFP Abnormal Occurrence or Accident Analysis	Effect on Current Analysis Posed by Calciner Operations	Comments
Abnormal Operations			
9.1.1	Radioisotope-Bearing Liquid Spills	**No effect.** Analysis generically covers spills of plutonium nitrate solution within the facility. The analysis adequately covers potential spills of plutonium nitrate in the load in/load out area (Glovebox HC-227S and Hood HC-227T) and within Glovebox HC-230C-2.	Accident scenario analyzed is a 10-L of plutonium nitrate from a height of 3 m. Analysis credits building ventilation system and a single stage of HEPA filtration with mitigating the release to the atmosphere.
9.1.2	Radioisotope-Bearing Pressurized Liquid Container	**No effect.** Analysis adequately covers pressurized releases from PR cans and polybottles in the LI/LO area (Glovebox HC-227S and Hood HC-227T).	Analysis postulates that 5 L of solution are ejected upon depressurization when opening container; splatter release fraction is for 3 m fall. E-3 ventilation system and single stage HEPA filter is credited with limiting release to the atmosphere.
9.1.3	Radioisotope-Bearing Powder Spills	**No effect.** Analysis covers PuO_2 spills outside of gloveboxes. Analysis adequately covers potential spills of powder inside or outside the product handling glovebox HC-21A.	1 kg powder spill is assumed to occur from height of 3 m, releasing 1.2 g. E-4 and E-3 ventilation systems and single stage HEPA filtration credited with limiting release to atmosphere.
9.1.4	Radioisotope-Bearing Pressurized Powder Container	**No effect.** Analysis covers, generically, pressurized powder releases from cans in gloveboxes, vaults or rooms. Improper calciner operation has the potential to produce insufficiently stabilized PuO_2, with potential canister ruptures during handling or NDA testing in the 2736-ZB Building or potential canister ruptures in the storage vaults in the 2736-Z Building. Ruptured canister releases are considered to be adequately represented by the pressurized powder release evaluated in Section 9.1.4.	Analysis is based on historical facility airborne contamination levels measured following off-normal events. Single stage HEPA filter is credited with limiting release to the atmosphere.
9.1.5	Stack Release Resulting from Filter Changes	**No effect.** Second stage filter source term is insignificantly effected by vertical denitration calciner operations. Changes to analysis not required.	Analysis assumes filter is dropped containing twice the contamination levels ever measured on the secondary filters.
9.1.6	Overpressure of Remote Mechanical C Line Pressure Vessel	**No effect.** The RMC Line pressure vessel is no longer used. Accident no longer relevant.	
9.1.7A	Excessive Building Pressurization–234-5Z	**No significant effect.** Analysis presents qualitative argument that the consequences of building pressurization would be low because the structure remains intact and multiple failures would have to occur for a significant quantity of radiological material to be released from Zone 4 areas into Zone 3 areas.	Potential source term added by calciner operations is small in comparison to the total source term in the plant.
9.1.7B	Excessive Pressurization of 236-Z Building	**No effect.** Calciner operations not relevant to 236-Z.	

Table 9-54. Effect of Production Vertical Denitration Calciner Operations on Prior PFP Abnormal Occurrence and Accident Analyses (4 sheets)

PFP FSAR Section	PFP Abnormal Occurrence or Accident Analysis	Effect on Current Analysis Posed by Calciner Operations	Comments
9.1.7C	Excessive Building Pressurization 2736-ZB Building	**No effect.** The analysis concludes that the building pressurization does not result in a significant release to the environment because the building has no significant levels of contamination and the building structure is not compromised by the overpressure.	
9.1.7D	Excessive Building Pressurization 2736-Z Building	**No effect.** The analysis concludes that building pressurization would not cause the storage packages to rupture or the vault structure to be compromised. The analysis concludes there is no loose radiological material stored in the vaults. Storage of convenience cans filled with stabilized PuO_2 from the VDC presents no new hazards to the storage vaults.	
9.1.7E	Excessive Building Pressurization, 241-Z Building	**No effect.** Calciner operations not relevant to 241-Z.	
9.1.7F	Building Depressurization--All Plutonium Finishing Plant Operations	**No effect.** The analysis in Section 9.1.7F concludes that depressurization of Building 234-5Z will not result in structural failures. The analysis also concludes that the RMC line pressure will remain more negative than room pressure should the building depressurize due to dry air supply regulating valve. Based on the conclusions of the analysis in Section 9.1.7F, the glovebox containing the vertical denitration calciner (Glovebox HC-230C-2) will not contribute to an environmental release.	Any contamination spread from the calciner glovebox (Glovebox HC-230C-2) to the 230C room would pass through the E-3 HEPA filters before discharge to the atmosphere.
9.1.8	Loss of Ventilation	**No significant effect.** An air flow reversal from the exhaust stack is concluded to only result in minor contamination spread from Zone 4 to Zone 3 areas. The plutonium inventory in Glovebox HC-230C-2 is small compared to total inventory in all the gloveboxes in the plant.	
9.1.9	Glovebox Glove Breach	**No effect.** Glovebox glove breach analysis is representative of potential glove breach accident in HC-230C-2.	
Accidents			
9.2.1C	Not Used	**No effect.**	
9.2.1F	Flammable Gas Explosion	**No effect.** The risk associated with flammable gases in PFP is determined to be acceptable in Section 9.2.1F based on the implementation of specific controls on gas bottle purchase, storage and use. Bottled flammable gases are not used in calciner operations.	

Table 9-54. Effect of Production Vertical Denitration Calciner Operations on Prior PFP Abnormal Occurrence and Accident Analyses (4 sheets)

PFP FSAR Section	PFP Abnormal Occurrence or Accident Analysis	Effect on Current Analysis Posed by Calciner Operations	Comments
9.2.2A	Mechanical C Line Fire	**Additional source term potential.** Glovebox HC-230C-2 is located at the west end of the RMC line. The plastic panels in the HC-2 and HC-3 conveyor could allow the RMC line fire to propagate to Glovebox HC-230C-2. Pu material in Glovebox HC-230C-2 could add to the release in a seismic event.	See Section 9.2.9.5.
9.2.2B	Hydraulic Oil fire in Room 321	**No effect.** VDC operations do not effect the likelihood or consequences of a hydraulic fire on the third floor of the facility.	
9.2.2C	Not Used	**No effect.**	
9.2.2D	Waste Drum Fire	**No effect.** Calciner operations not relevant to waste drum accidents.	
9.2.3	Criticality	**No effect.** Glovebox HC-230C-2 handles greater than a critical mass of Pu at any given time. The HC-230C-2 glovebox and vessel supports are seismically qualified, the glovebox is equipped with a criticality drain, and the glovebox vessels are geometrically favorable. These factors preclude criticalities in Glovebox HC-230C-2. In the extremely unlikely event a criticality occurs in Glovebox HC-230C-2, the criticality analysis in Section 9.2.3 is adequately representative. No changes are required to Section 9.2.3 as a result of calciner operations.	
9.2.4	Seismic Event	**Additional source term potential.** The radiological inventory in Glovebox HC-230C-2 adds to the potential source term in the seismic event due to the potential for calciner pressurization and vessel ruptures.	See revisions to the seismic analysis in Section 9.2.4 and seismic delta analysis in Section 9.2.9.4. The HC-230C-2 Glovebox structure is qualified to withstand the DBE. The interconnecting conveyor glovebox and exhaust ductwork are not qualified for the DBE, providing potential leakage paths to Zone 3 for particulates made airborne inside the glovebox. Vessel supports inside Glovebox HC-230C-2 are qualified for only the UBC level earthquake.
9.2.5	Strong Wind	**No effect.** The 234-5Z Building is shown in the analysis to survive the design basis wind. No releases from the RMC Line area are postulated. Calciner operations do not affect the Strong Wind accident analysis.	

Table 9-54. Effect of Production Vertical Denitration Calciner Operations on Prior PFP Abnormal Occurrence and Accident Analyses (4 sheets)

PFP FSAR Section	PFP Abnormal Occurrence or Accident Analysis	Effect on Current Analysis Posed by Calciner Operations	Comments
9.2.6	Flood	**No effect.** External floods are not identified as a safety issue relative to the RMC line in the accident analysis. Water intrusion into gloveboxes as a result of internal floods is a contingency in criticality-control documentation. Like the other RMC Line Gloveboxes, HC-230C-2 is equipped with a criticality drain. Worst-case consequence of internal flooding of HC-230C-2 is bounded by the criticality analysis in Section 9.2.3.	
9.2.7	Aircraft Accident	**No effect.** Aircraft impacts into the PFP facility are shown in the analysis to be incredible given flight restrictions prohibit helicopter operation in proximity to the PFP.	
9.2.8	Toxic Chemical Release	**No effect.** The postulated accident in Section 9.2.8 (failure of the 7000 gal outside HNO_3 storage tank) bounds potential NO_x or nitric acid vapor releases through the plant vacuum system caused by calciner or scrubber upsets within Glovebox HC-230C-2. The accident in Section 9.2.8 also bounds potential accidents involving the nitric acid or NaOH supplies to the VDC process.	

Table 9-55. Not Used

Table 9-56. Not Used

Table 9-57. Not Used

Table 9-58. Radiological Consequences For Glovebox HC-230C-2 Seismic Release (ventilation case)

Receptor	Dose (rem)	
	EDE	Bone Surface
Onsite	0.67	10.3
Offsite	0.24	3.7

Table 9-59. Decomposition Temperature and Auto-Ignition Temperature for Plastics and Pyrolysis Products

Material	Decomposition Temperature, °C[1]	Auto Ignition Temperature, °C
PE	340-440	349
PVC	200-300	454
PS	300-400	492
PC	420-620	580
Benzene	--	592
Carbon Monoxide	--	609
Toluene	--	568
Butene	--	443
Styrene	--	490
Ethylene	--	485

Note [1]: The decomposition temperature is the temperature at which the material undergoes pyrolysis.

Table 9-60. Summary Reaction Products at 100 °C after Pyrolysis, Cooling, and Reaction with Air at Temperatures Above the Auto-ignition Temperature

Grams of Plastic	Moles plastic at 100 °C	Moles air at 100 °C	Moles N_2 at 100 °C	Ratio of Plastic/to total	Ratio of N_2 to Total
50 g, ethylene	0.051	0.10	0.044	0.26	0.22
10 g, ethylene	0.042	0.10	0.055	0.21	0.28
10 g (15% H_2 85% C_2H_4)[1]	0.038	0.10	0.058	0.19	0.30
1.0 g ethylene[1]	0.012	0.10	0.084	0.06	0.43
10 g, benzene	0.032	0.10	0.066	0.16	0.34
1.0 g benzene[1]	0.006	0.10	0.09	0.03	0.45

Note[1]: These are quantities that result in ethylene or butene concentrations within the flammable limits. Other quantities of similar magnitude may also result in flammable gas concentrations within the flammable limits.

Table 9-61. Criticality Prevention Specification Total Plutonium Limits from Marusich 1994. (5 sheets)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS
Glovebox 1	131	234-5Z	150
Glovebox 2	131	234-5Z	150
Glovebox 3	131	234-5Z	150
Hood 1	134	234-5Z	400
Hood 2	134	234-5Z	150
Hood 3	134	234-5Z	150
Hood 4	134	234-5Z	150
Hood 1	135	234-5Z	150
Hood 2	135	234-5Z	400
Hood 3	135	234-5Z	150
Hood 4	135	234-5Z	400
Glovebox 1	136	234-5Z	150
Glovebox 2	136	234-5Z	400
Glovebox 3	136	234-5Z	400
Glovebox 1	137	234-5Z	150
Glovebox 2	137	234-5Z	400
Glovebox 3	137	234-5Z	400
Glovebox 1	139	234-5Z	1,000
Glovebox 2	139	234-5Z	1,000
Glovebox 3	139	234-5Z	1,000
Glovebox 4	139	234-5Z	1,000
Glovebox 5	139	234-5Z	21,000
Glovebox 6	139	234-5Z	2,500
Hood 1+2	143	234-5Z	250
Hood 3	143	234-5Z	150
Hood 4	143	234-5Z	250
Hood 5	143	234-5Z	250
Hood 1	144	234-5Z	150
Hood 2	144	234-5Z	150
Hood 3	144	234-5Z	250
Hood 4	144	234-5Z	250
Hood 5	144	234-5Z	150
Hood 6	144	234-5Z	150
Hood 7	144	234-5Z	150
Hood 8	144	234-5Z	150
Hood 9	144	234-5Z	150

Table 9-61. Criticality Prevention Specification Total Plutonium Limits from Marusich 1994. (5 sheets)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS
Glovebox	145	234-5Z	2,500 inactive*
Hood 1	146	234-5Z	150
Hood 2	146	234-5Z	150
Hood 3	146	234-5Z	150
Hood 4	146	234-5Z	250
Glovebox 5	146	234-5Z	2,500
Hood 1	148	234-5Z	150
Hood 2	148	234-5Z	150
Hood 1	149	234-5Z	150
Hood 2	149	234-5Z	150
Glovebox 552	152	234-5Z	3,400
Hood 521	152	234-5Z	250
Glovebox 5	153	234-5Z	250
Hood 1	153	234-5Z	250
Hood 2	153	234-5Z	250
Hood 3	153	234-5Z	250
Hood 4	153	234-5Z	250
Glovebox 1	154	234-5Z	Inactive*
Glovebox 2+3	154	234-5Z	150
Hood 1	155	234-5Z	400
Hood 2	155	234-5Z	150
Hood 3	155	234-5Z	150
Hood 4	155	234-5Z	150
Glovebox 1+2	156	234-5Z	150
Hood 3	156	234-5Z	150
Hood 4	156	234-5Z	150
Glovebox 1+2	157	234-5Z	150
Glovebox 3+4	157	234-5Z	150
Glovebox HC-4	166	234-5Z	52,800
Glovebox HC-6	166	234-5Z	3,000 inactive*
South hood	166	234-5Z	400
Glovebox HA-40F	169	234-5Z	12,000 inactive*
Glovebox HC-46F	170	234-5Z	12,000 inactive*
Hood	170	234-5Z	inactive
Glovebox 1	179	234-5Z	2,500
Glovebox 10	179	234-5Z	2,500
Glovebox 12	179	234-5Z	2,500
Glovebox 4	179	234-5Z	2,500
Glovebox 6	179	234-5Z	2,500
Glovebox 9	179	234-5Z	2,500
Hood 11	179	234-5Z	400 inactive*
Hood 2	179	234-5Z	400 inactive*
Hood 3	179	234-5Z	400 inactive*
Hood 1	180	234-5Z	15

Table 9-61. Criticality Prevention Specification Total Plutonium Limits from Marusich 1994. (5 sheets)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS
Glovebox-179-5	183	234-5Z	Inactive*
Hood 1	187	234-5Z	15
Hood 2	187	234-5Z	15
Hood 3	187	234-5Z	15
Hood 4	187	234-5Z	15
Hood 5	187	234-5Z	15
Glovebox 1	188	234-5Z	2,500
Glovebox 3	221-C	234-5Z	2,500
Hood/Glovebox 1	221-C	234-5Z	150
Hood/Glovebox 2	221-C	234-5Z	150
Storage Cabinet SC-221C	221-C	234-5Z	250
Hood/Glovebox 1	221-D	234-5Z	150
Hood/Glovebox 2	221-D	234-5Z	150
Hood/Glovebox 3	221-D	234-5Z	150
Hood/Glovebox 4	221-D	234-5Z	250
Hood/Glovebox 5	221-D	234-5Z	400
Hood/Glovebox 1	221-E	234-5Z	150
Hood/Glovebox 2	221-E	234-5Z	250
Hood/Glovebox 3	221-E	234-5Z	150
Glovebox HC-227S	227	234-5Z	58,080
Glovebox HC-227T	227	234-5Z	2,500
Glovebox HC-1, conveyor	228-A, B,C	234-5Z	Normally empty (see note)
Glovebox HC-2, conveyor	228-A, B,C 230-A, B,C	234-5Z	Normally empty (see note)
Glovebox HC-7	228-A	234-5Z	3,000
Glovebox HC-9B	228-A	234-5Z	32,700
Glovebox HC-10	228-A	234-5Z	2,500
Glovebox HC-11	228-A	234-5Z	30,000
Glovebox HC-12S	228-A	234-5Z	4,000 inactive*
Glovebox HC-13MD	228-B	234-5Z	4,000 inactive
Glovebox HC-15A,-B,-C	228-B	234-5Z	12,000 inactive*
Glovebox HC-16CC	228-B	234-5Z	4,000 inactive*
Glovebox HC-17-SBB	228-C	234-5Z	5,500 inactive*
Glovebox HC-17DC	228-C	234-5Z	4,000 inactive*
Glovebox HC-17P	228-C	234-5Z	1,500 inactive
Glovebox HC-18BS	228-C	234-5Z	50,000 as metal Limited to 20,000 as powder
Glovebox HC-18M	228-C	234-5Z	2,500
Glovebox HC-21C	230-A	234-5Z	20,000
Glovebox HC-21A	230-B	234-5Z	9,000
Glovebox HC-3, conveyor	230-C	234-5Z	1,500 normally empty (see note)
Glovebox HC-4, conveyor	230-C 235-B	234-5Z	2,500 normally empty (see note)
Glovebox HC-5, conveyor	230-C	234-5Z	1,500 normally empty (see note)

Table 9-61. Criticality Prevention Specification Total Plutonium Limits from Marusich 1994. (5 sheets)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS
Glovebox HC-60	230-C	234-5Z	3,000 inactive*
Glovebox HA-46	232	234-5Z	150 Inactive*
Glovebox H-8, conveyor	235-A	234-5Z	Inactive*
Glovebox H-9A conveyor	235-A	234-5Z	Inactive*
Glovebox H-9D, conveyor	235-A	234-5Z	Inactive*
Glovebox H-9E, conveyor	235-A	234-5Z	20,000 inactive*
Glovebox HA-7A	235-A	234-5Z	Inactive*
Glovebox HA-9C	235-A	234-5Z	Inactive*
Glovebox HC-10, conveyor	235-A	234-5Z	Inactive*
Glovebox HA-19	235-B	234-5Z	2,500
Glovebox HA-20MB	235-B	234-5Z	10,000
Glovebox HA-21I	235-B	234-5Z	20,000 inactive*
Glovebox HA-23S	235-B	234-5Z	110,000
Glovebox HA-28, conveyor	235-B	234-5Z	2,500
Glovebox HC-1A	235-B	234-5Z	Inactive
Glovebox 235-B-2	235-C	234-5Z	2,500
Glovebox HA-16BS	236-A	234-5Z	2,500 inactive*
Glovebox HA-16CS	236-A	234-5Z	2,500 inactive*
Glovebox HA-22B	236-A	234-5Z	Inactive*
Glovebox (1st floor)	East corridor	236-Z	3000 g in 2 containers plus 2500 g/ft^2 in each section
Glovebox (1st floor)	West corridor	236-Z	3000 g in 2 containers plus 2500 g/ft^2 in each section
Glovebox (2nd floor)	East corridor	236-Z	3000 g in 2 containers plus 2500 g/ft^2 in each section
Glovebox (2nd floor)	West corridor	236-Z	3000 g in 2 containers plus 2500 g/ft^2 in each section
Glovebox (2nd floor PH and maintenance RPT)	27	236-Z	5500 g
Glovebox (MT-conveyor)	41	236-Z	1,500 normally empty (see note)
Glovebox MT-1	41	236-Z	6,000
Glovebox MT-3	41	236-Z	Inactive*
Glovebox MT-4	41	236-Z	4,000 inactive*
Glovebox MT-5	41	236-Z	29,000
Glovebox MT-6	41	236-Z	9,000
Glovebox (4th floor column)	42	236-Z	4,500
Glovebox (S&C canning and loading)	43	236-Z	3,200
Glovebox (S&C charging glovebox)	43	236-Z	1,200
Glovebox (5th floor column)	50	236-Z	4,500
Glovebox (6th floor column)	60	236-Z	4,500
Glovebox (repackaging glovebox)	636	2736-ZB	20,000

Table 9-61. Criticality Prevention Specification Total Plutonium Limits from Marusich 1994. (5 sheets)

Glovebox/room	Room	Building	Maximum plutonium allowed (g) per CPS

*Inactive gloveboxes-no plutonium containers may be added. Residual quantities are allowed.
NOTE: This limit does not include containers that may be on the conveyer. Assumed time spent on conveyer is negligible.

Table 9-62. Summary of Thermal Degradation Information for Hydraulic Oil, and Sealants

Material	Flammable Constituents	Fire Data
Hydraulic Oil		
Phosphate esters	Organic esters	Fire point 224 °C
Siloxanes	Methyl or ethyl groups	Fire point 260 °C
Chlorosilicones	Methyl or ethyl groups	Fire point 325 °C
Water-glycol	Not flammable	
Mineral oil	Organic esters and straight chain hydrocarbons	Fire point 110 °C
Sealants		
RTV	Methyl and ethyl groups, carboxylic acid, formaldehyde, phosgene	---

Table 9-63. Rates of Butene Gas Generation from TBP Pyrolysis

Temperature, °C	Butene Generation Rate g/min - g TBP
112	0.00024
132	0.0014
152	0.0033
172	0.0084
192	0.022
212	0.045
232	0.11
252	0.33
268	3.43

Table 9-64. Butene Release During 300 °C/hr Heat Up with 10 g TBP as a Contaminant

Elapsed Time, min	Temperature, °C	Butene Generation Rate at that Temperature, g/min	Total Butene Evolved, g
0	112	0.0024	0
4	132	0.014	0.023
8	152	0.033	0.11
12	172	0.084	0.32
16	192	0.22	2.2
20	212	0.45	2.2
24	232	1.1	5.3
24.5[1]	252	3.3	6.3[1]

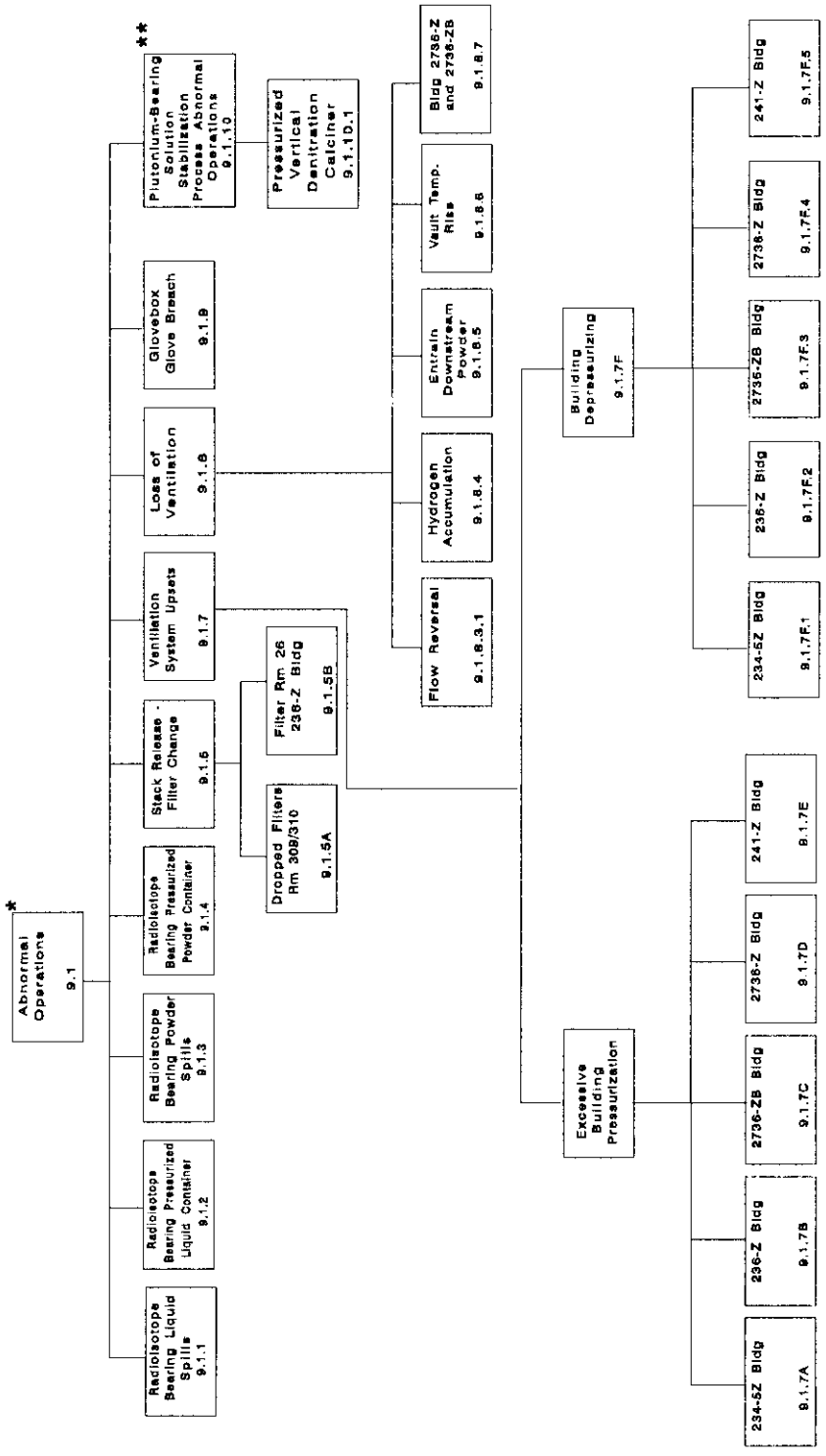
Note[1]: 10 g of TBP equates to 6.3 g butene that can be evolved.

Table 9-65. Mass and Volume of Butene in the Furnace (furnace temperature - 175 °C)

t, min	Mass of butene in furnace, g	Volume of Butene, L	Volume %
0	0	0	0
5	0.5	0.32	5.3
10	1.0	0.62	10
20	1.8	1.2	20
40	3.2	2.1	35
60	4.4	2.9	48
63[1]	4.5	2.95	49

Note[1]: 6.3 g butene evolved over 63 minutes.

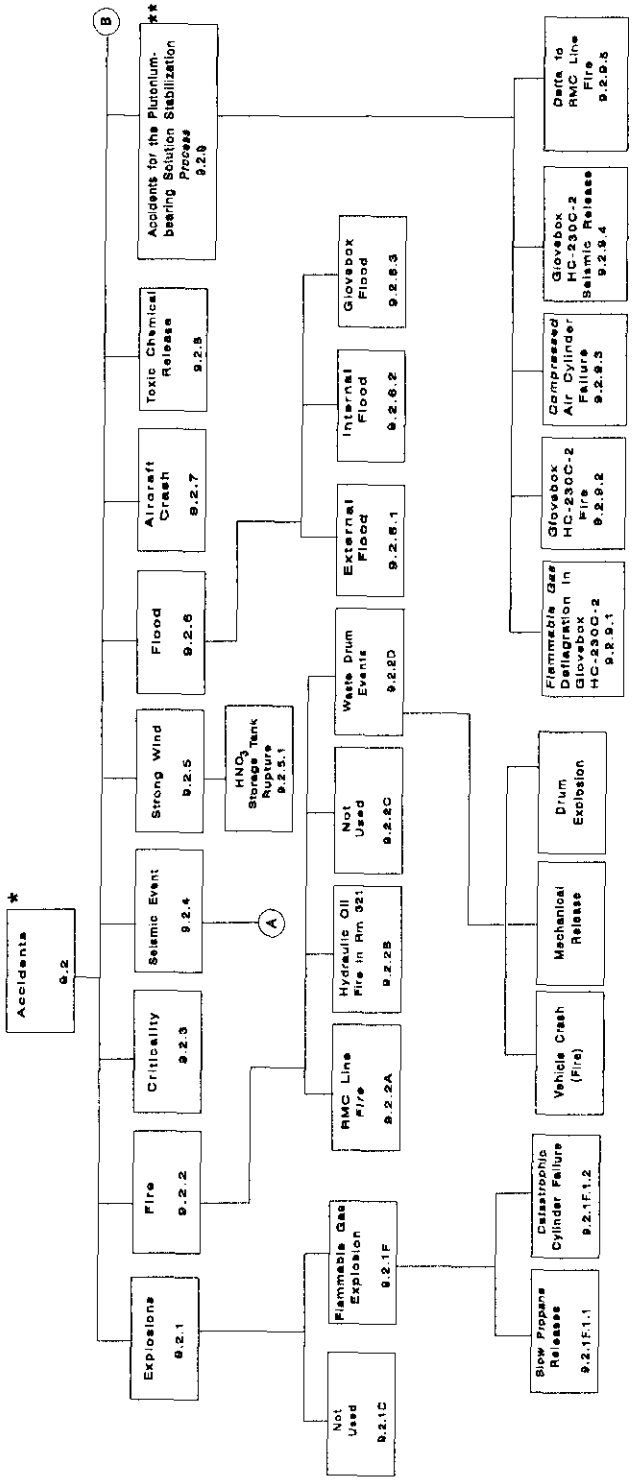
Figure 9-1. Logic Diagram for Abnormal Operations and Accidents.
(Sheet 1 of 4)



*There were no unique abnormal operations associated with the Laboratory Prototype Calciner - refer to The Laboratory Prototype Calciner addendum to this FSAR

** Applies to the Production Vertical Denitration Calciner

Figure 9-1. Logic Diagram for Abnormal Operations and Accidents.
(Sheet 2 of 4)



* Accidents analyzed for the Laboratory Prototype Calciner are provided in the Laboratory Prototype Calciner Addendum to this FSAR.

** Applies to the Production Vertical Denitration Calciner.

Figure 9-1. Logic Diagram for Abnormal Operations and Accidents.
(Sheet 3 of 4)

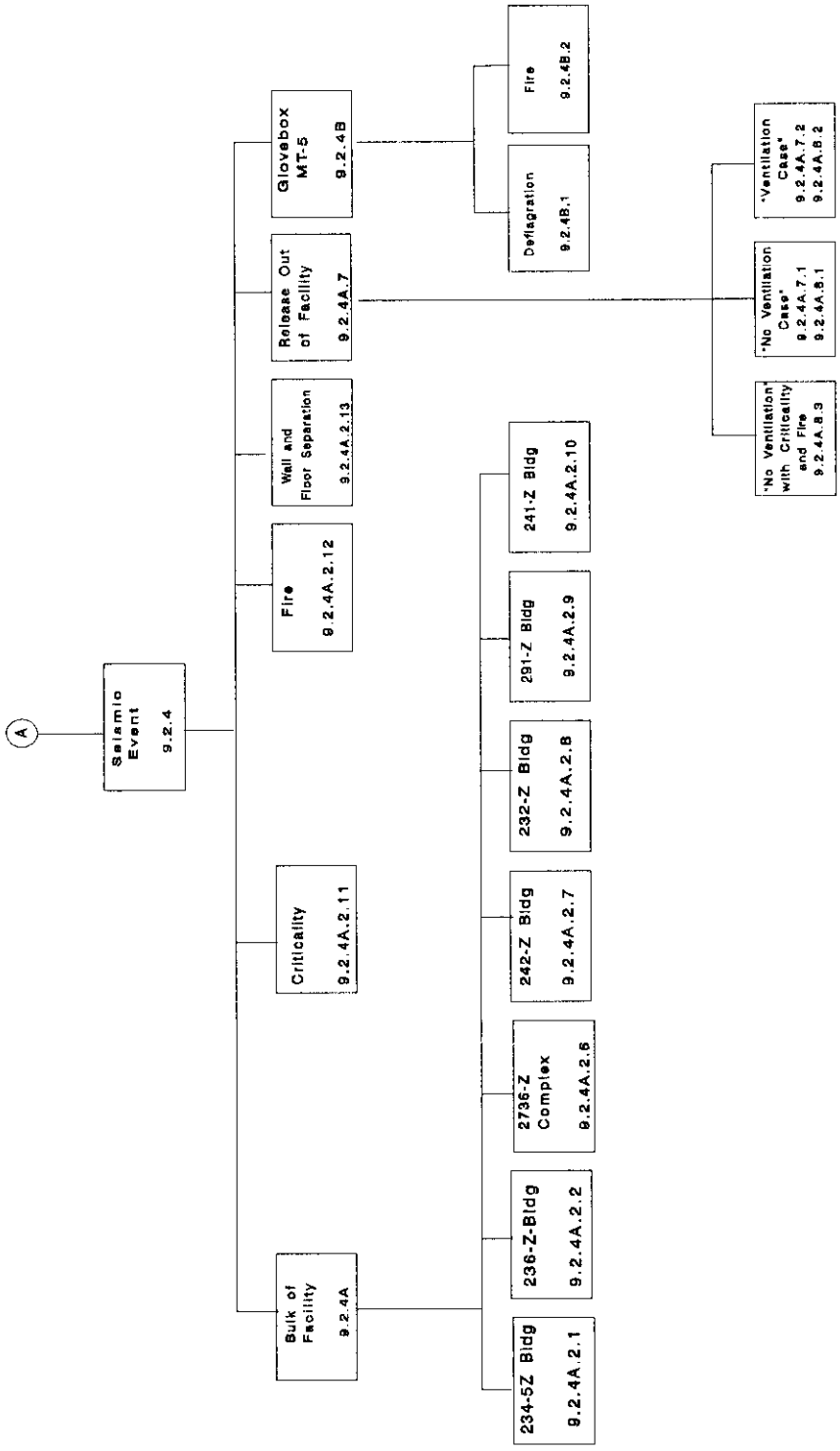


Figure 9-1. Logic Diagram for Abnormal Operations and Accidents.
(Sheet 4 of 4)

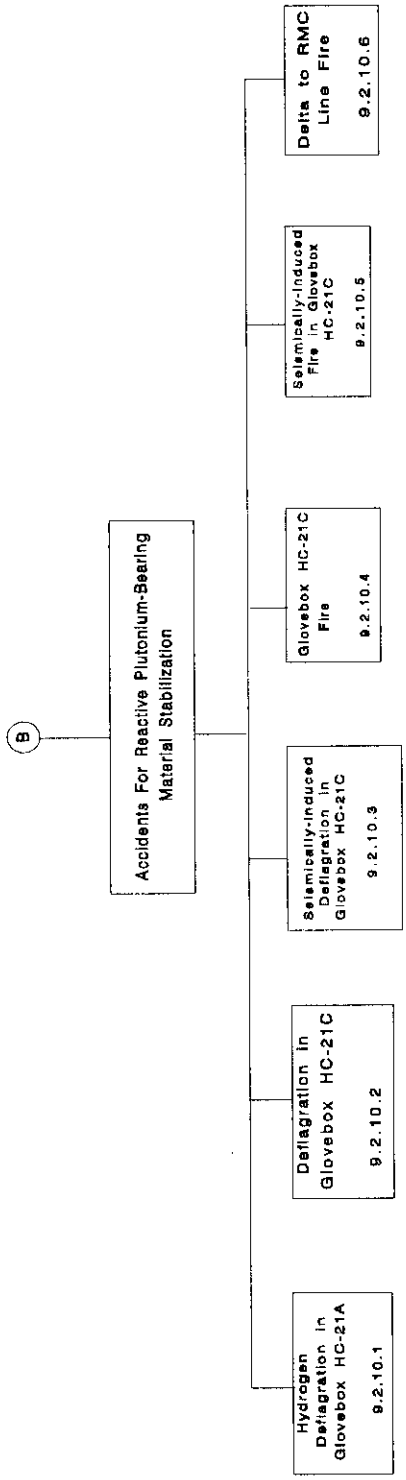


Figure 9-2. Plutonium Finishing Plant Floor Plans and Room Description. (Sheet 1 of 2)

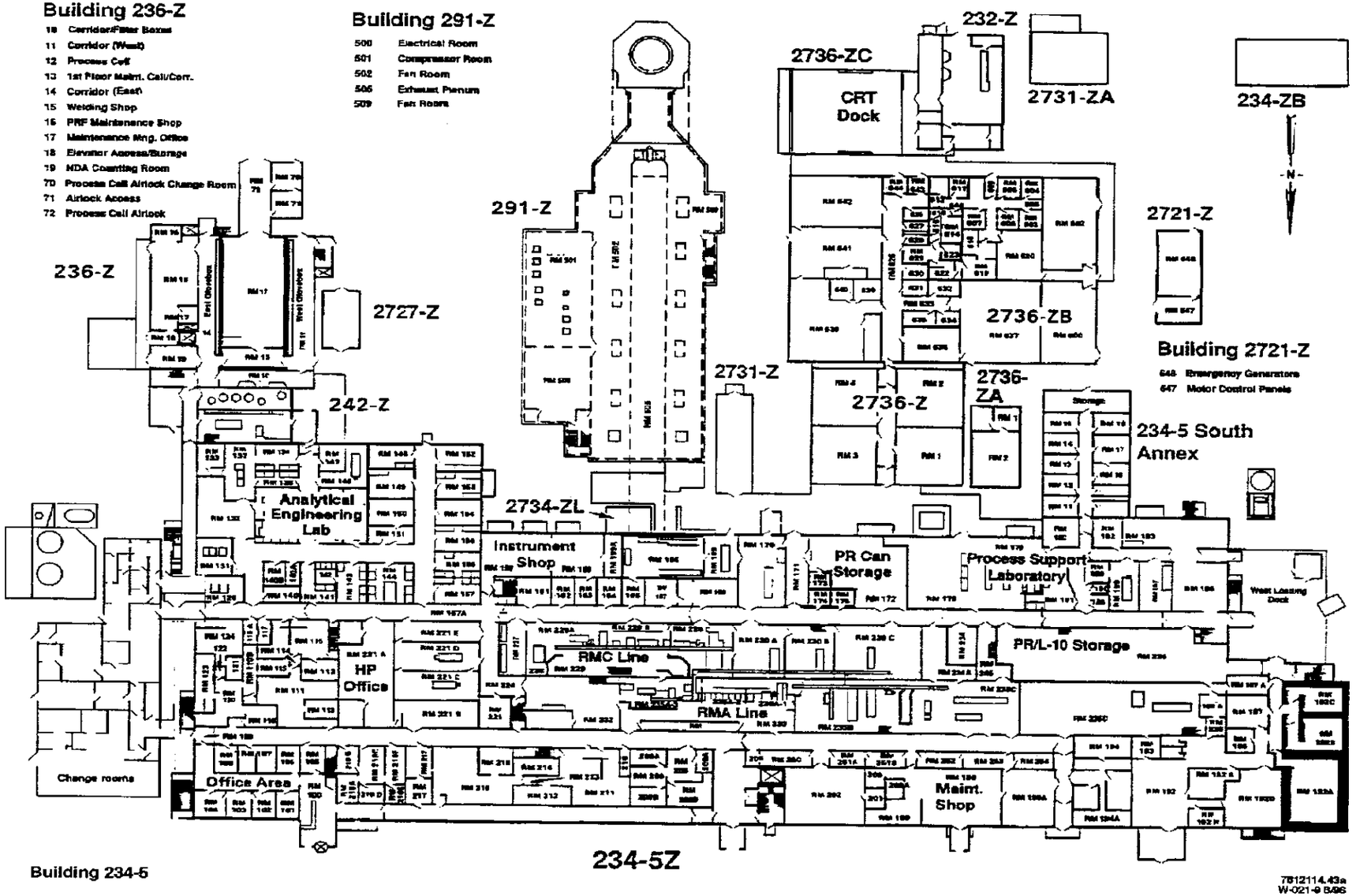
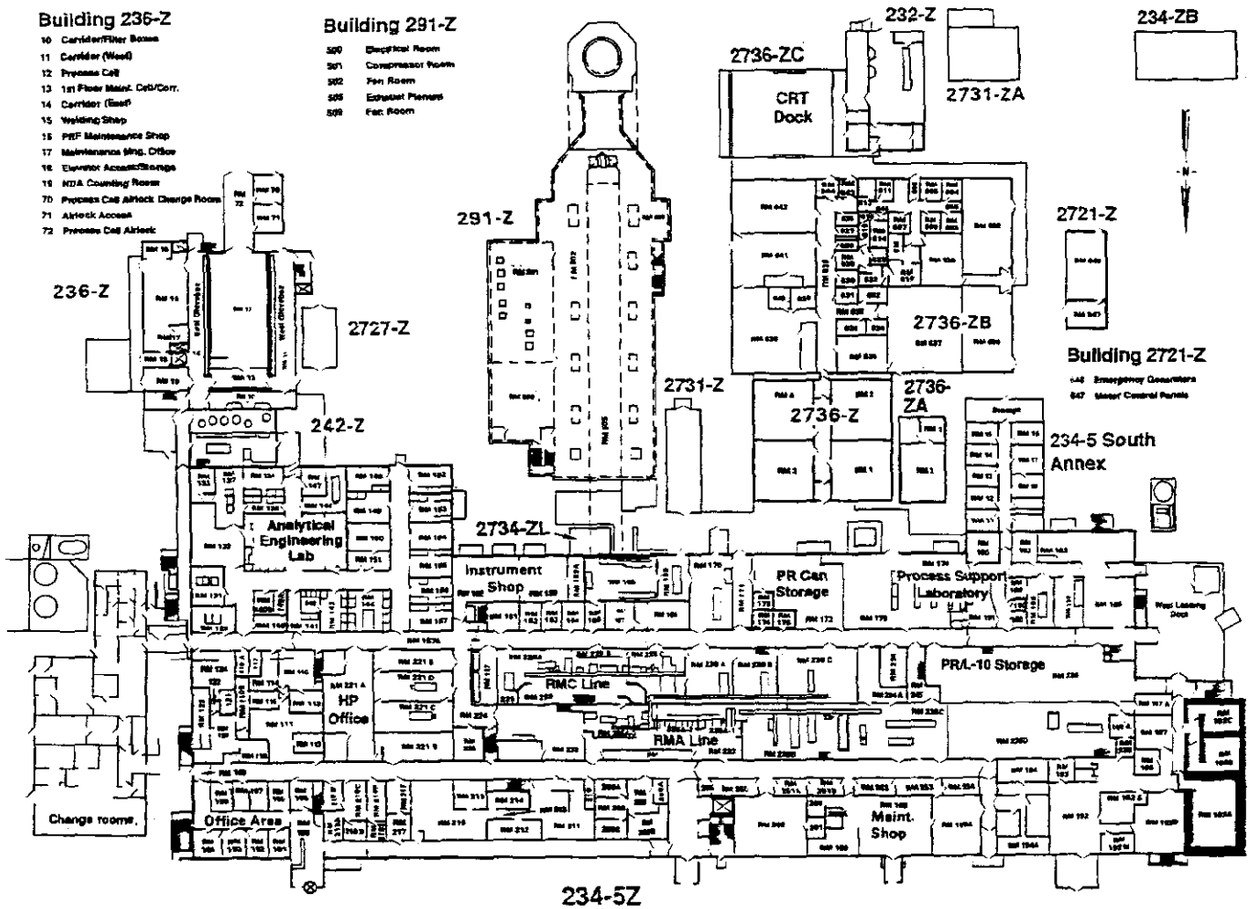


Figure 9-2. Plutonium Finishing Plant Floor Plans and Room Description. (Sheet 2 of 2)



Building 236-Z

10	Corridor/Filter Boxes
11	Corridor (West)
12	Process Cell
13	1st Floor Maint. Cell/Corr.
14	Corridor (East)
15	Welding Shop
16	PEF Maintenance Shop
17	Maintenance Mtg. Office
18	Elevator Access/Storage
19	NDA Counting Room
70	Process Cell Airlock Change Room
71	Airlock Access
72	Process Cell Airlock

Building 291-Z

500	Electrical Room
501	Compressor Room
502	Fan Room
505	Exhaust Plenum
509	Fan Room

Building 2736-ZB

600	Exhaust/Vacuum Pump
602	Supply Fans/Air Compressors
603	Manufacturing Engineer
604	Real Time Inventory
605	Adm. Specialist
606	Shift Support Manager
607	2736-ZB Manager
608	Entrance/Airlock
609	Corridor
610	Receptionist
611	Shift Manager
612	Water Heater
613	Janitor Closet
614	Womens Restroom
615	Airlock
616	Womens Change Room
617	Corridor
618	Mens Restroom
619	Mens Change Room
620	Lunch Room
621	Airlock
622	Change Room
623	UPS Room
624	Corridor
625	Corridor
626	Janitor Closet
627	Womens Restroom
628	Mens Restroom
629	Mendix
630	Decontamination Facility
631	RPT Office (DHP)
632	Applied Technology Chem.
633	Corridor
634	Shift Manager
635	Operator Ready Room
636	Repackaging Glovebox
637	HDA Lab
638	Packaging Room
639	Unpackaging Room
640	Supply Room
641	Receiving Room
642	Shipping Room
643	Personnel Entry Zone III
644	Material Passageway
645	Airlock

Building 2721-Z

646	Emergency Generators
647	Motor Control Panels

Building 234-5

100	Lobby/Receptionist	109	Airlock	116	Unused (Future Office Space)	122	Mass Spectrometry	141	Non Radioactive Solution Prep.	148	Sample Dissolution
100A	RADTU Filter Booth	110	Womens Locker Room	117	Unused (Future Office Space)	123	Dark Room	142	Misc. Storage	150	Lab Shift Manager
101	Office Space	110A	Womens Laundry Hookups	120	Womens Change Room	124	Mass Spectrometry Sample Prep.	143	Waste Process	151	Misc. Counting Room
102	Office Space	110B	Womens Locker Room	121	Womens Rest Room Zone III	125	Mass Spectrometry Sample Prep.	144	Process Support	152	Waste Compactor
103	Office Space	111	Unused (Future Office Space)	122	Airlock	126	Emission Spectroscopy	145	Physics Test	153	Product Specification Analysis
104	Surveillance Shift Office	112	Unused (Future Office Space)	123	Womens Change Room	127	Emission Spectroscopy	145A	Stock Room	154	Product Specification Analysis
105	Corridor/Hand and Foot Counters	113	Mens Restroom Zone I	124	Womens Locker Room	139	Pu Oxide Sample Rec./Storage	146	Radio Chemical Standards	155	UV/Infared Spectrophotometer
106	Office Space	114	Unused (Future Office Space)	125	Personnel Decontamination Room	140A	A Lab Support Services Mng.	147	Technical Support	156	Product Specification Analysis
107	Office Space	115	Unused (Future Office Space)	131	Plutonium Assay	140B	Lab Manager	148	Sample Dissolution	157	Product Specification Analysis
108	Office Space										

Building 234-5 (Continued)

158	Instrument Shop	218F	Pu Production Control Clerk
159	Instrument Shop	221A	OHP Office
159A	Instrument Storage	221B	HP Storage
161	RMC Shift Manager	221C	HP Storage
162	RMC Ready Room	221D	Radio Chem. Standards Lab
163	Maintenance Storage	221E	Radio Chem. Standards Lab
164	RMC Shift Office	224	Corridor
165	Calcium Storage	225	Analytical Labs Vault
166	RMC Bench Tests	227	Process Landings/Loadout
167	RMC Operations Storage	228	HC-7 Hood RMC-Line
168	Storage Ready Room RMC	228A	HC-6B Hood RMC-Line
169	Ash Classification Glovebox	228B	RMC Process Glovebox
170	Miscellaneous Treatment	228C	RMC Process HD/Storage
171	Corridor	229	RMC Control Room Zone I
172	PR Can Storage	230A	RMC Bastard Hood
173	Maintenance Storage	230B	RMC Scrap Oxidor HD
174	SNM Storage Vault	230C	Hydrolyser Glovebox
175	SNM Storage Vault	232	HF Scrub
176	Process Support Lab Glovebox	233	RMA-Line Control Room Zone II
180	Metallic Research	234	Trash Compactor
182	Process Support Lab Microscope	234A	HDA Drum Counting
183	Specialized Processing	235	Airlock
185	Misc. Storage	235A-1	RMA Button Line (Layaway)
187	Lab Open Feed Hoods	235A-2	RMA Button Line (Layaway)
188	Lab Glovebox/Chem. Storage	235A-3	RMA Oxide Line (Layaway)
189	Equipment Storage	235B	Furnaces/Storage Gloveboxes
190	Radioactive Material Storage	235C	Waste Repackaging
191	Process Support Cold Lab	235D	Radio Gloveboxes (Layaway)
192	Drum Staging Area	236	PR/L-10 Storage Vault
192S	Storage	245	Corridor to Room 235C
192N	NDA Storage	250	Office Space
192A	SNM Storage Vaults	251	Office Space
192B	SNM Storage Vaults	251A	Office Space
192C	SNM Storage Vaults	252	Office Space
192D	PR Can Storage	253	Office Space
193	Airlock	254	Office Space
194	Storage Vault (Layaway)		
194A	Material Coordinator		
196	Waste Drum Storage		
197	Waste Drum Storage		
197A	Radioactive Mixed Waste Storage		
198	Maintenance Shop Zone I		
199	Welding Room		
200	Maintenance Lockers		
200A	Maintenance Manager		
201	Pu Process Support, Vault		
202	Pu Process Support Lab		
205	Support Lab Engineer		
208	Work Authorization System		
209	Office Space		
209A	Office Space		
209B	Office Space		
209	Office Space		
209A	Office Space		
209B	Office Space		
210	Material Control Area		
211	Material Control Area		
212	Material Control Area		
213	Material Control Area		
214	Material Control Area		
215	Material Control Area		
216	Material Control Area		
217	Assay/Seal Lab Manager		
216A	Maintenance Group Manager		
216B	Maintenance Secretary		
216C	Maintenance Shift Manager		
216D	Maintenance Day Shift Manager		
216E	Pu Production Control Manager		

Building 2736-ZA

1	Emergency Diesel Generator
2	Exhaust Fans/Filters

Building 2736-Z

1	Scrap/Product, Feed Pack Cans
2	Land Cans/Cubical Storage
3	Scrap/Product, Feedpack Cans
4	Scrap/Product, Feedpack Cans

Building 234-5 South Annex

11	Plutonium Process Support Office
12	Plutonium Process Support Office
13	Plutonium Process Support Office
14	Plutonium Process Support Office
15	Plutonium Process Support Office
16	Plutonium Process Support Office
17	Plutonium Process Support Office
18	Plutonium Process Support Office
19	Male Rest Room
20	Womens Rest Room

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Figure 9-3. Center of Building 234-5Z Floor Plan-
Remote Mechanical A and C Line Layout.

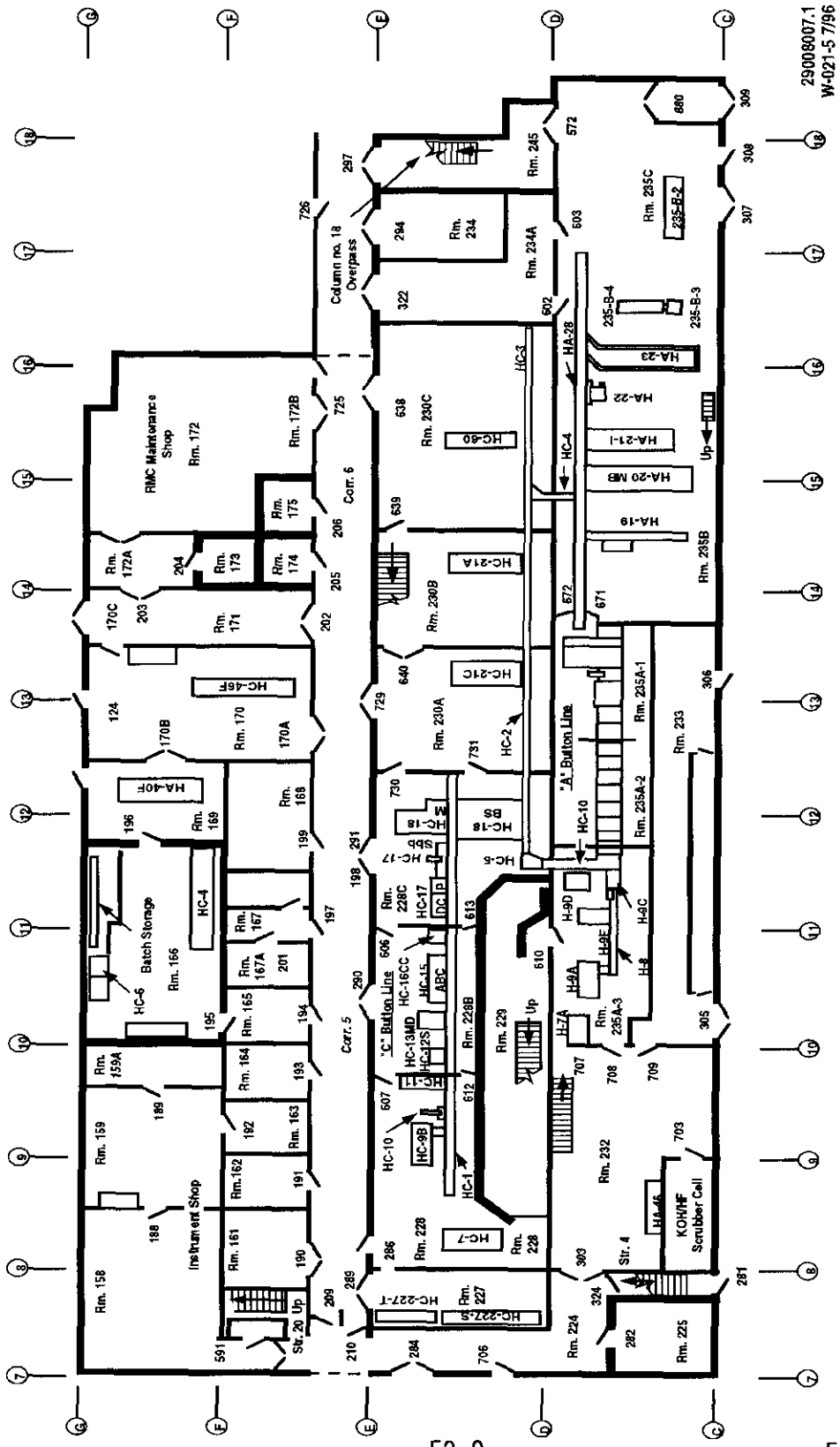


Figure 9-4. Floor Plans, Building 236-Z.

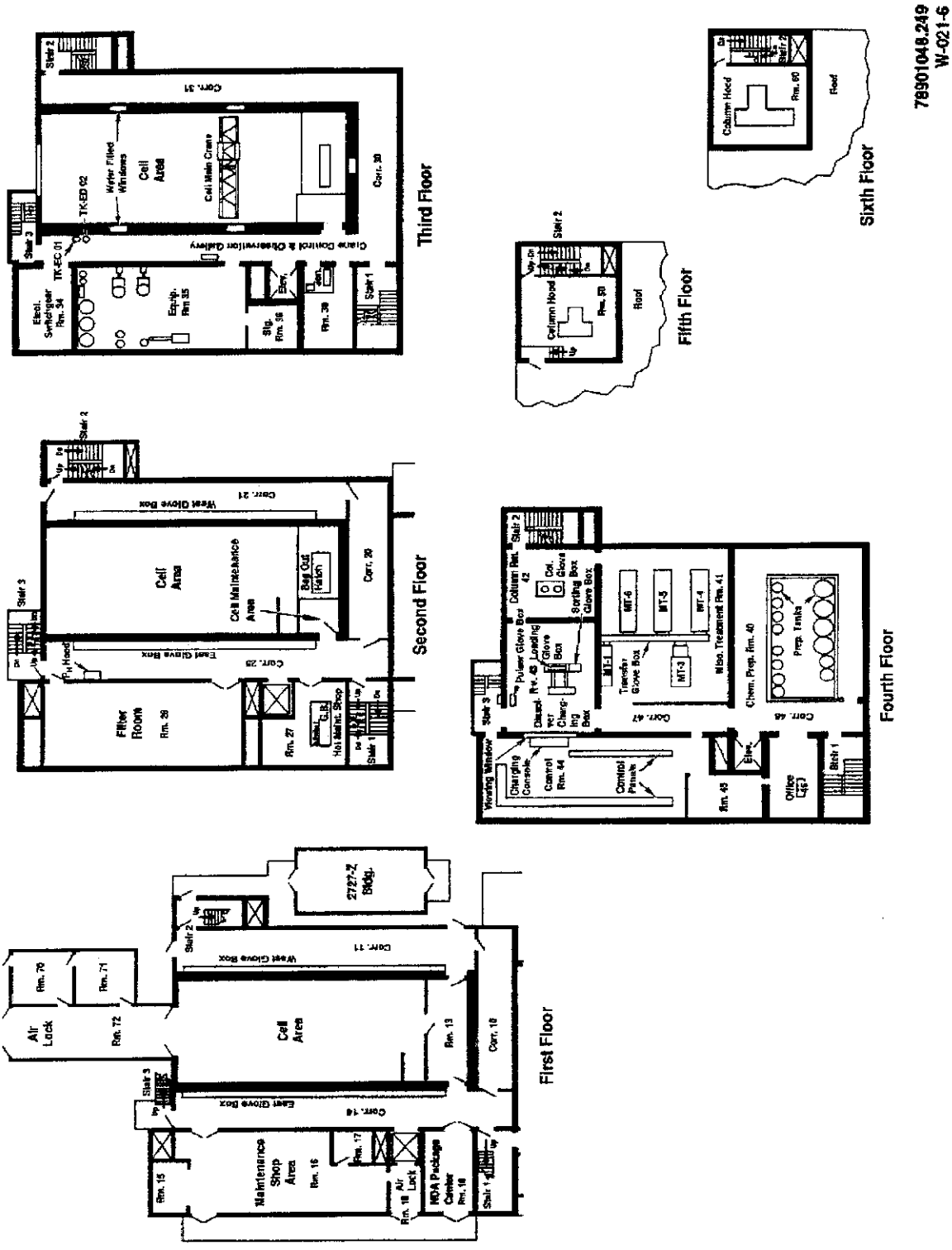


Figure 9-5. Plutonium Finishing Plant Looking South, September 1993.

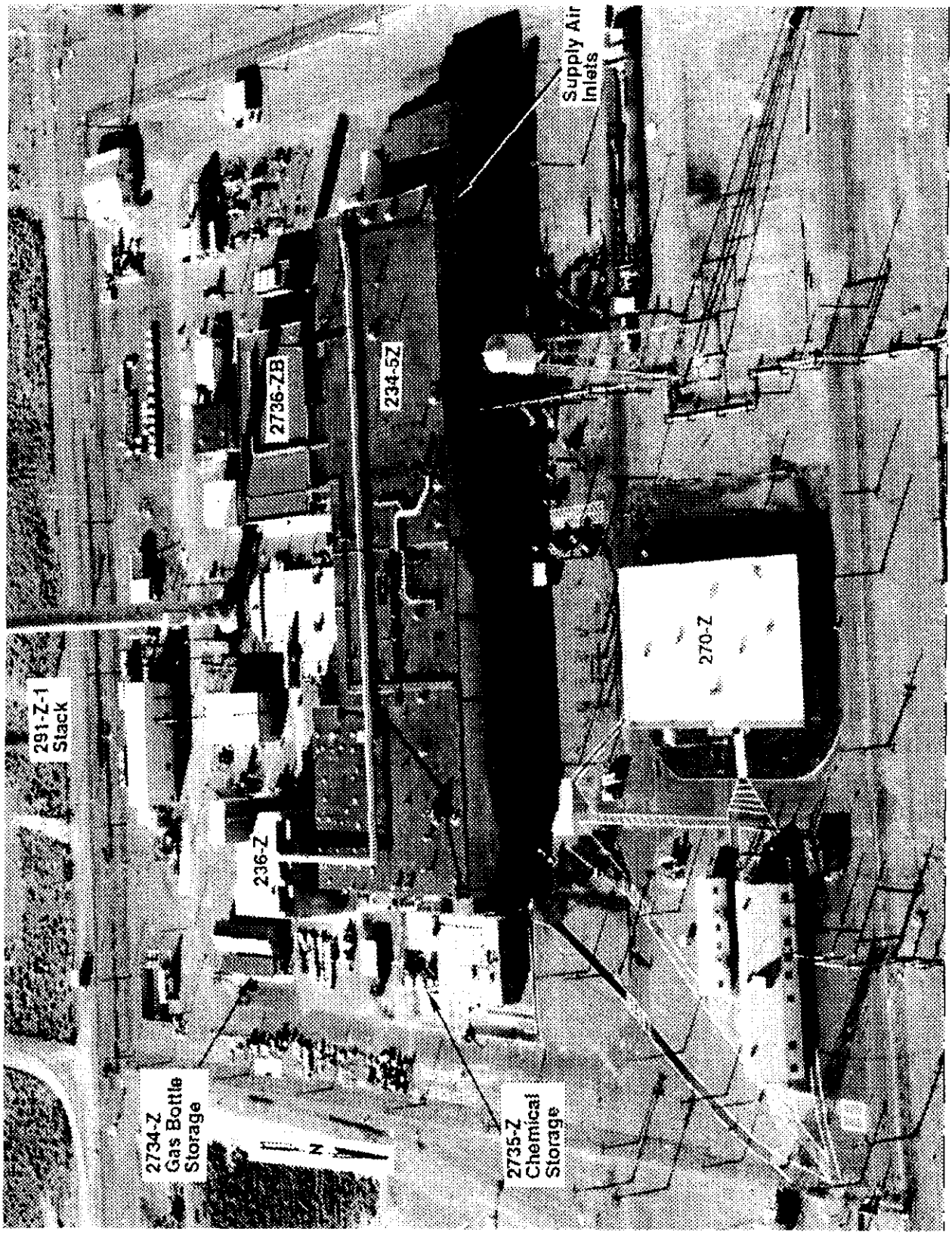


Figure 9-6. Plutonium Finishing Plant Looking Northeast, September 1993.

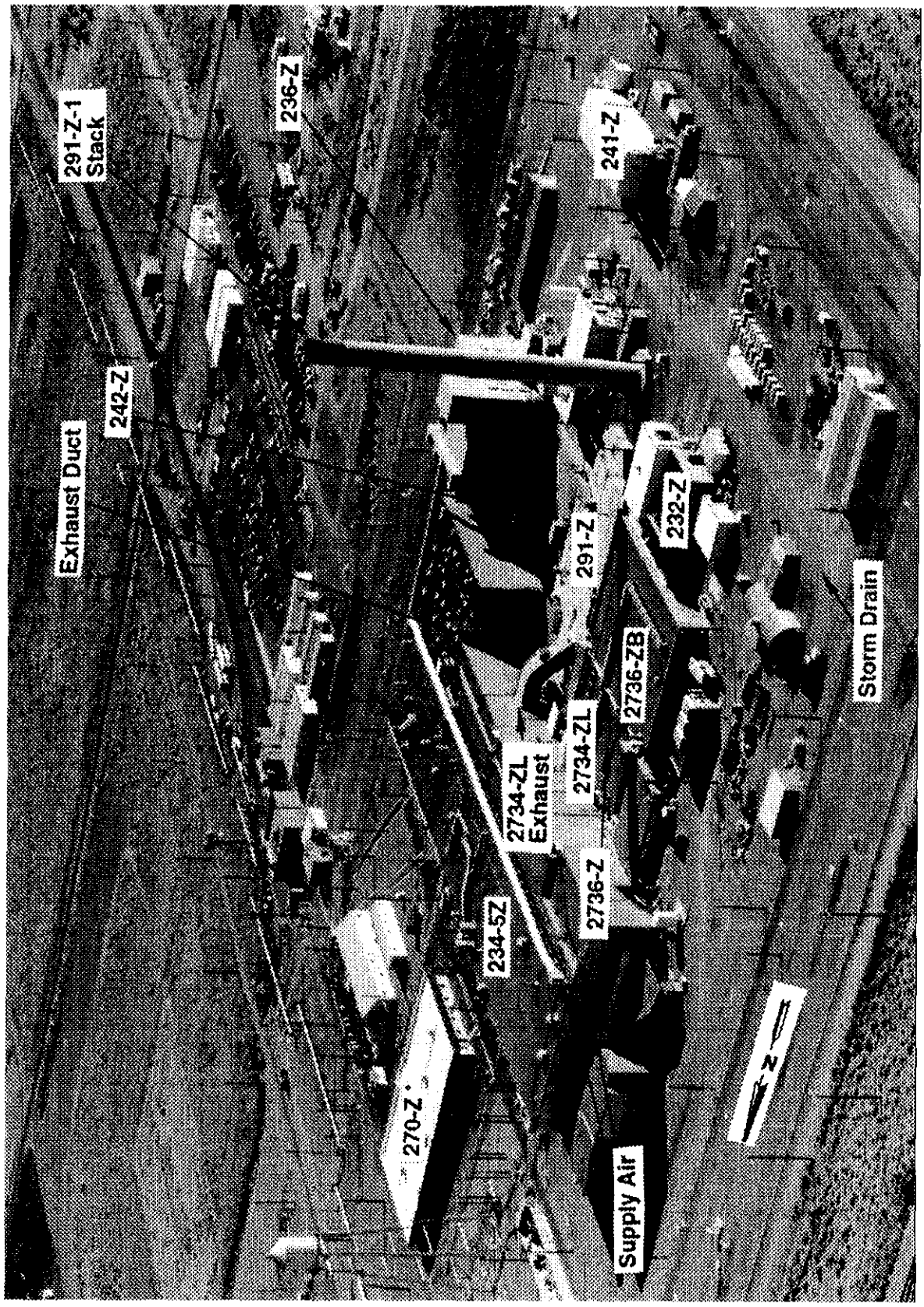


Figure 9-7. Ventilation Air Pressure Profile
in Passage through Building Zone 3.

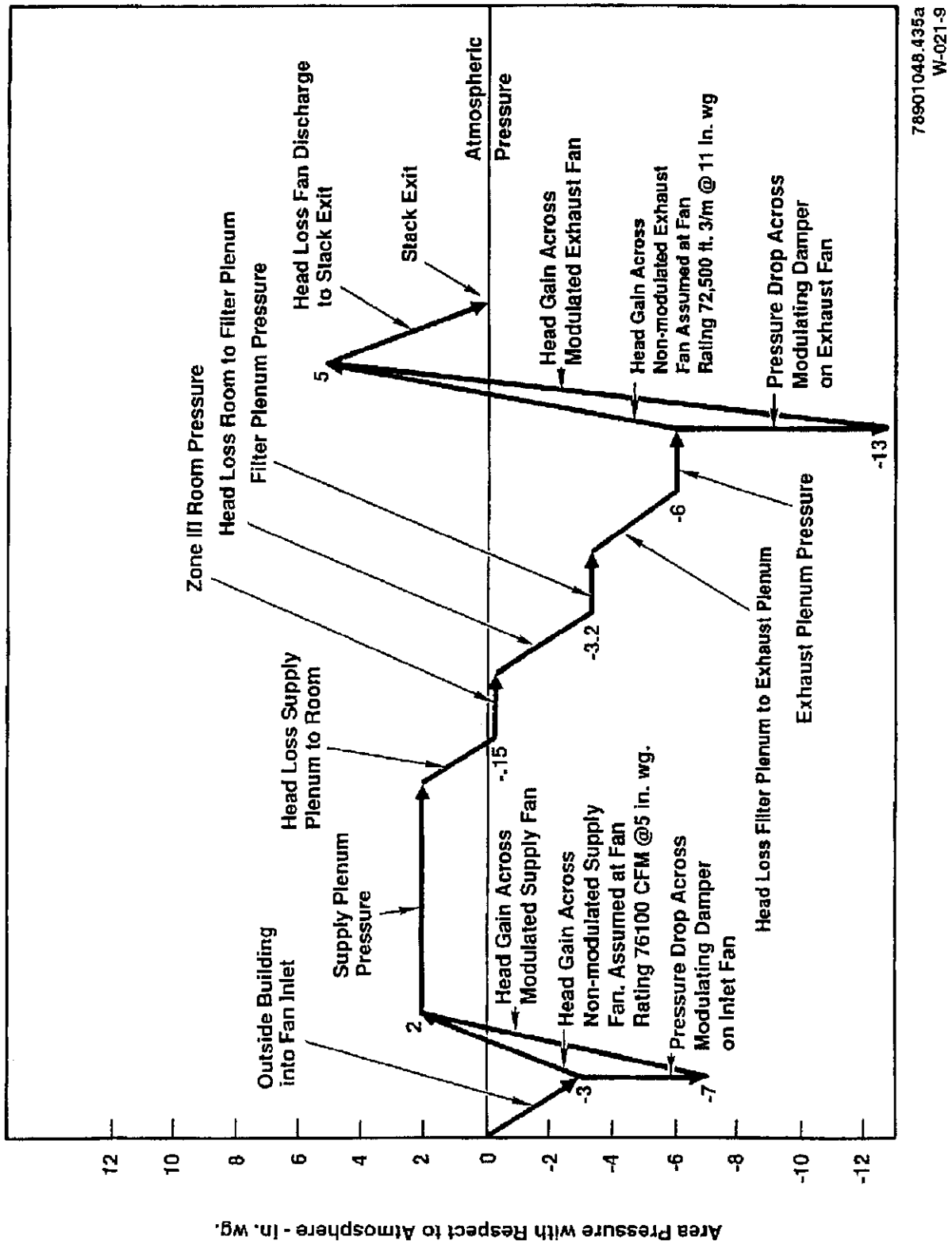


Figure 9-8. Analog of 234-5Z Building Airflow.

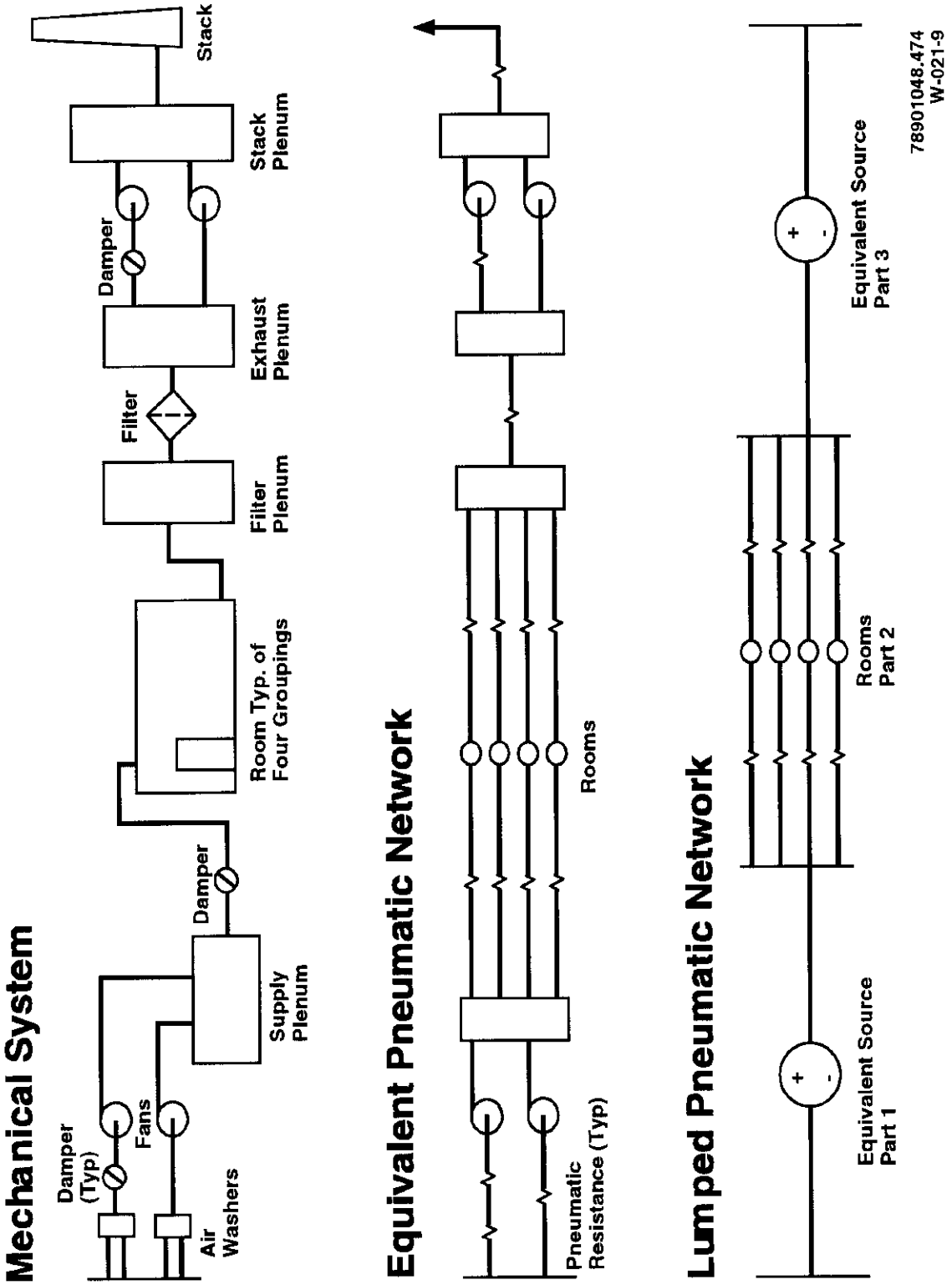
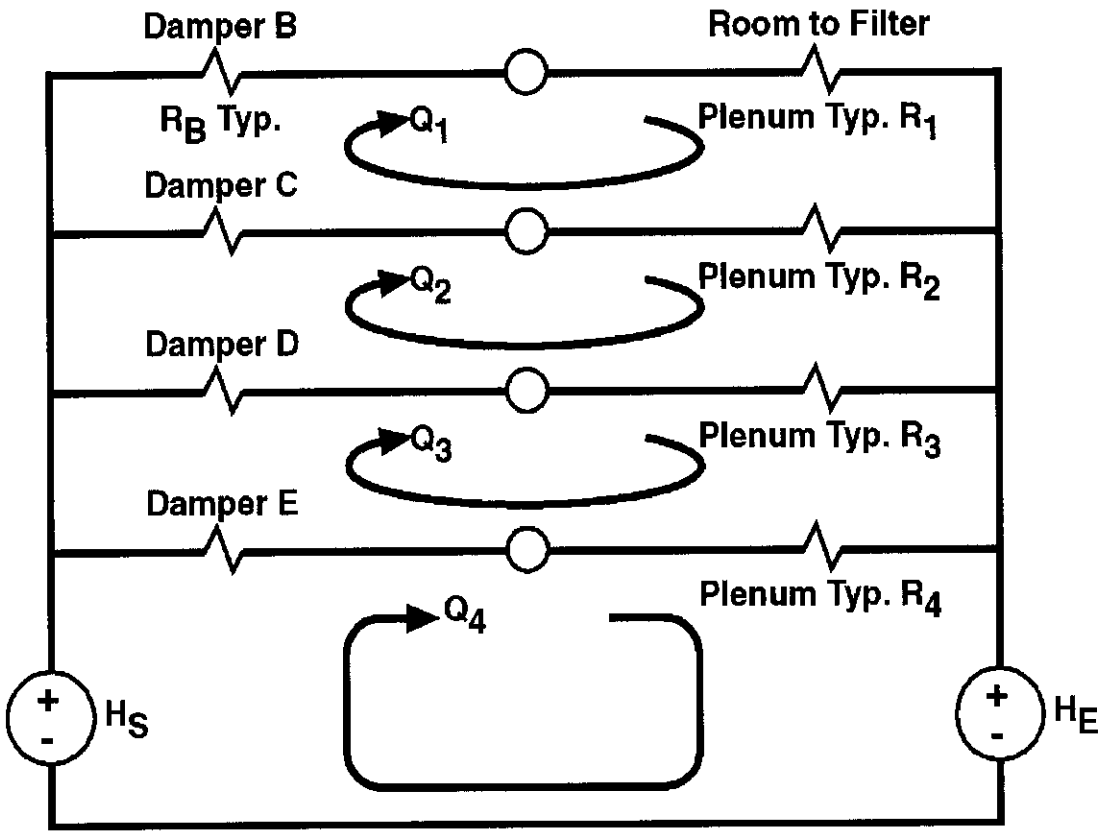


Figure 9-9. Building Equivalent Network, Building 234-5Z.



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Figure 9-10. Building Equivalent for Supply.

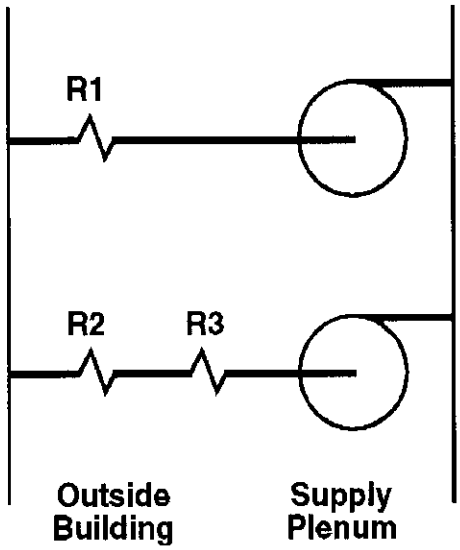
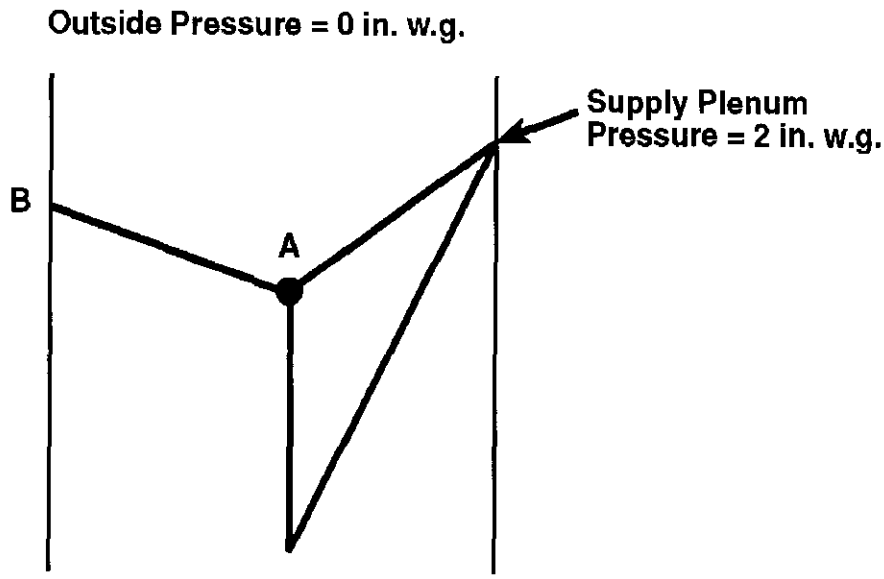


Figure 9-11. Supply Side Pneumatic Performance.



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Figure 9-12. Simplified Exhaust System for Building 234-5Z.

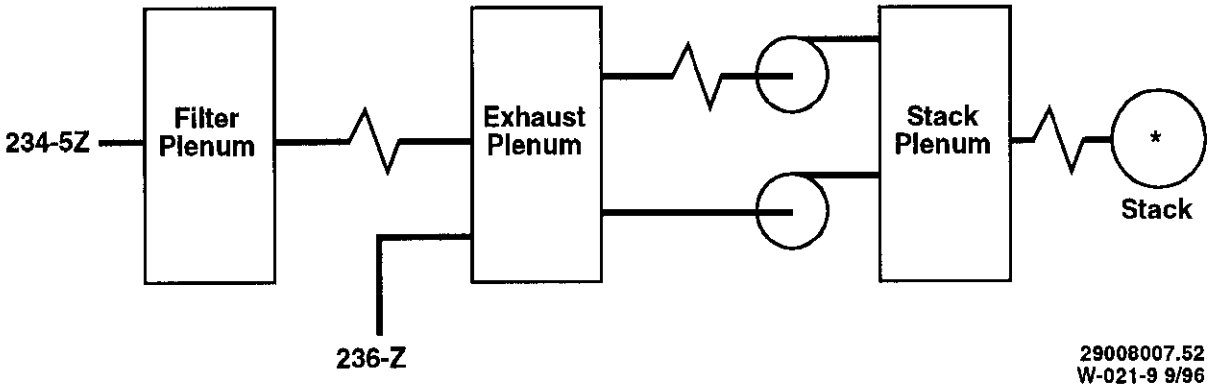


Figure 9-13. Pressure Profile through the Exhaust System.

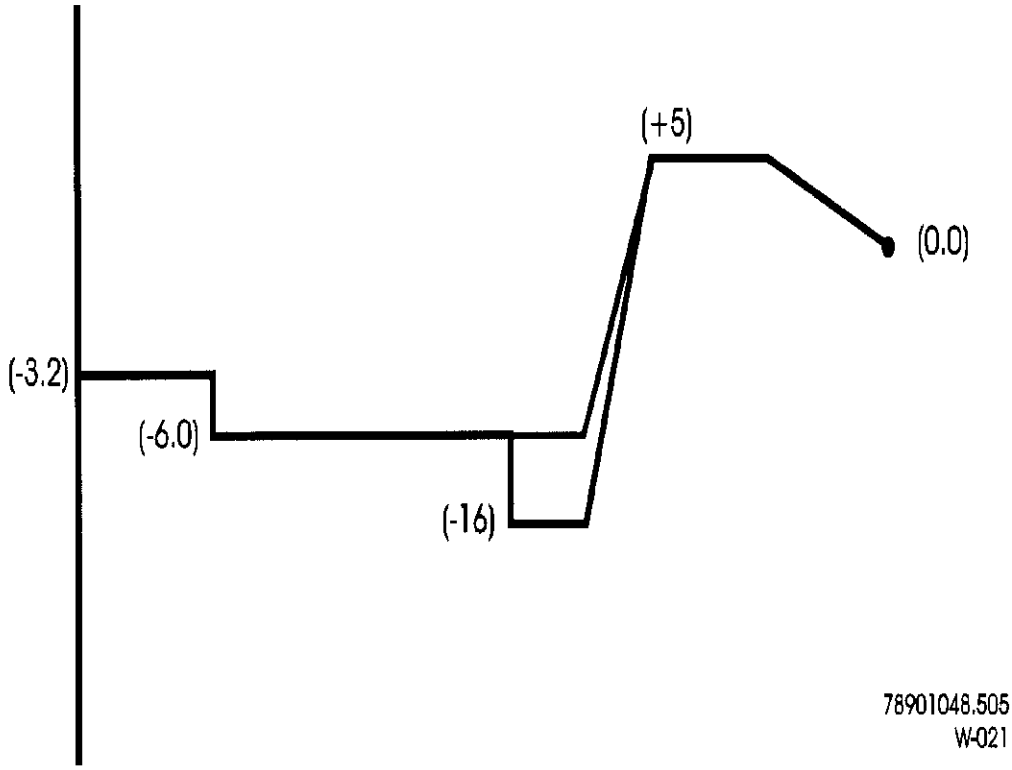


Figure 9-14. Airflow Through Building 236-Z.

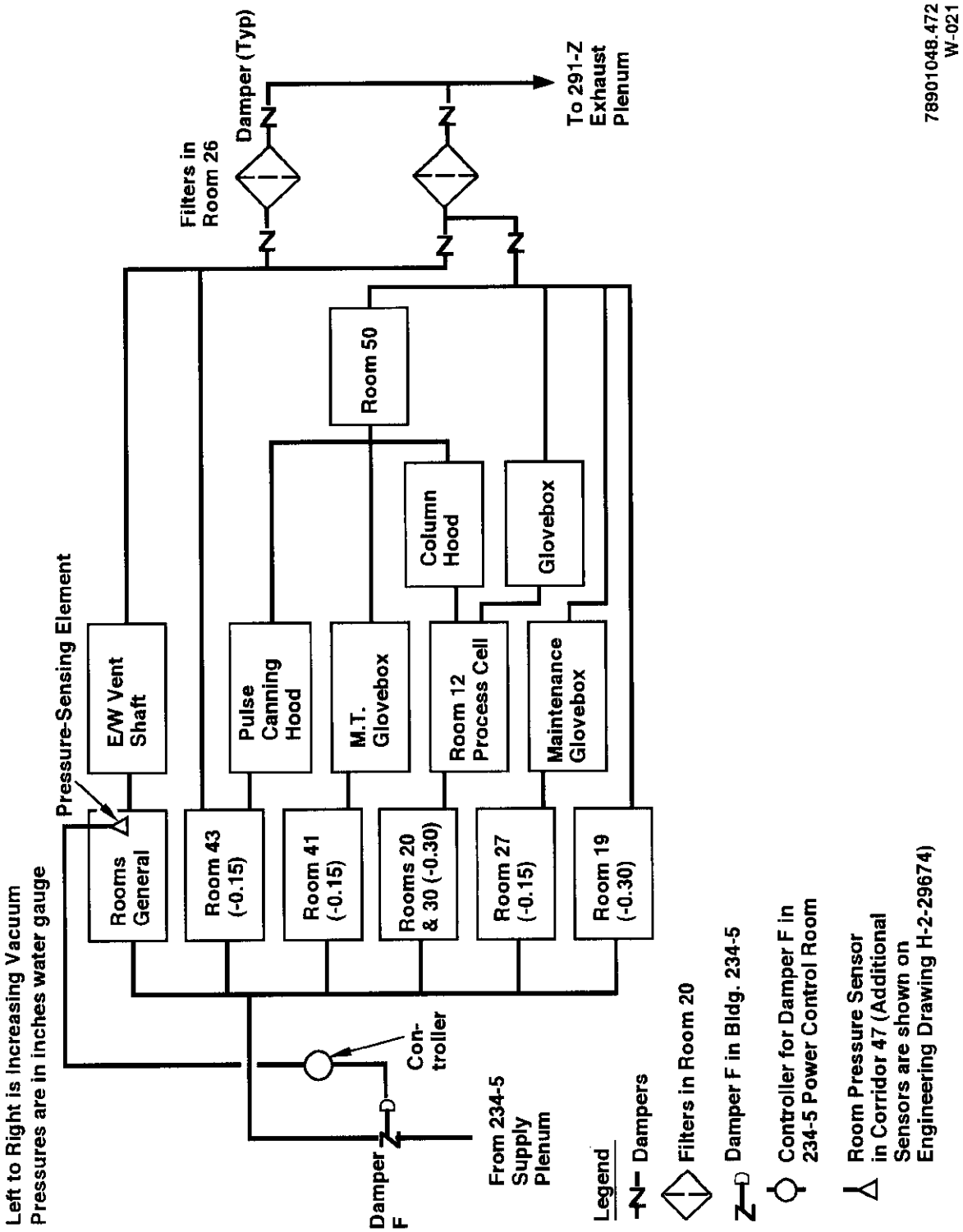


Figure 9-15. Model of Airflow Through Building 236-Z.

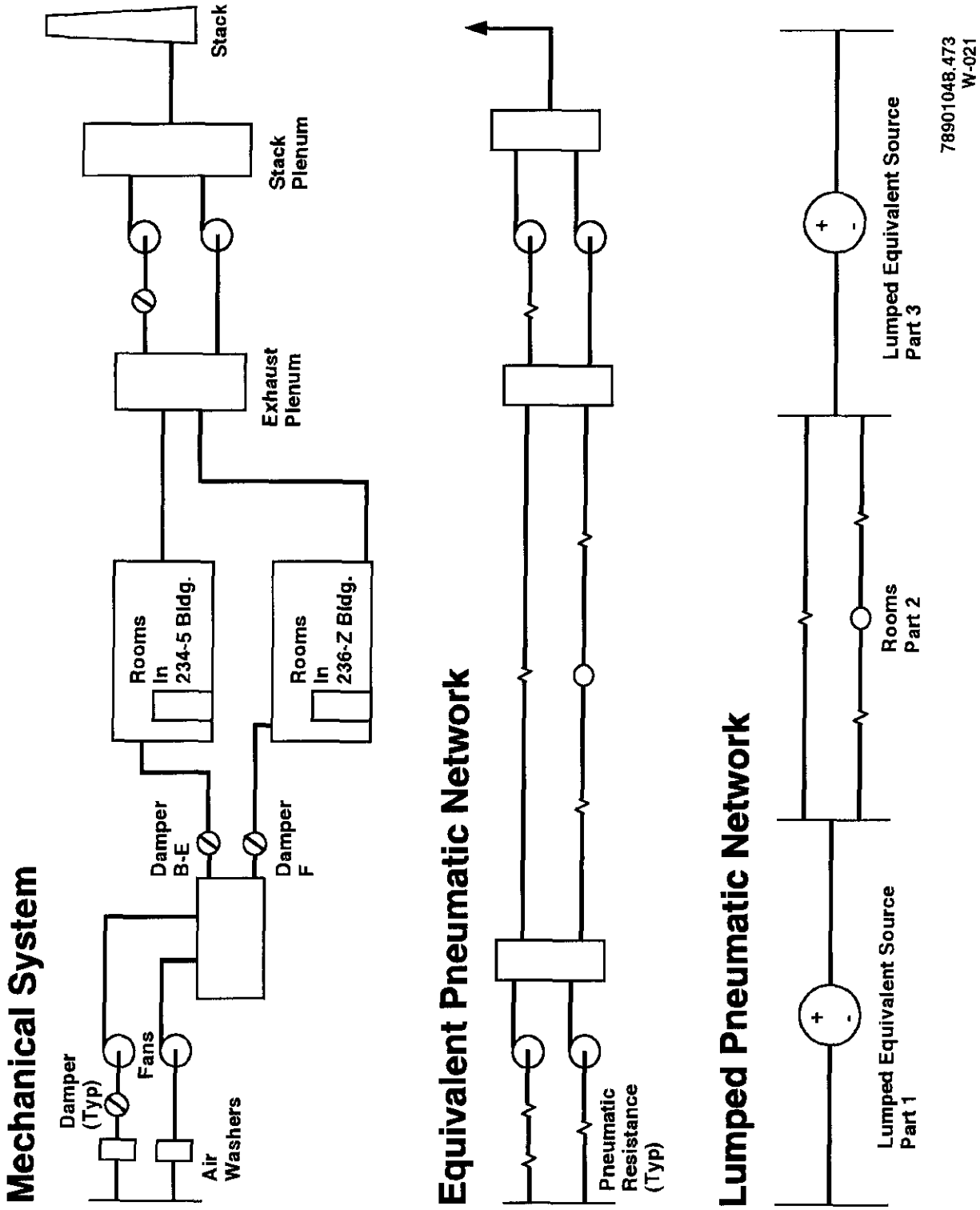
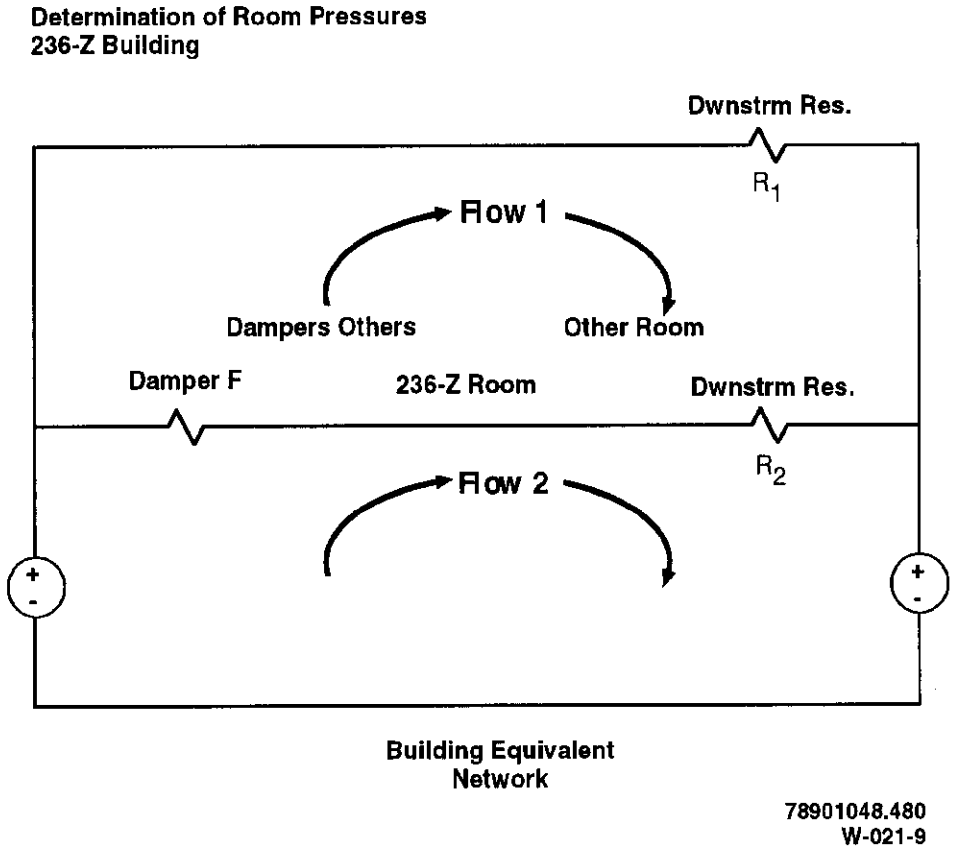


Figure 9-16. Building Equivalent Network, Building 236-Z.



SYSTEM DESCRIPTION

Air flow in the facility will be controlled to flow from the less contaminated areas to the more contaminated areas. The facility is divided into the following zones:

Zone	Reference Point	Pressure	Symbol
I	Repackaging Room	(-)1.2 in WG (Glovebox) (-)0.5 in WG (Airlock)	
II	Atmosphere	(-)0.25 in WG	
III	Atmosphere	(-)0.10 in WG	
IV	Atmosphere	(+)0.05 in WG	

ZONE PRESSURE CONTROL

Zone I glovebox pressure is controlled, during normal operation conditions, by manually setting air supply flow rate to the glovebox and modulating the exhaust air flow. PX-4 senses glovebox pressure with respect to the repackaging room, sends a signal to DPC-4 which compares the signal to the set point, (-)1.2 in WG, and modulates D-58 to maintain glovebox pressure. Glovebox pressure can be manually controlled by placing switch MS-4 in the manual position. This activates EV-25 which locks out DPC-4. D-58 can then be controlled from MC-4 to regulate glovebox pressure. To prevent positive pressure in the glovebox, DPS-1 is provided to sense glovebox pressure. Should pressure in the glovebox rise to (-)0.25 in WG, DPS-1 signals EV-23 to close. Also at this condition, an alarm annunciates at the 234-5Z Power Control Room, and the system can then be manually controlled. EV-23 is manually opened (reset) after conditions stabilize. DPS-1A signals EV-23A to close. Glovebox pressure is indicated on MC-4. Glovebox pressure is also indicated on local DPT's that are furnished with the glovebox. Zone pressure is recorded on DPR-4.

Zone II Main Support Area (Room 636) pressure is controlled by modulating the supply air to the zone and maintaining constant exhaust flow. PX-2 senses zone pressure with respect to the atmosphere, sends a signal to DPC-2 which compares the signal to set point, (-)0.25 in WG, and modulates D-3 to maintain zone pressure. Zone pressure can be manually controlled by placing switch MS-2 in the manual position. This activates EV-26 which locks out DPC-2. D-3 can then be controlled from MC-2 to regulate zone pressure. Should zone pressure rise to (-)0.05 in WG, an alarm will annunciate on the 234-5Z Power Control Room panel. The system shall be manually controlled until conditions stabilize. Zone pressure is indicated on MC-2 and is recorded on DPR-2.

Zone II NDA Lab (Room 637) pressure is controlled by synchronizing the return and supply air volumes. The return air volume is maintained at constant value by FC-1 which senses velocity pressure from AFM-2 and modulates either RF-1 or RF-2 inlet dampers. FC-1 also signals FC-2, which will adjust the supply air volume (SF-3, SF-4) to match changes in the exhaust volume and also maintain zone pressure. The zone pressure is sensed by PX-3 which sends a signal to DPC-3, and should zone pressure rise to (-)0.10 in WG, PS-8 sends a signal to EV-24A causing DPC-3 to override FC-2 to reduce supply volume to maintain zone pressure. As zone pressure stabilizes, DPC-3 allows FC-2 to return to normal operation.

Should zone pressure rise to (-)0.10 in WG, an alarm will annunciate in234-5Z Power Control Room Panel. The system shall be manually controlled by placing switch MS-3 in the manual position. This activates EV-24 which locks out DPC-3 and FC-2. SF-3 or SF-4 inlet Dampers can then be controlled from MC-3 to regulate zone pressure. Zone pressure is indicated on MC-3 and is recorded on DPR-3.

Radiation Monitoring Equipment samples the return air from the NDA Lab. When readings exceed allowable limits, the system diverts to a once through system. (See System Interlocks description below for damper opening and closing sequence).

Zone III Mechanical Room exhaust pressure is controlled by manually adjusting D-20 to obtain required zone pressure. Zone pressure is indicated on DPI-34.

Zone IV pressure is controlled by modulating the supply air volume to the zone. PX-1 senses zone pressure with respect to the atmosphere, sends a signal to DPC-1 which compares the signal to set-point, (+)0.05 in WG, and modulates D-5 to maintain zone pressure. Should zone pressure drop to 0.00 in WG, an alarm will annunciate on the 234-5Z Power Control Room Panel. Zone pressure can be manually controlled by placing switch MS-1 in the manual position. This activates EV-27, which locks out DPC-1. Damper D-5 can then be controlled from MC-1 to regulate zone pressure. The system shall be manually controlled until conditions stabilize. Zone pressure is indicated on MC-1 and is recorded on DPR-1.

FAN STATIC PRESSURE CONTROL

Supply and exhaust air flow (SF-1, SF-2, EF-1, EF-2) is controlled by maintaining constant pressure in the Supply or Exhaust Plenums. PC-1A senses Supply Plenum pressure with respect to atmosphere, sends a signal to PC-1 which compares the signal to the set-point, (+)2.0 in WG, and modulates either SF-1 or SF-2 inlet Dampers. Exhaust Plenum pressure is controlled in a similar manner by PC-2A and PC-2. Set-point is (-)4.5 in WG. During manual control modes, the Exhaust Plenum pressure can be changed manually by placing switch MS-5 in the manual position. This activates EV-28 which locks out PC-2. Either EF-1 or EF-2 Inlet Dampers can then be controlled from MC-5 to regulate Exhaust Plenum pressure.

MAIN SUPPORT AREA SYSTEM AUTOMATIC FAN CONTROLS

- Place Selector Switch MS-LL-3 for Exhaust Fans to EF-1 or EF-2.
- Place Selector Switch MS-LL-1 for Supply Fans to SF-1 or SF-2.
- Press Main Support Area Start Button. The selected Exhaust Fan starts. EV-21 will open allowing instrument air to all controls associated with the Main Support Area System. After selected Exhaust Fan produces acceptable Exhaust Plenum pressure (sensed by DPS-2) the selected Supply Fan will automatically start.
- Start up of the selected Exhaust Fan activates EV-12 or EV-14 to allow the Outlet Isolation Damper, D-13 or D-14, to open. Also, EV-11 or EV-13 is activated to allow PC-2 to control the operating fan's Inlet Vane Damper. A similar sequence happens on start up of the Supply Fan with EV-2, EV-3, D-2, D-4, EV-1, EV-4 and PC-1.
- With Exhaust Fan EF-1 operating, EF-2 is on standby. Loss of EF-1 is sensed by FS-5 which alarms at the 234-5Z Power Control Room Panel. The HVAC Computer signals EF-2 to start. EV-14 is activated to allow D-14 to open. EV-13 is activated to allow PC-2 to operate EF-2 Inlet Damper. Shutdown of EF-1 deactivates EV-12 to allow D-13 to close and deactivates EV-11 to prevent EF-1 Inlet Damper operation by PC-2. The interlock sequence is similar if EF-2 is operating and EF-1 is on standby.

SYSTEM INTERLOCKS (See drawings H-2-80141, H-2-80142, H-2-80169 for interfaces to Computerized Control System)

- During failure of the operating Exhaust Fan and startup of the standby Exhaust Fan, the operating Supply Fan continues to operate as long as DPS-2 senses Plenum Static Pressure above it's set-point. Should Exhaust Plenum pressure drop below the DPS-2 set-point, the operating Supply Fan is shut down. When Exhaust Plenum pressure reaches DPS-2 set-point, the Supply Fan will restart.
- With Supply Fan SF-1 operating, SF-2 is on standby. Loss of SF-1 is sensed by FS-1 which alarms at 234-5Z Power Control Room Panel. SF-2 is started automatically by the HVAC Computer. Loss of SF-1 deactivates EV-2 to allow Damper D-2 to close, deactivates EV-1 to prevent SF-1 Inlet Damper operation by PC-1. Startup of SF-2 activates EV-3 to allow Damper D-4 to open and activates EV-4 to allow PC-1 to operate SF-2 Inlet Damper. The interlock sequence is similar if SF-2 is operating and SF-1 is on standby.
- Fans SF-1, SF-2, EF-1 and EF-2 can also be operated in hand control mode.

GLOVEBOX DRY AIR SYSTEM

Compressors AC-1 and/or AC-2 are manually started and they cycle on and off to maintain Receiver Air pressure. Pressure Switches PS-9 and PS-10 start AC-1 or AC-2 at 85 psig and stop the compressions at 105 psig.

EV-23 is interlocked with Exhaust Fans EF-1 and EF-2, and will close on loss of the exhaust fans.

NDA LAB AUTOMATIC FAN CONTROLS

- Place selector switch MS-LL-4 for Return Fans to RF-1 or RF-2. Place selector switch MS-LL-2 for Supply Fans to SF-3 or SF-4.
- Press NDA auto-start button. The selected Return Fan starts, EV-20 will open, allowing instrument air to all controls associated with the NDA Lab system. After the selected Return Fan is running, the selected Supply Fan automatically starts. Start up of the Return and Supply Fans activates EV-15, EV-16, EV-17, EV-18, EV-5, EV-6, EV-7, EV-8 and Dampers D-15, D-16, D-8 and D-9 in a similar manner as described previously for Fans EF-1, EF-2, SF-1, SF-2.
- Radiation Monitoring equipment samples the return air from NDA Lab. When readings exceed allowable limits, an alarm annunciates at the 234-5Z Power Control Room Panel and also activates EV-10 to allow Dampers D-17 to open, D-6 to open and D-10 to close. After radiation levels recede, EV-19 is manually reset to place the system back into a recirculating operation mode.
- RF-1, RF-2, SF-3 and SF-4 are interlocked to start the Standby Fan when the Operating Fan fails (similar to EF-1, EF-2, SF-1 and SF-2) an alarm annunciates at 234-5Z Power Control Room if an operating Supply or Return Fan fails.
- Fans SF-3, SF-4, RF-1 and RF-2 can also be operated in hand control mode.

GENERAL CONDITIONS

- Fans SF-1, SF-2, EF-1, EF-2, SF-3, SF-4, RF-1, RF-2, SF-5 and SF-6 are equipped with manual override start-stop stations located on the 234-5Z Power Control Room Panel board. Hand controls are also located at the Motor Control Center in Mechanical Room 602 of 2736-ZB. Running lights and ammeters are located at the 234-5Z Power Control Room Panel.
- Fans SF-1, SF-2, EF-1, EF-2, SF-3, SF-4, RF-1, RF-2, SF-5 and SF-6 are connected to emergency power. If loss of power to the Operating Fan occurs, emergency power will automatically start the Standby Fan. The Instrument Air Compressor is also connected to emergency power.

ALARMS

- Alarms are provided for the following functions:

Supply Fan SF-1 loss of pressure
Supply Fan SF-2 loss of pressure
Supply Fan SF-3 loss of pressure
Supply Fan SF-4 loss of pressure
Supply Fan SF-5 loss of pressure
Supply Fan SF-6 loss of pressure
Exhaust Fan EF-1 loss of pressure
Exhaust Fan EF-2 loss of pressure
Exhaust Fan RF-1 loss of pressure
Exhaust Fan RF-2 loss of pressure
Zone I Glovebox pressure off normal
Zone II Process Area pressure off normal
Zone II NDA Lab pressure off normal
Zone IV Administration Area pressure off normal
NDA Lab CAM high alarm
Loss of 2736-ZB instrument air

FIRE ALARM SYSTEM INTERLOCKS

The following table indicates mode of operation for Supply and Exhaust Fans when a fire alarm energizes:

Alarm Location	SF-1 SF-2	SF-3 SF-4	RF-1 RF-2	EF-1 EF-2	Dry Air System
NDA Lab	Off	Off	On	On	Off
Glovebox	Off	Off	Off	On	Off
Zone II Main Support Area	Off	On	Off	On	Off
Zone IV Main Support Area	Off	On	Off	On	Off
Mechanical Room 606	Off	Off	Off	On	Off
Mechanical Room 602	Off	Off	Off	On	Off
Generator Building	On	On	On	On	On

SYSTEM TEMPERATURE CONTROLS

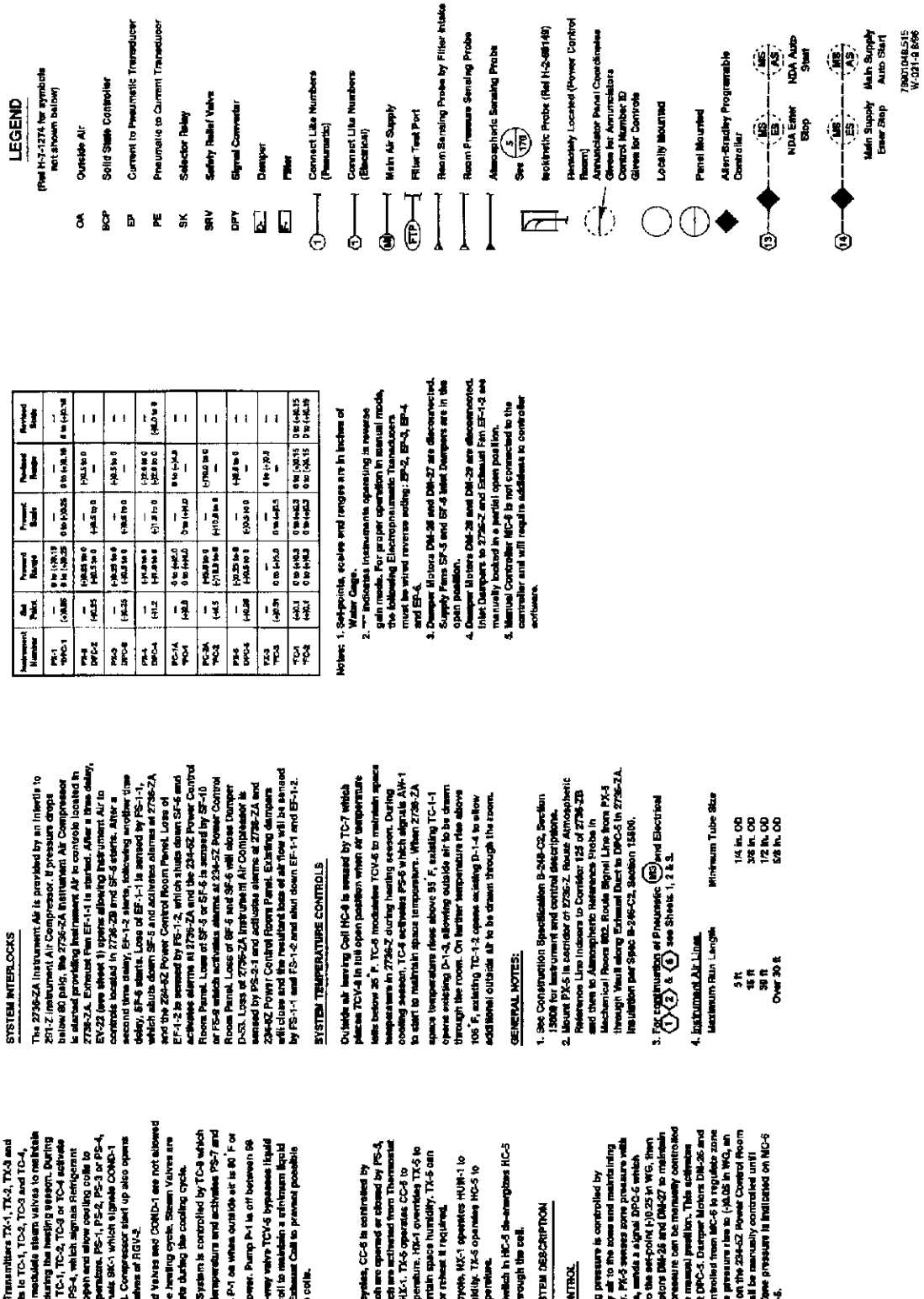
Main Support Area System:

- Outside air leaving HC-7 is sensed by TC-8 which places TCV-7 in full open position when temperature falls below 35°F.

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Figure 9-17. Heating, Ventilation, and Air Conditioning Control Diagram, Building 2736-ZB. (Sheet 1 of 5)
(for reference only - for current information, see appropriate facility drawings)

Figure 9-17. Heating, Ventilation, and Air Conditioning Control Diagram, Building 2736-ZB. (Sheet 2 of 5)
(for reference only - for current information, see appropriate facility drawings)



Instrument Number	Set Point	Present Range	Present Scale	Ranbout Range	Ranbout Scale
PX-1 TPCV-1	— (>0.05)	0 to (+)0.10 0 to (+)0.25	— 0 to (+)0.25	— 0 to (+)0.10	— 0 to (+)0.10
PX-5 DPC-2	— (-)0.25	(+)0.05 to 0 (+)0.25 to 0	— (+)0.5 to 0	— (+)0.1 to 0	— —
PX-5 DPC-5	— (-)0.25	(+)0.05 to 0 (+)0.25 to 0	— (+)0.25 to 0	— (+)0.1 to 0	— —
PX-4 DPC-4	— (+)1.2	(+)1.4 to 0 (+)1.4 to 0	— (+)1.2 to 0	(+)2.4 to 0 (+)2.4 to 0	— (+)2.4 to 0
PS-1A TPCV	— (+)0.3	0 to (+)0.5 0 to (+)0.5	— 0 to (+)0.5	0 to (+)0.5 —	— —
PC-2A TPCV	— (+)4.5	(+)0.5 to 0 (+)10.0 to 0	— (+)10.0 to 0	(+)10.0 to 0 —	— —
PS-6 DPC-6	— (+)0.05	(+)0.25 to 0 (+)0.5 to 0	— (+)0.5 to 0	(+)0.5 to 0 —	— —
TCV-8 TPCV	(+)0.25	0 to (+)1.0 0 to (+)1.0	— 0 to (+)1.0	0 to (+)1.0 —	— —
TCV-8 TPCV	(+)0.1 (+)0.1	0 to (+)0.2 0 to (+)0.2	0 to (+)0.2 0 to (+)0.2	0 to (+)0.15 0 to (+)0.15	0 to (+)0.15 0 to (+)0.15

Notes: 1. Setpoints, scales and ranges are in inches of Water Gage.
2. "—" indicates instruments operating in reverse gain mode. For proper operation in manual mode, the following Electropneumatic Transducers must be wired reverse acting: EP-2, EP-3, EP-4 and EP-4.
3. Damper Motors DM-26 and DM-27 are disconnected. Supply Fans SF-5 and SF-6 inlet Dampers are in the open position.
4. Damper Motors DM-28 and DM-29 are disconnected. Inlet Dampers to 2736-Z and Exhaust Fan EF-1-2 are manually locked in a partial open position.
5. Manual Controller MC-6 is not connected to the controller and will require addition to controller software.

Figure 9-17. Heating, Ventilation, and Air Conditioning Control Diagram, Building 2736-ZB. (Sheet 3 of 5)
(for reference only - for current information, see appropriate facility drawings)

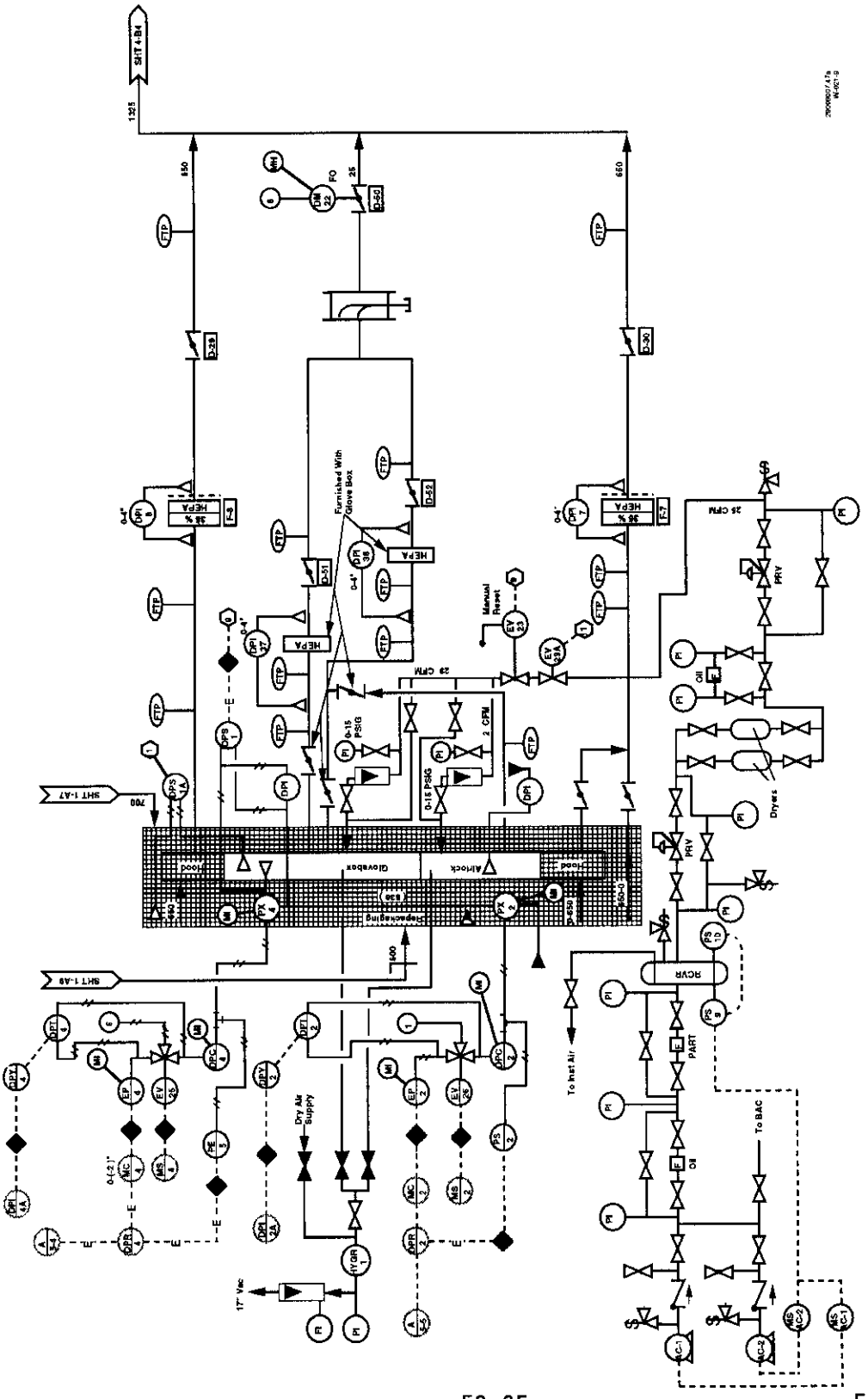


Figure 9-17. Heating, Ventilation, and Air Conditioning Control Diagram, Building 2736-ZB. (Sheet 4 of 5)

(for reference only - for current information, see appropriate facility drawings)

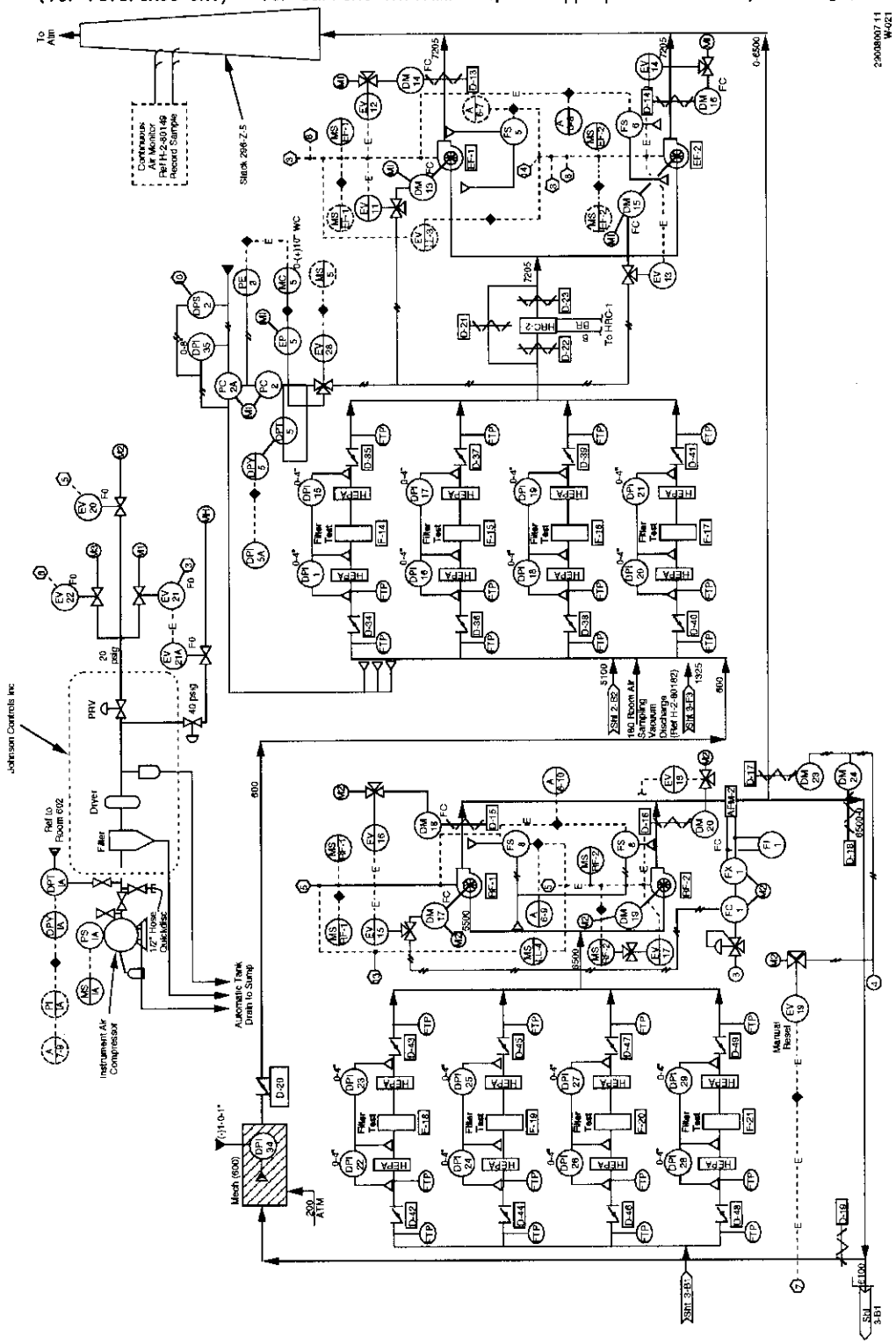


Figure 9-17. Heating, Ventilation, and Air Conditioning Control Diagram, Building 2736-ZB. (Sheet 5 of 5)
(for reference only - for current information, see appropriate facility drawings)

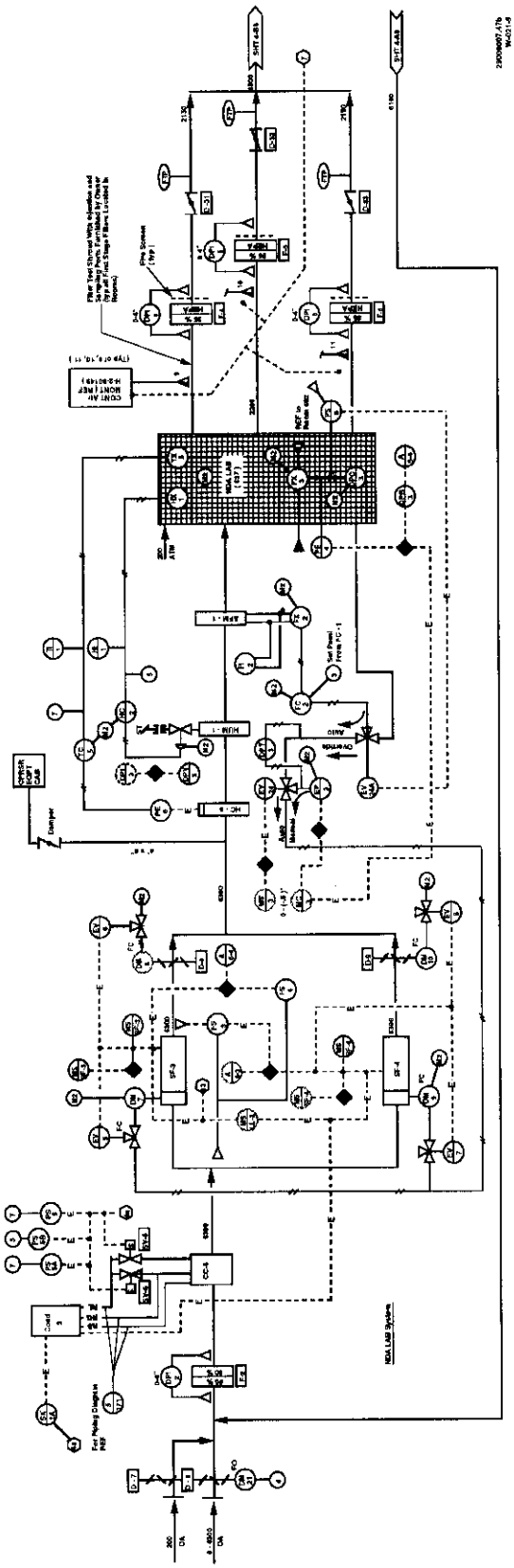


Figure 9-18. Heating, Ventilation, and Air Conditioning Control Diagram, Building 2736-Z.

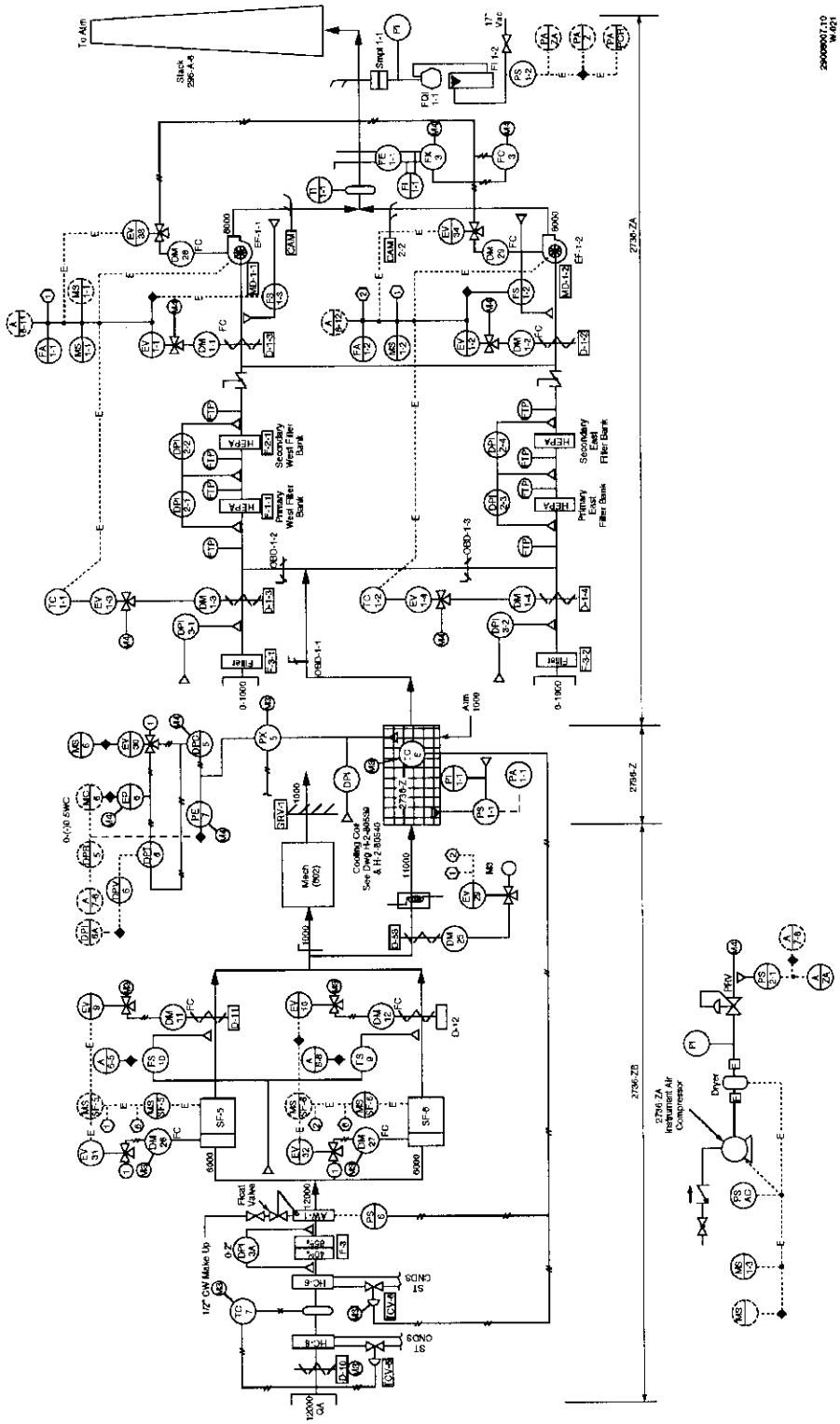


Figure 9-19. Not Used

Figure 9-20. Heating, Ventilating, and Air Conditioning Control Diagram, Building 241-Z.

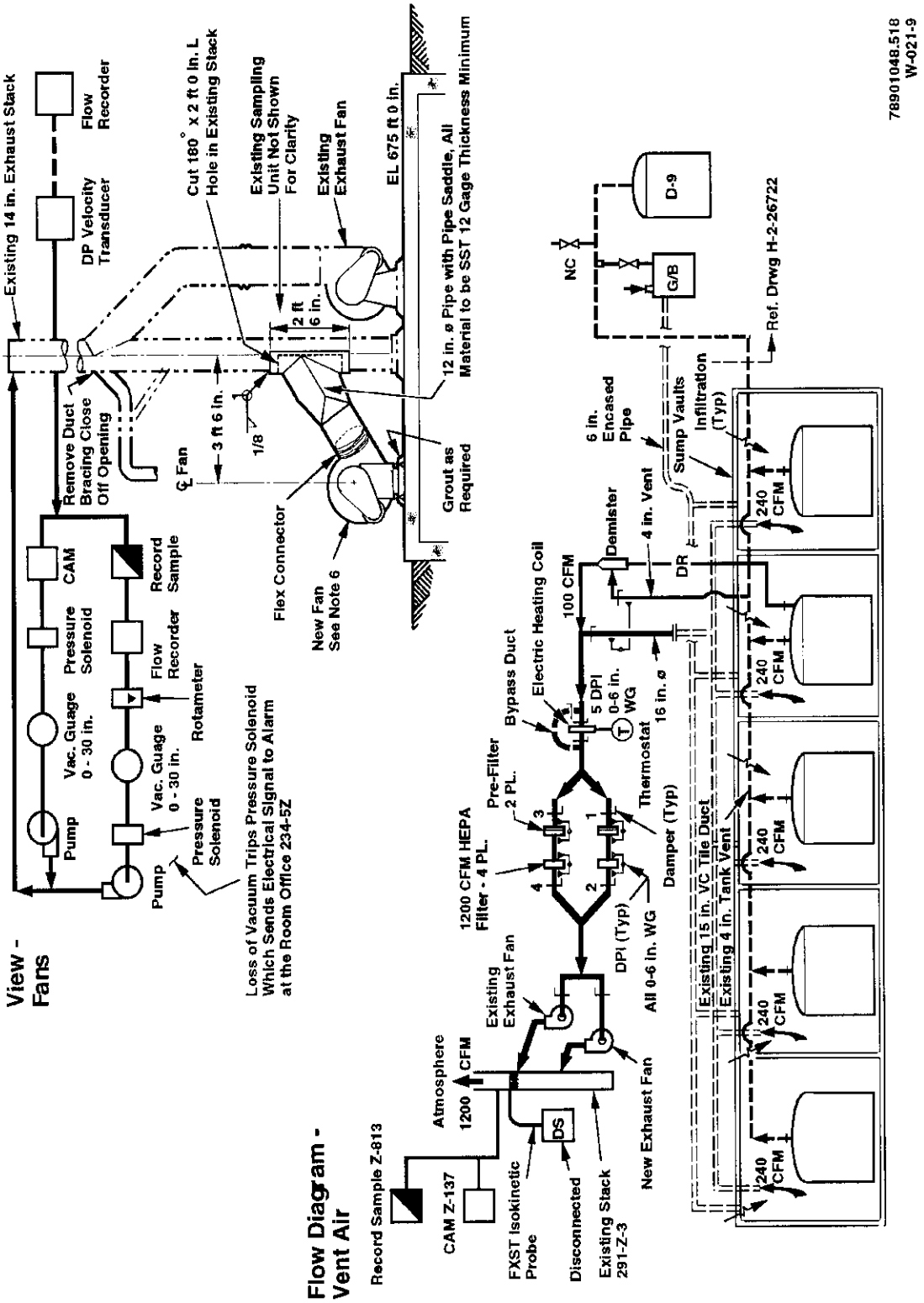


Figure 9-21. Stack 291-Z-1 Flow Upward, Fans Stopped.

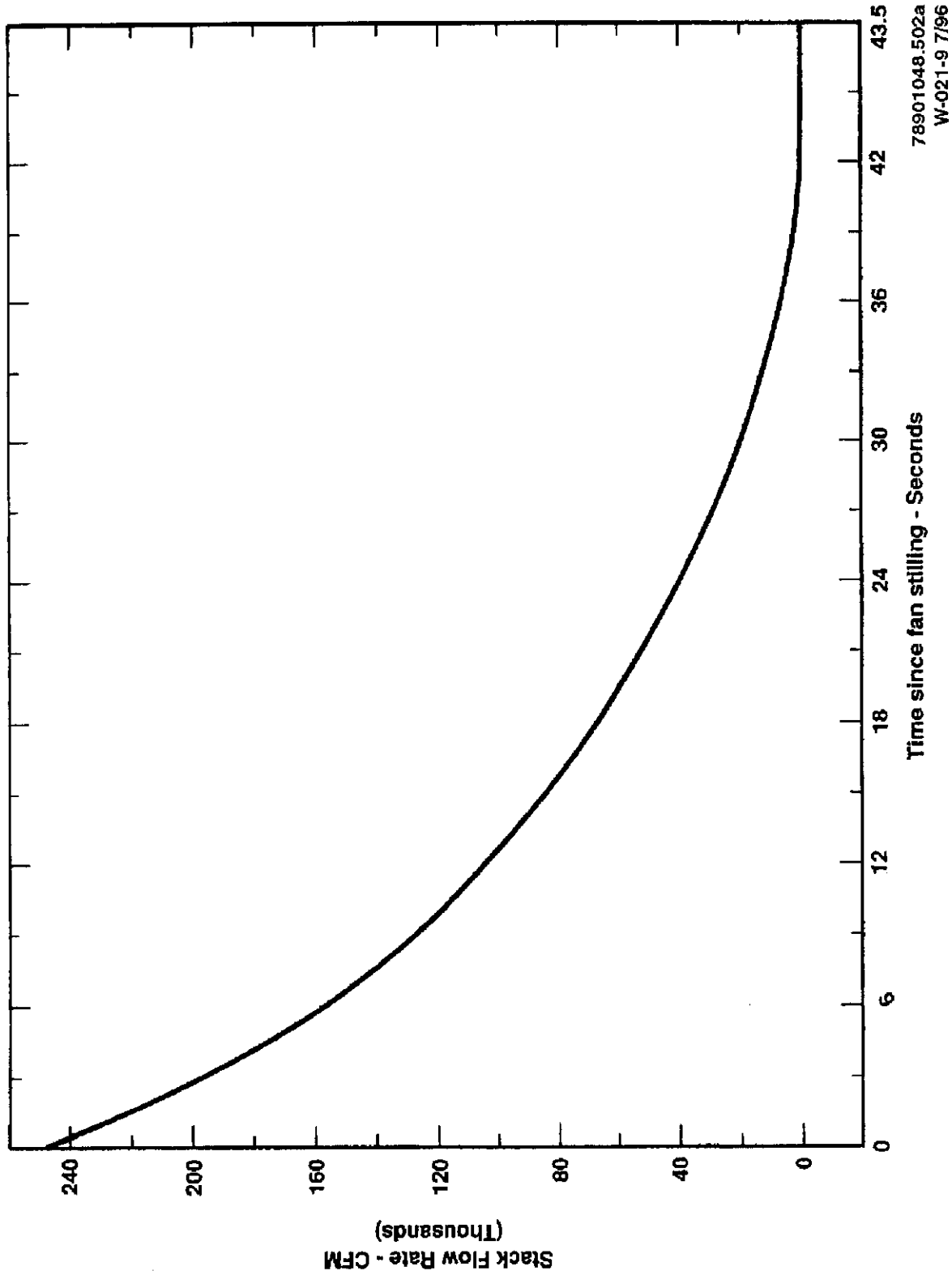


Figure 9-22. Backflow through Building 234-5Z.

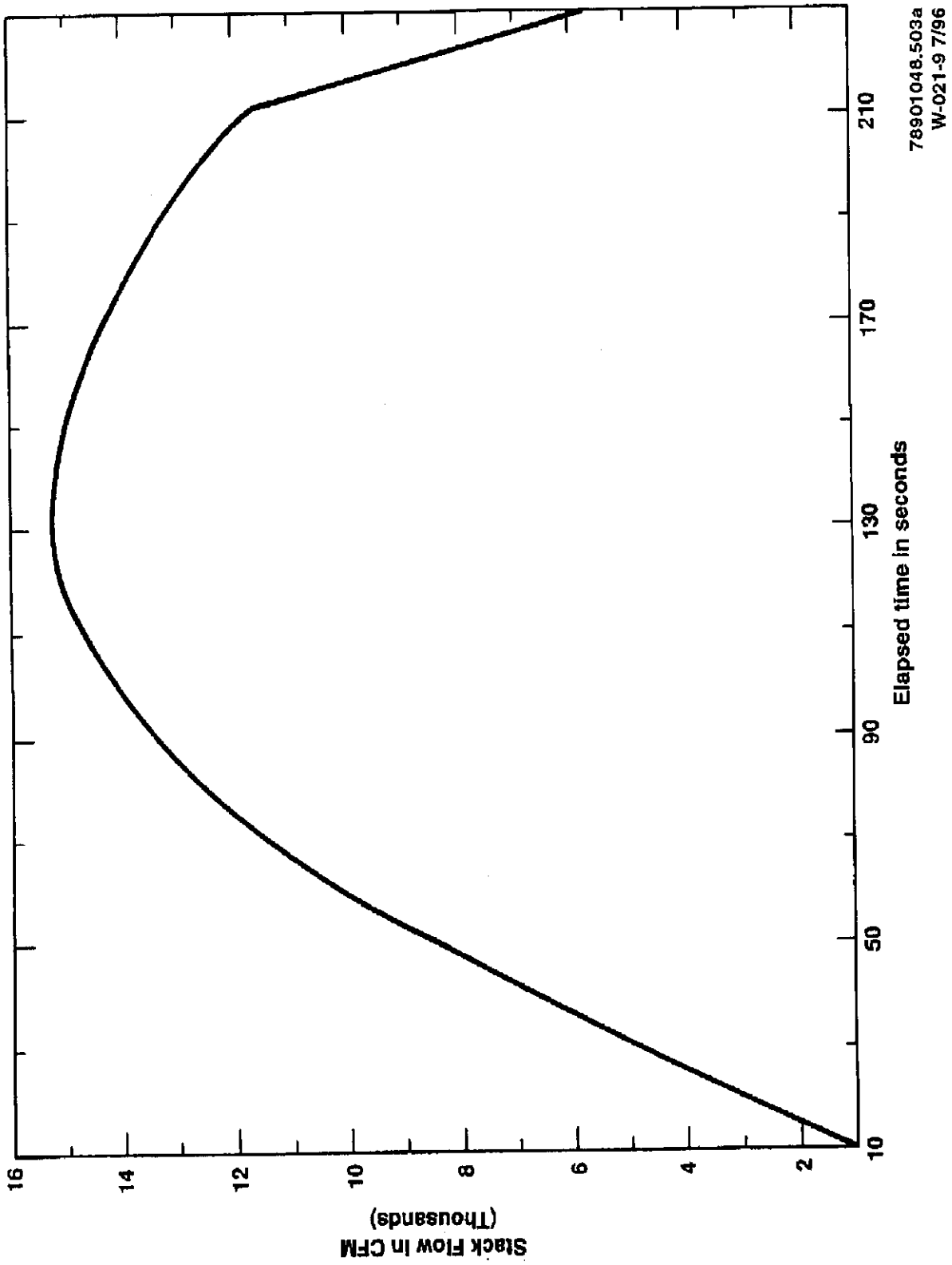


Figure 9-23. Schematic of Remote Mechanical
"C" Line Ventilation.
(Figure needs updated re: FB 9A, FB 9B and FB 9AB deletion)

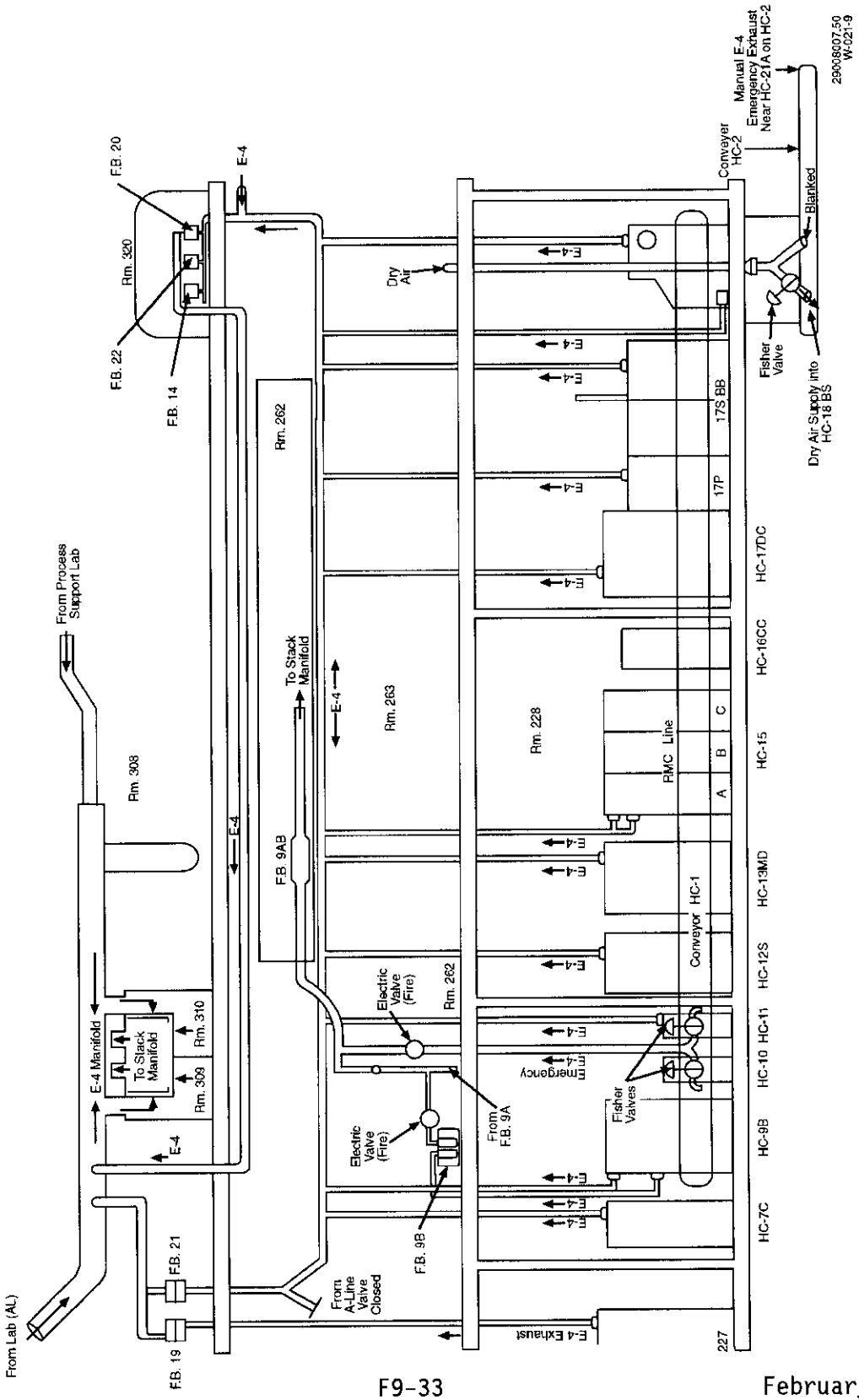


Figure 9-24. Exhaust (E-4) Emphasizing Remote Mechanical "C" Line.
(Sheet 1 of 5)

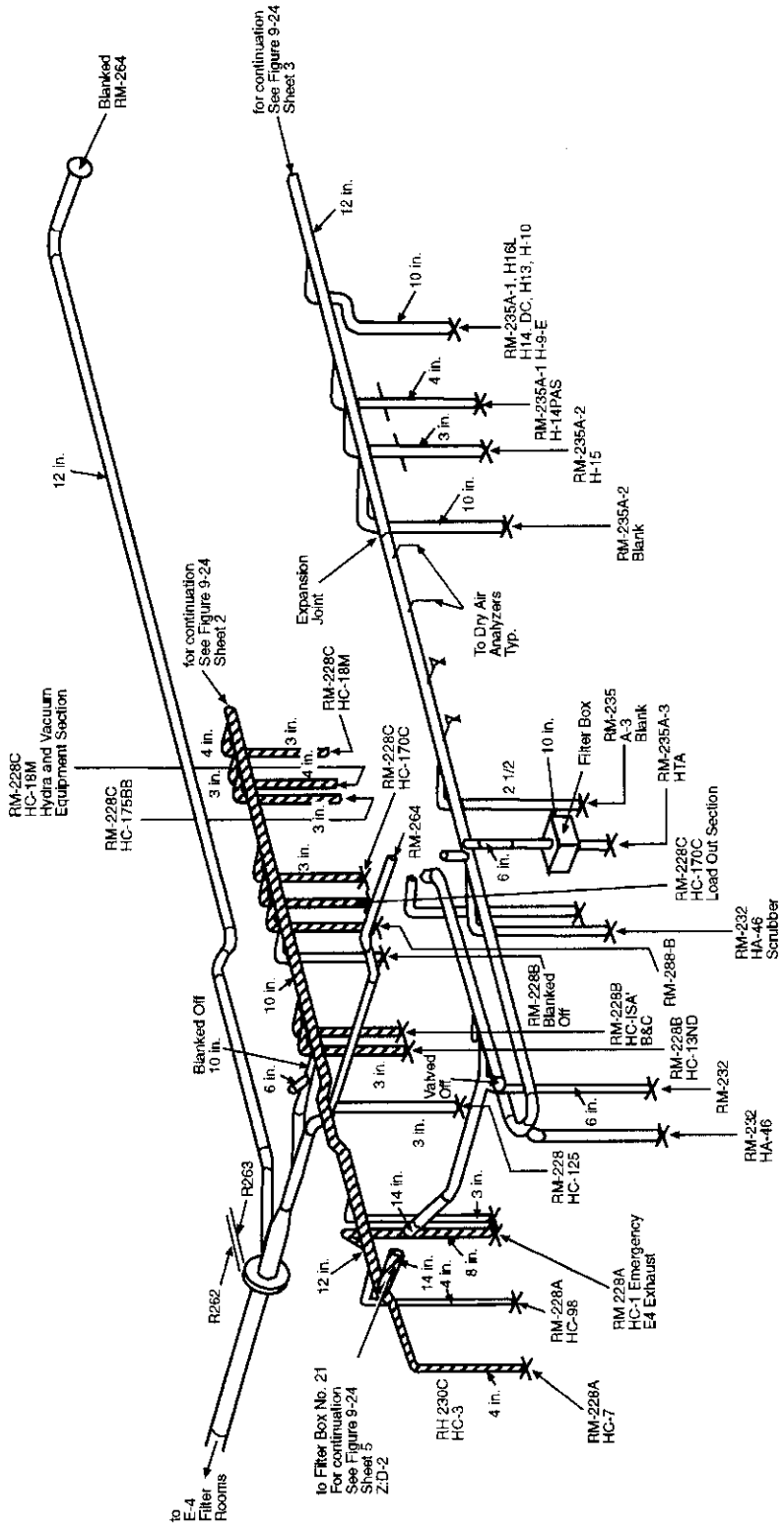


Figure 9-24. Exhaust (E-4) Emphasizing Remote Mechanical "C" Line.
(Sheet 2 of 5)

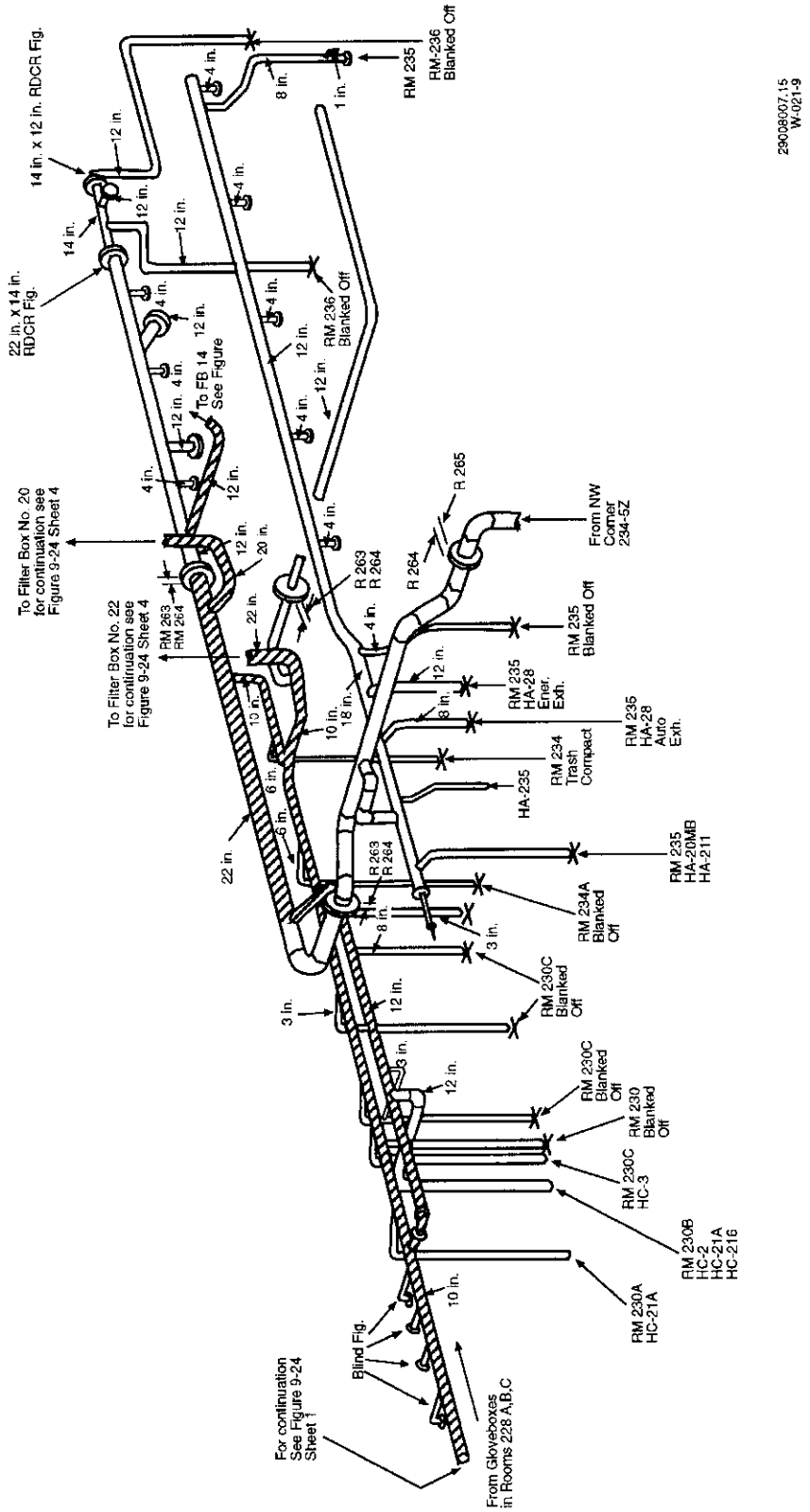


Figure 9-24. Exhaust (E-4) Emphasizing Remote Mechanical "C" Line.
(Sheet 3 of 5)

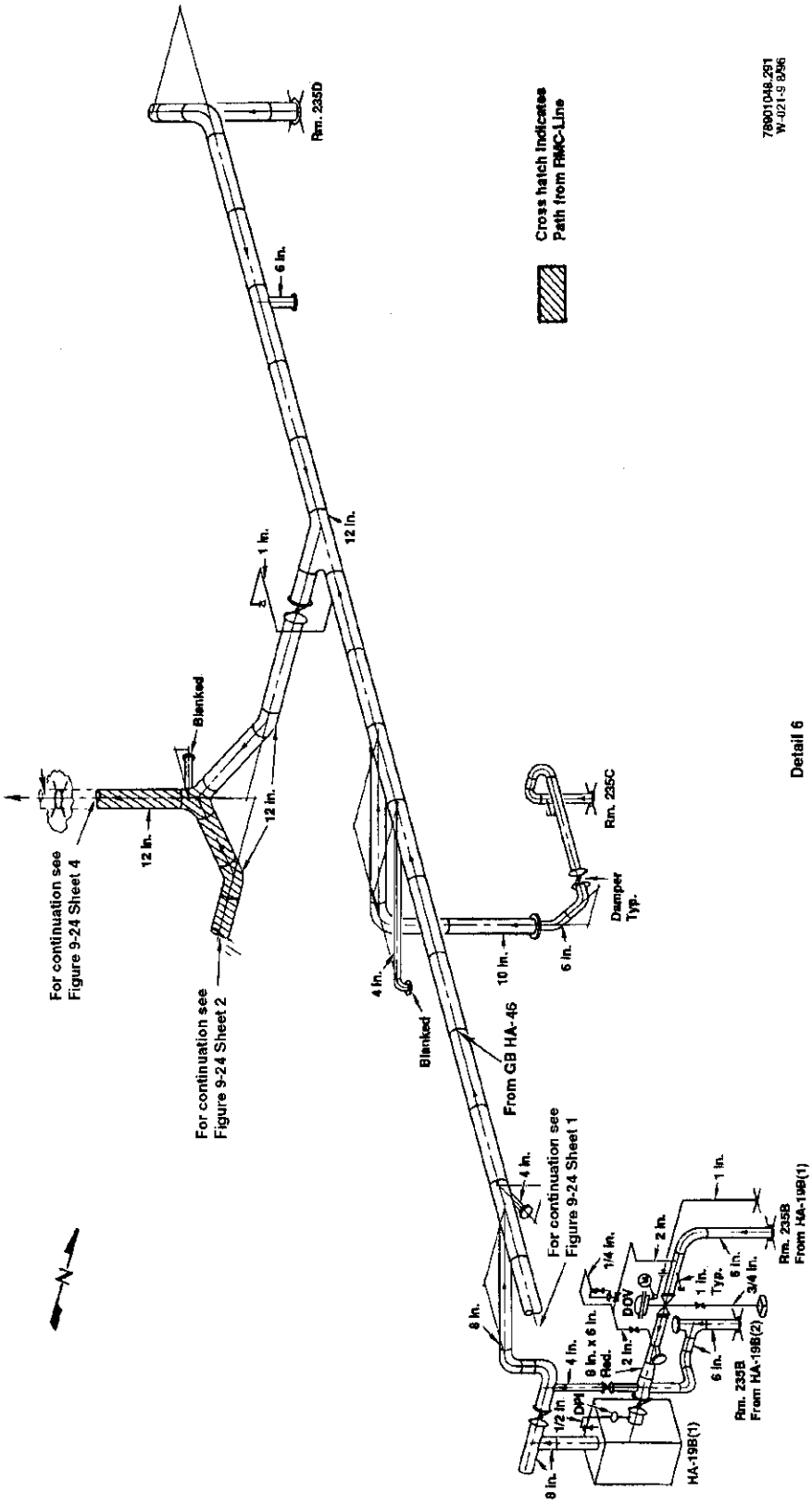


Figure 9-24. Exhaust (E-4) Emphasizing Remote Mechanical "C" Line.
(Sheet 4 of 5)

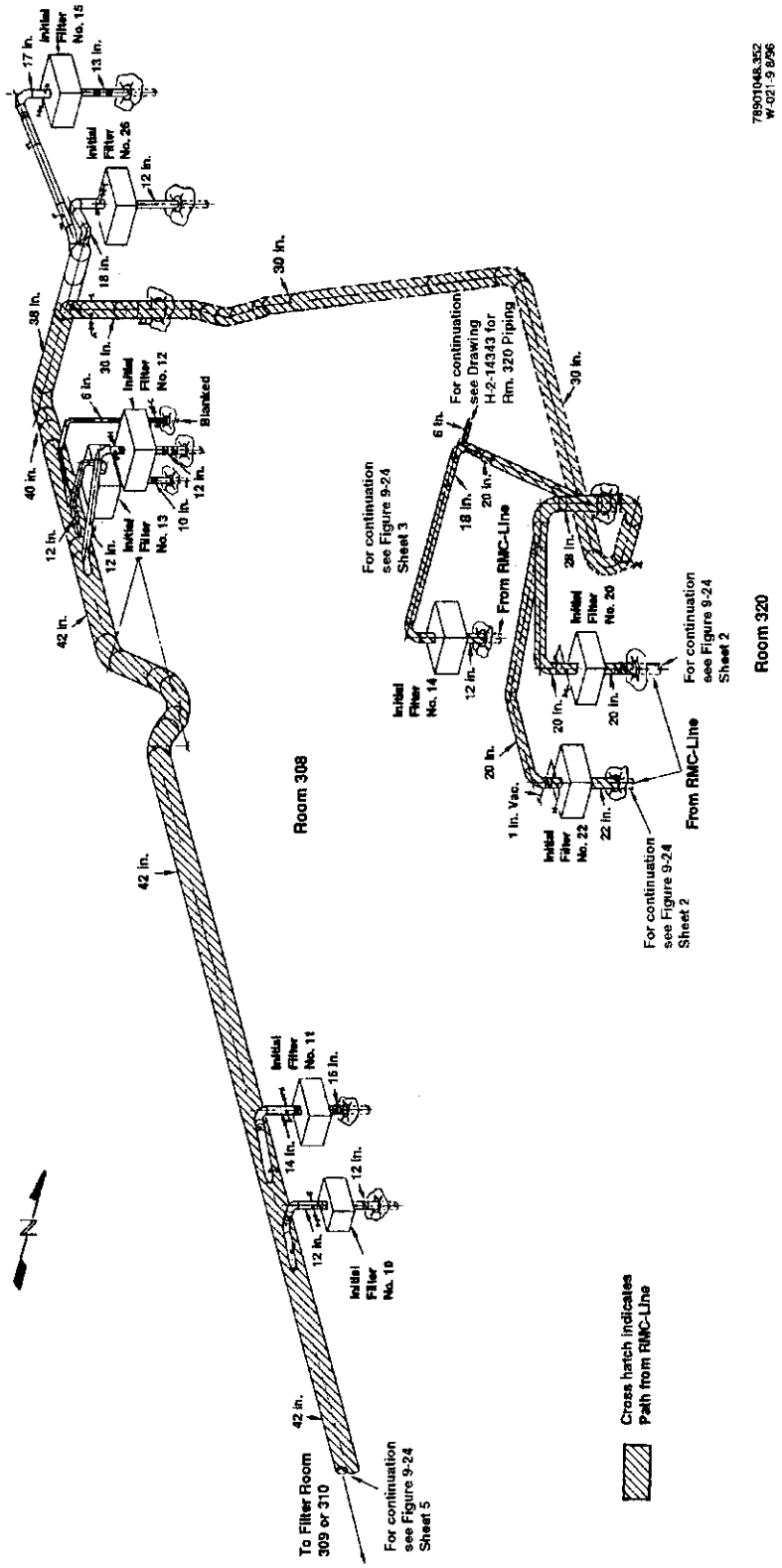


Figure 9-24. Exhaust (E-4) Emphasizing Remote Mechanical "C" Line.
(Sheet 5 of 5)

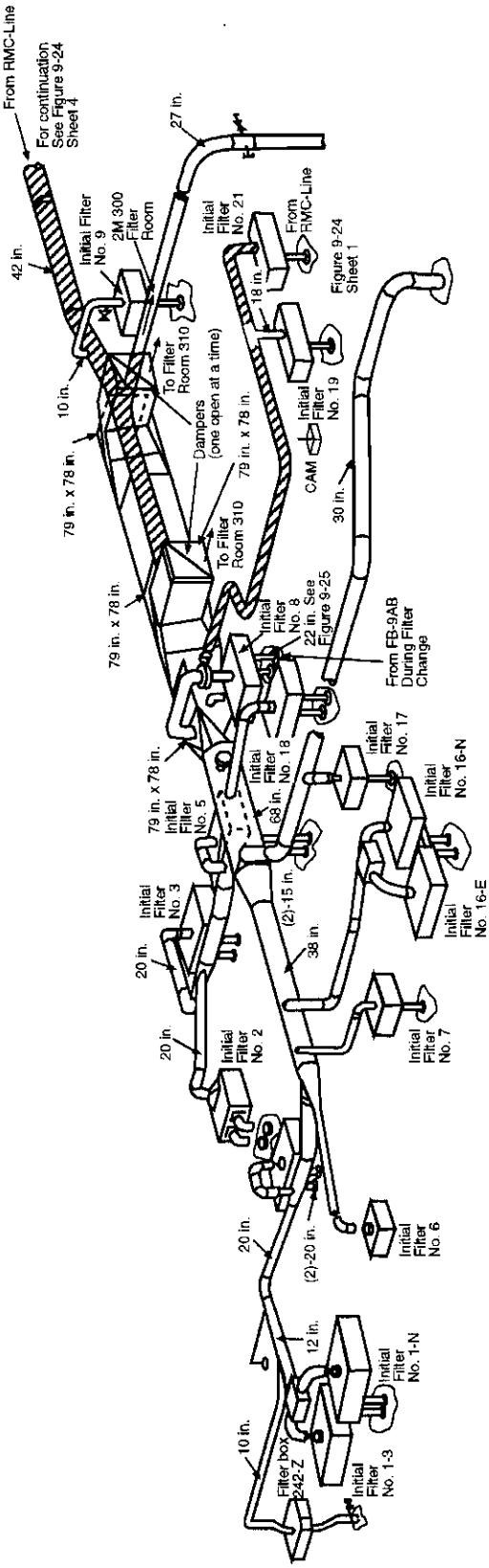


Figure 9-25. Exhaust (E-4) Middle Section Glovebox HC-9B.
(Figure needs updating re: FB 9A, FB 9B and FB 9AB deletion)

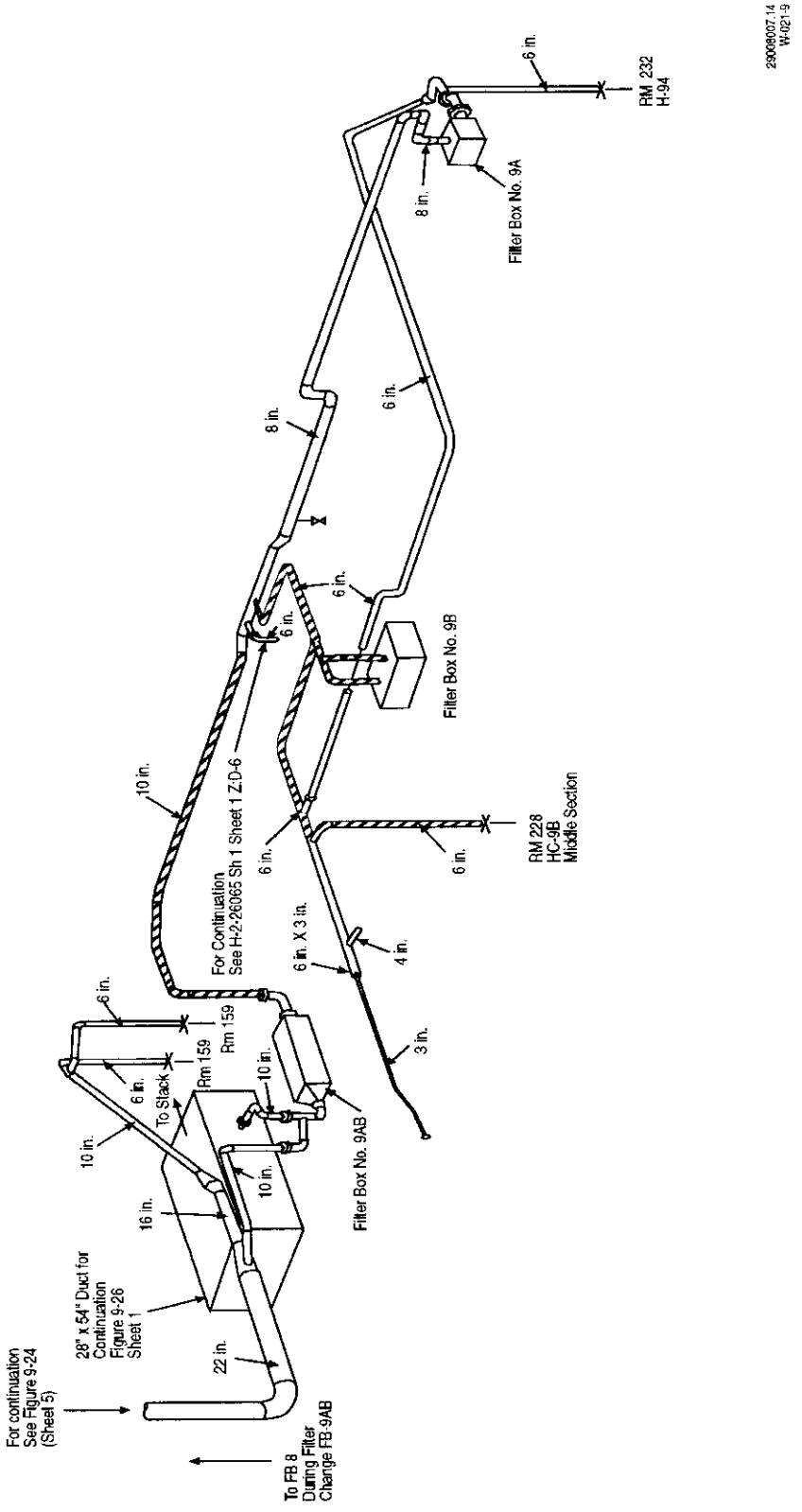


Figure 9-26. Exhaust (E-3) Emphasizing Remote Mechanical "C" Line. (Sheet 1 of 3)

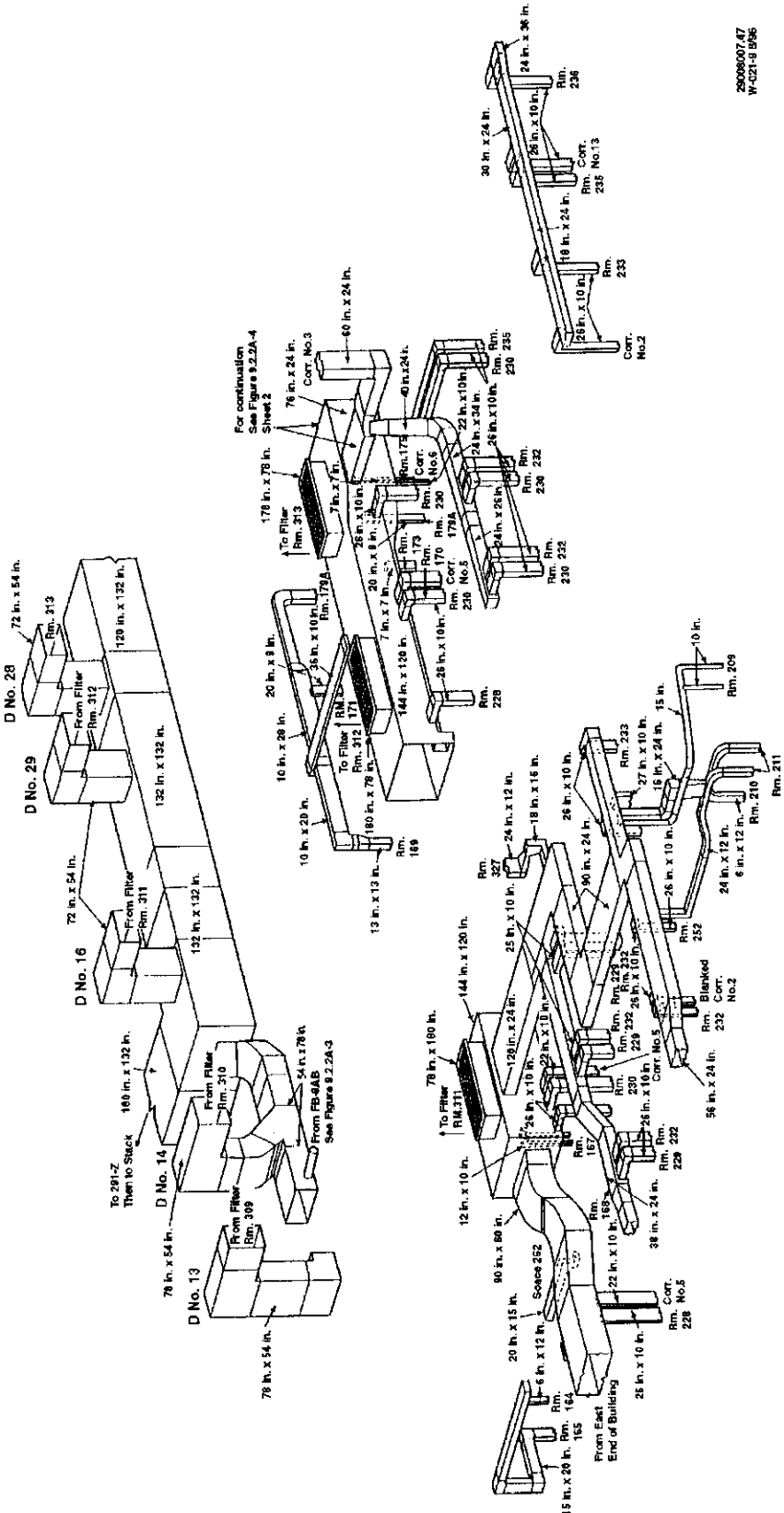


Figure 9-26. Exhaust (E-3) Emphasizing Remote Mechanical "C" Line.
(Sheet 2 of 3)

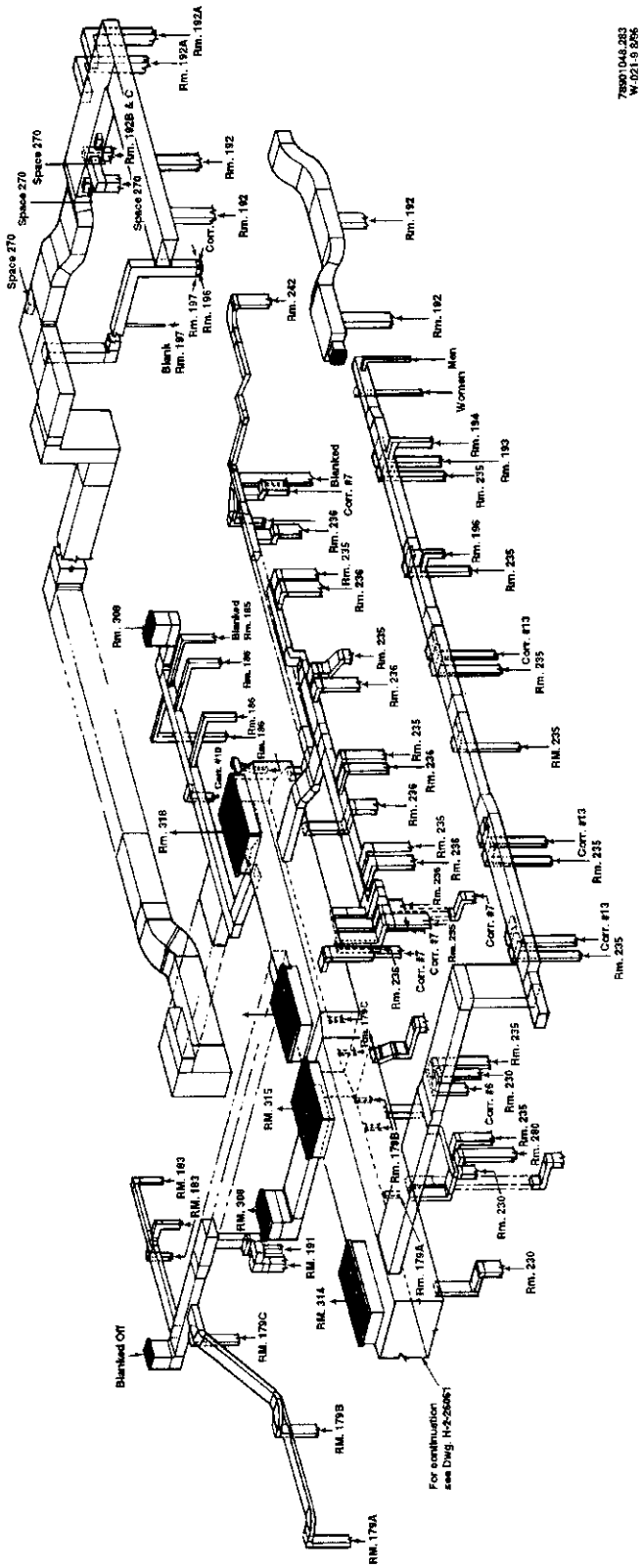


Figure 9-26. Exhaust (E-3) Emphasizing Remote Mechanical "C" Line.
(Sheet 3 of 3)

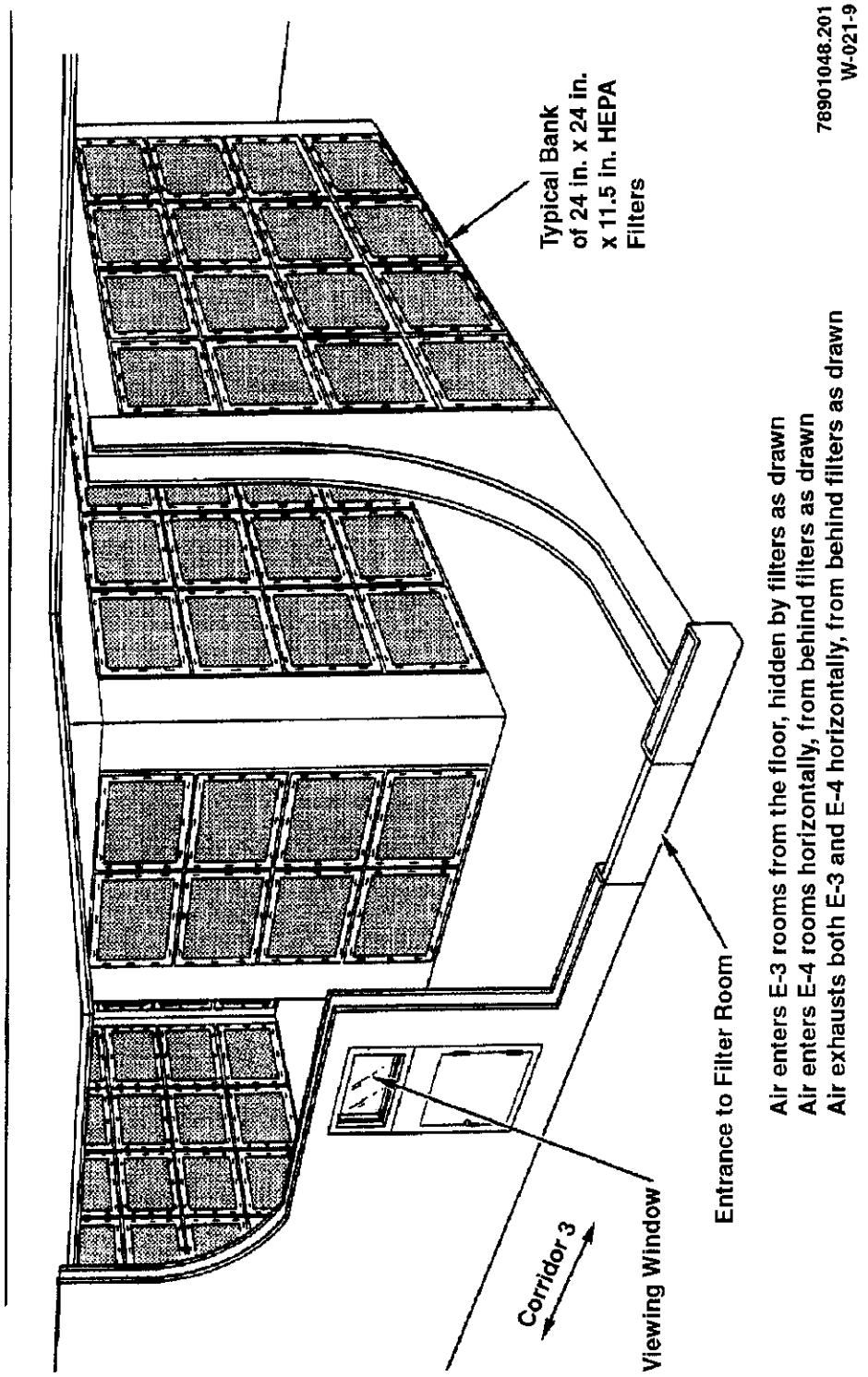


Figure 9-27. Probability/Logic Tree, Release of Pu Due to Glovebox Fire.

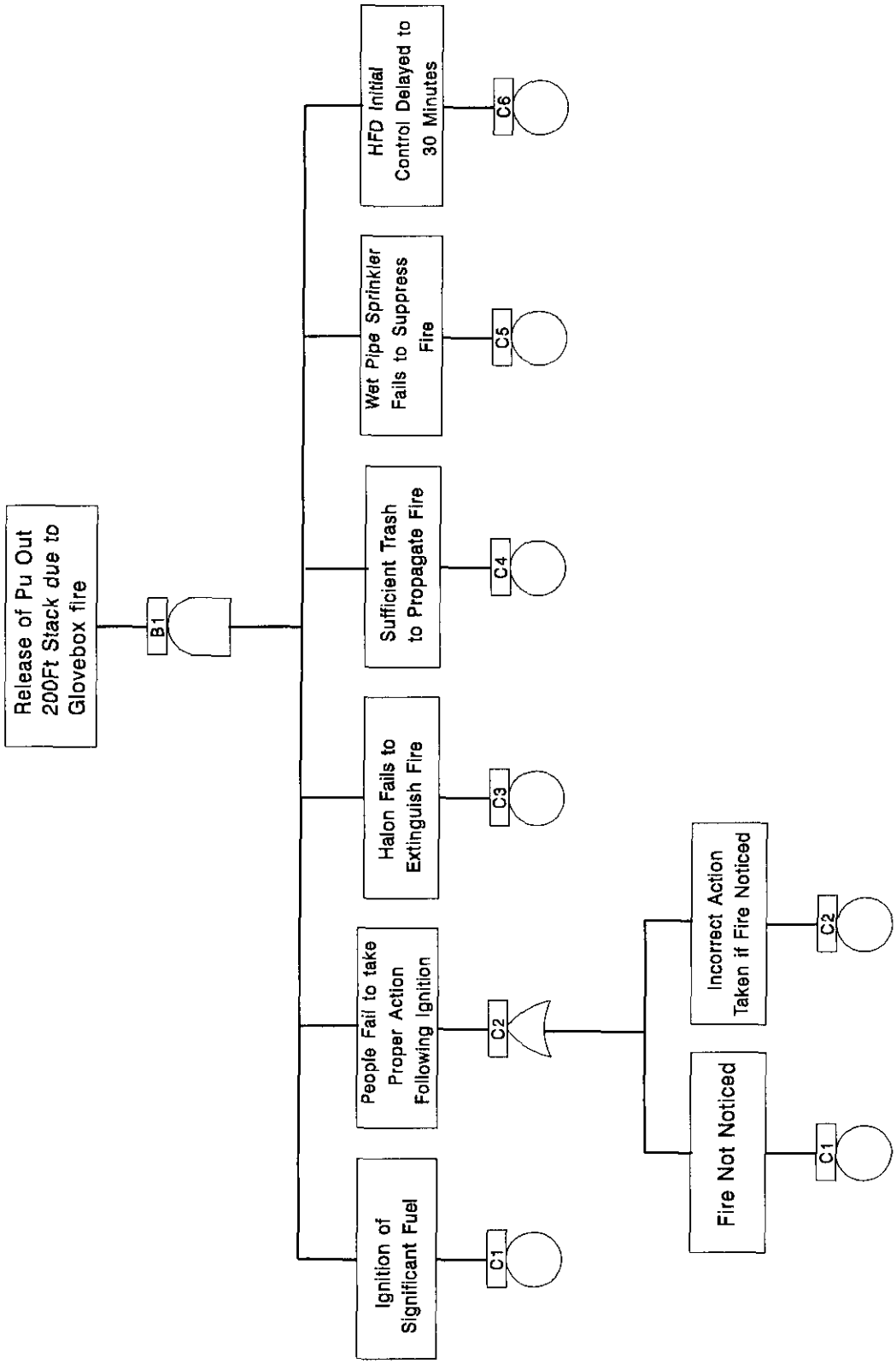


Figure 9-28. Size Distribution of PuF_4.

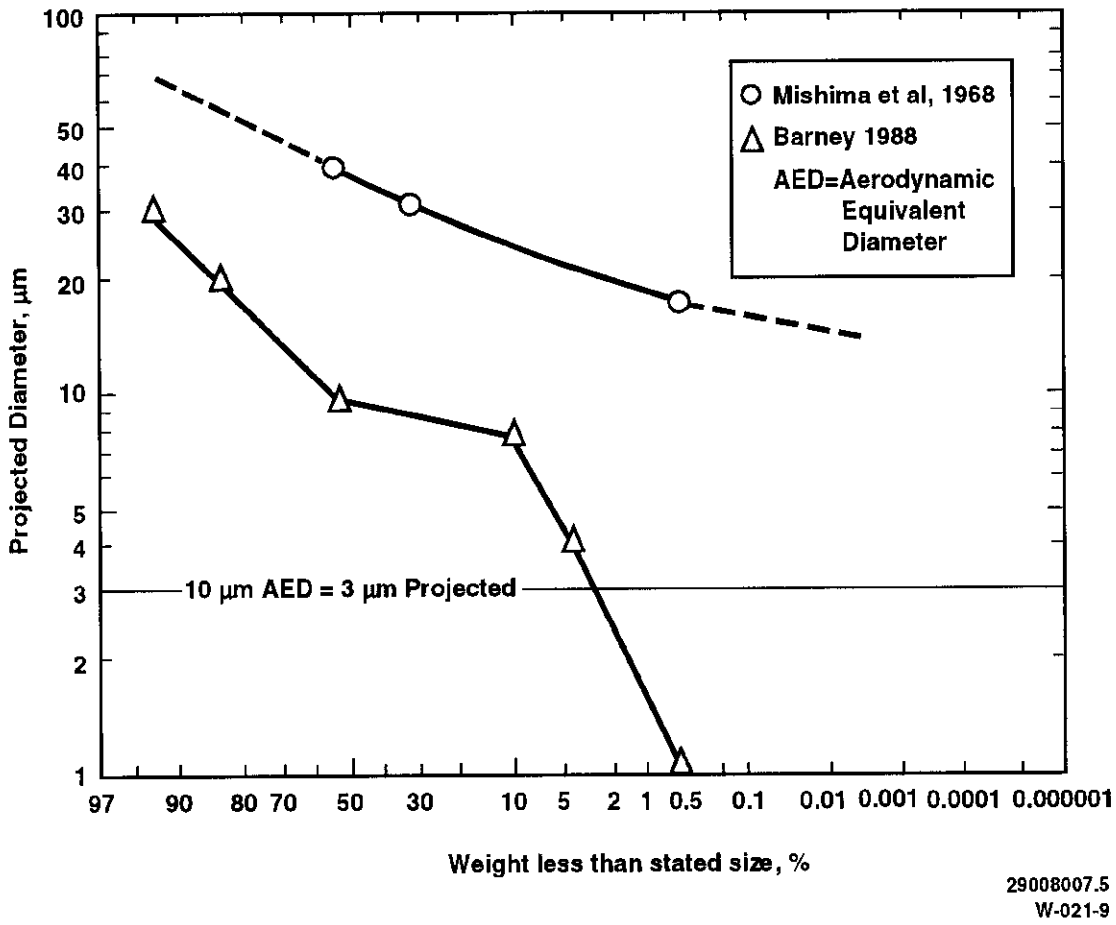
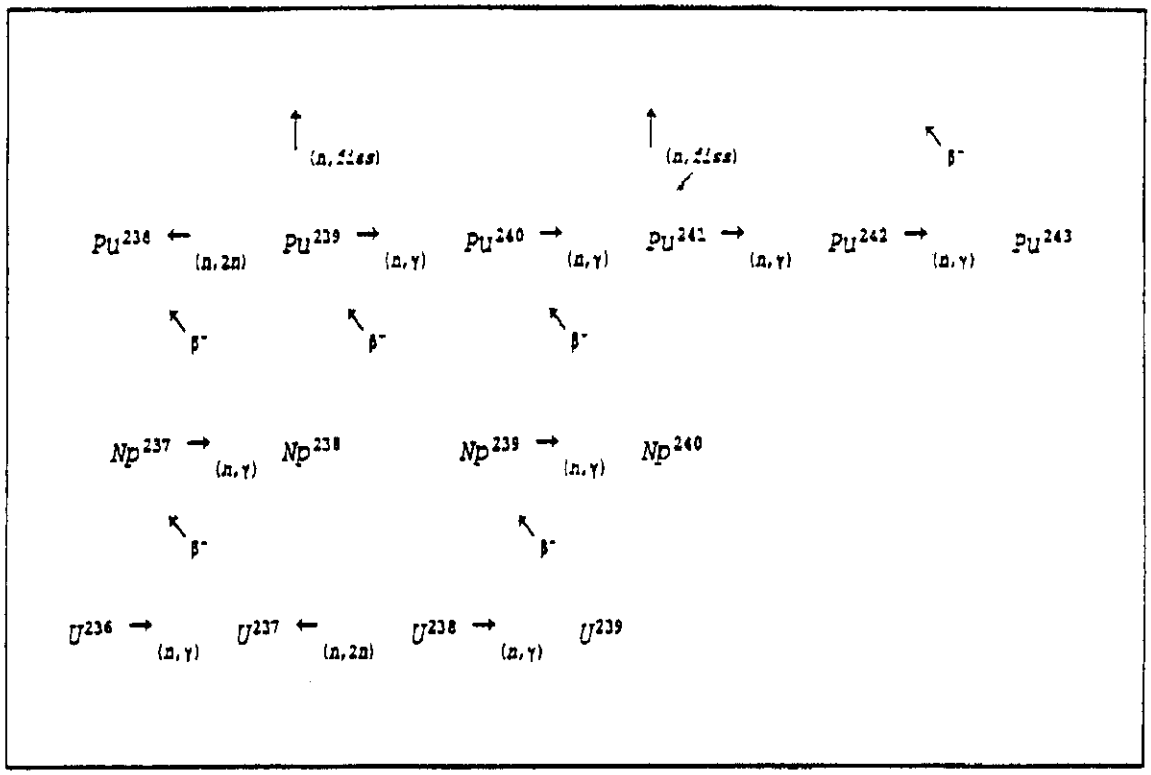


Figure 9-29. Not Used

Figure 9-30. Not Used

Figure 9-31. Production of Plutonium from Neutron Irradiation of ^{238}U.



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Figure 9-32. Dose/Gram for Nondestructive Verification.

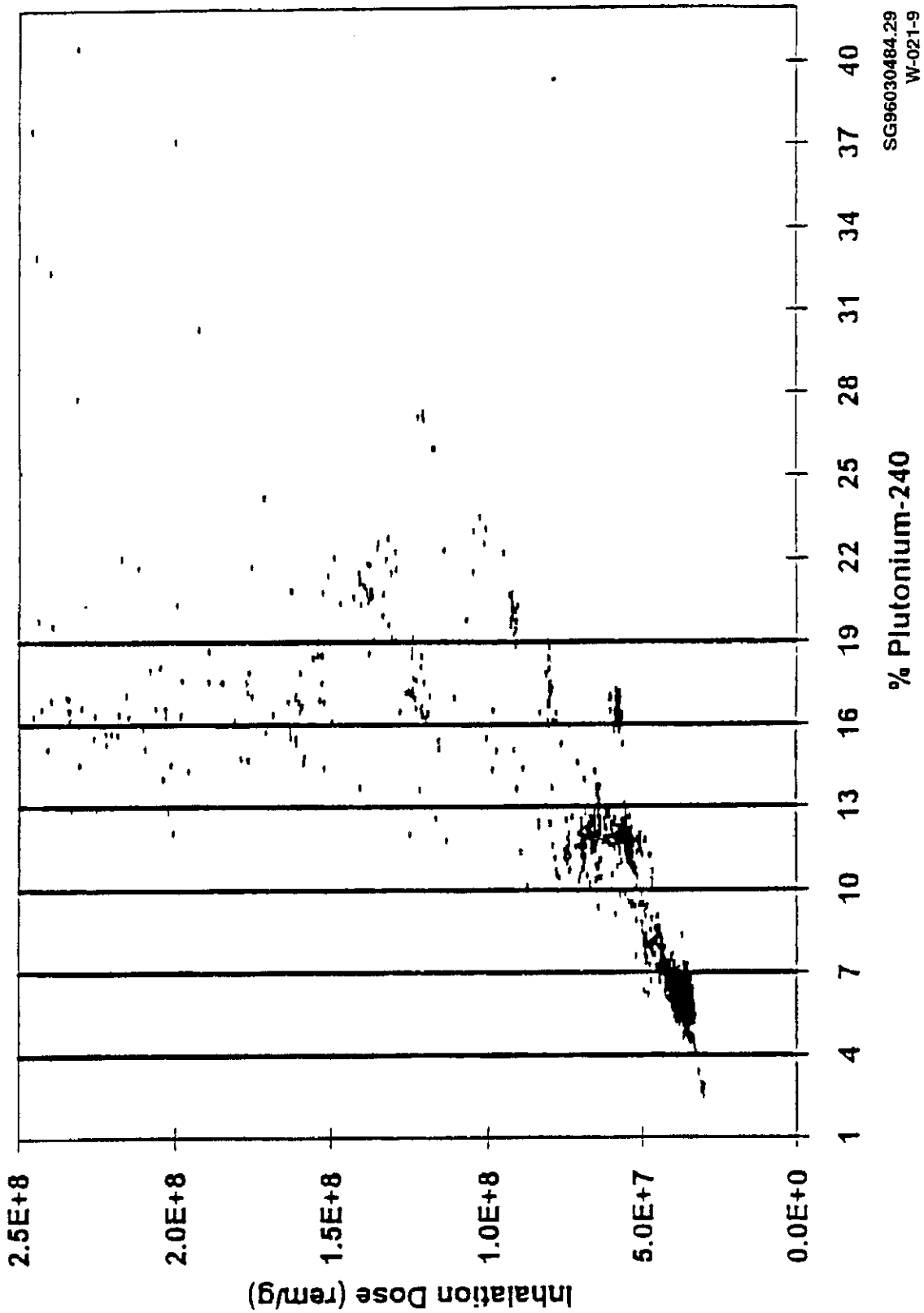


Figure 9-33. Annotated Excerpt for WHC-CM-4-46
Radiological Risk Comparison Guidelines.

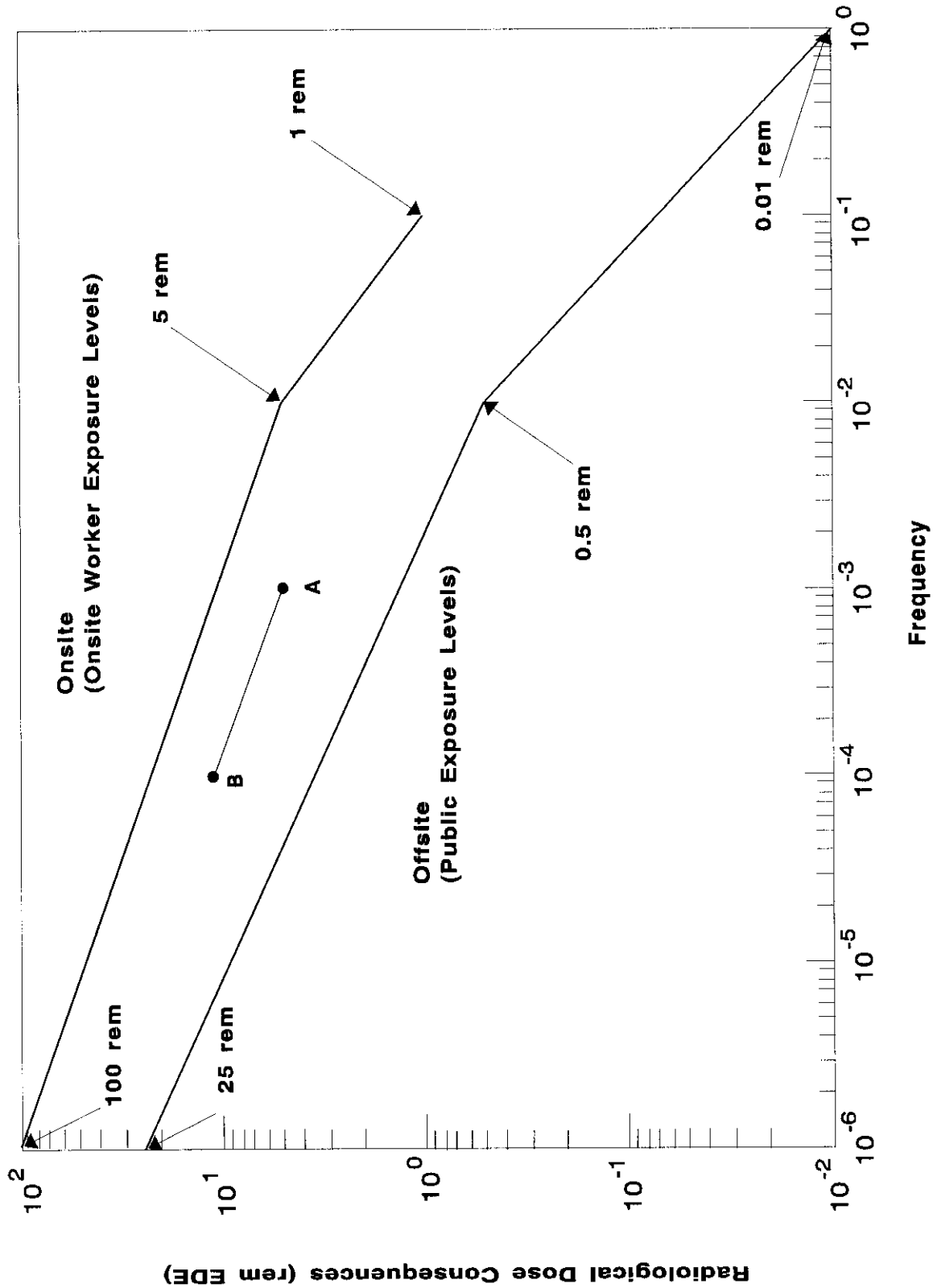


Figure 9-34. Application of Radiological Risk Acceptance Guidelines for Effective Dose Equivalent (From WHC-CM-4-46).

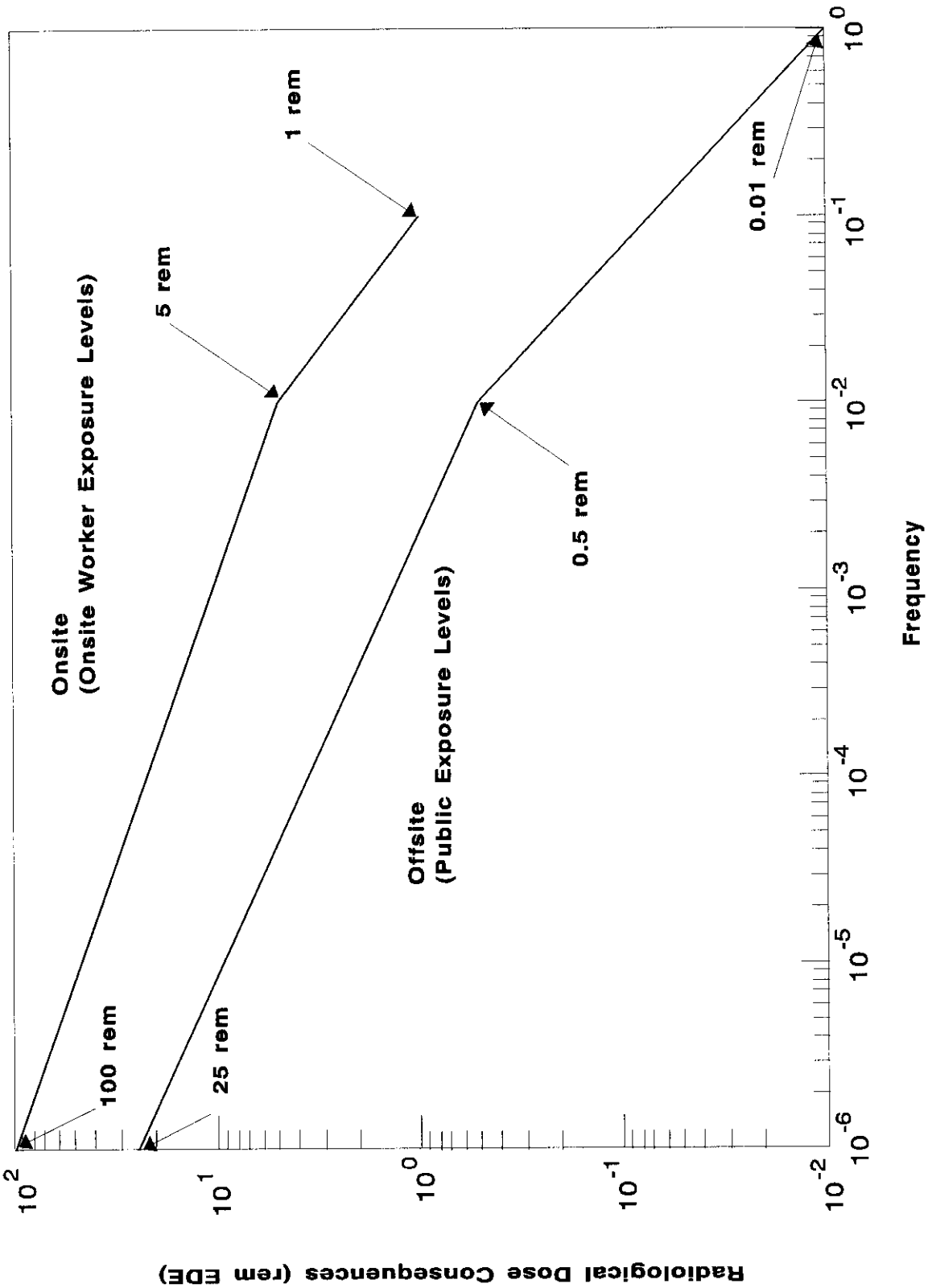
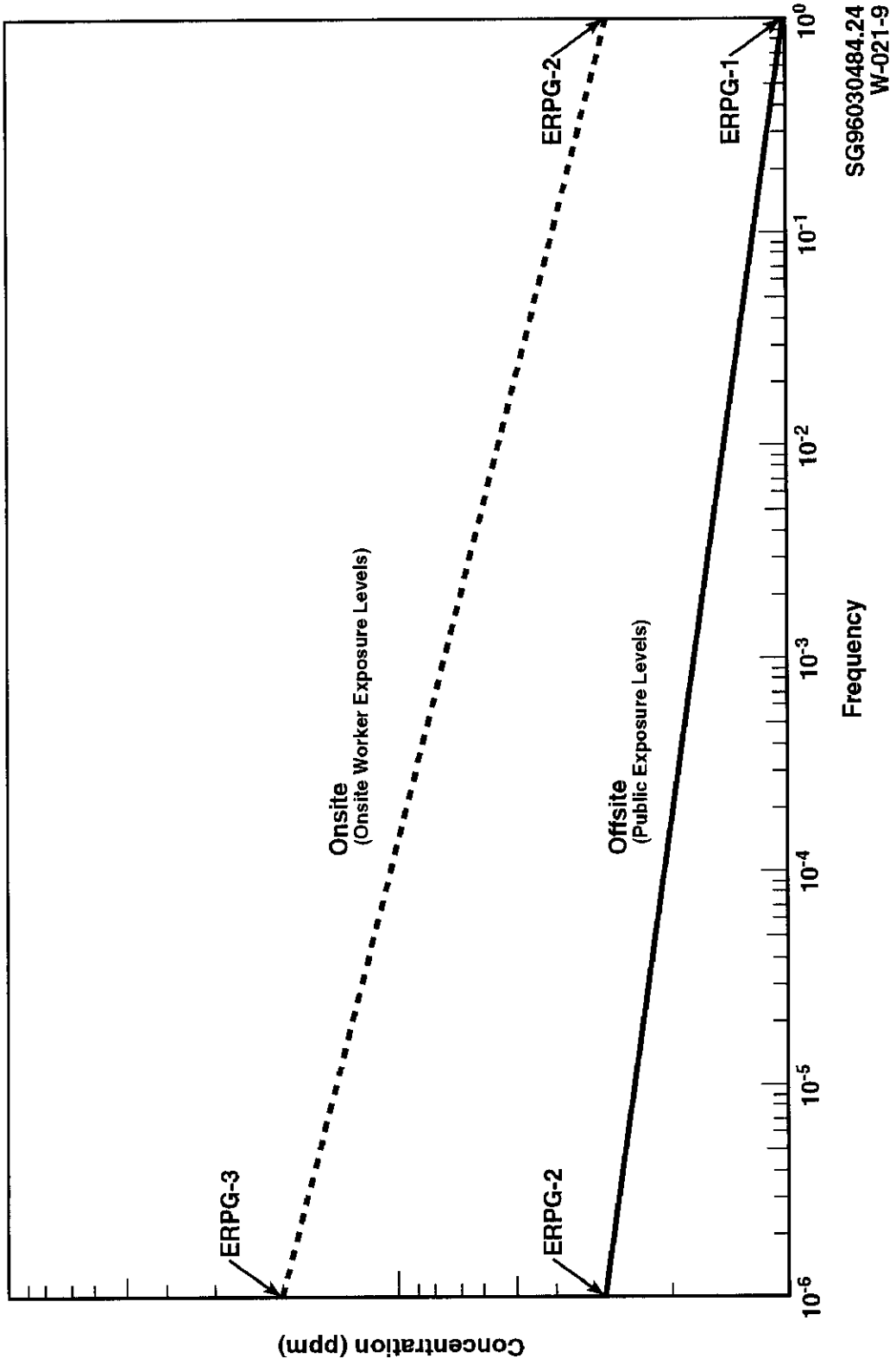


Figure 9-35. Application of Offsite Toxicological Risk Acceptance Guidelines for Nitric Acid.



Note: Needs units added on vertical axis.

Figure 9-36. Failed Air Cylinder--Plot of Cylinder Velocity, Acceleration and Distance vs. Time

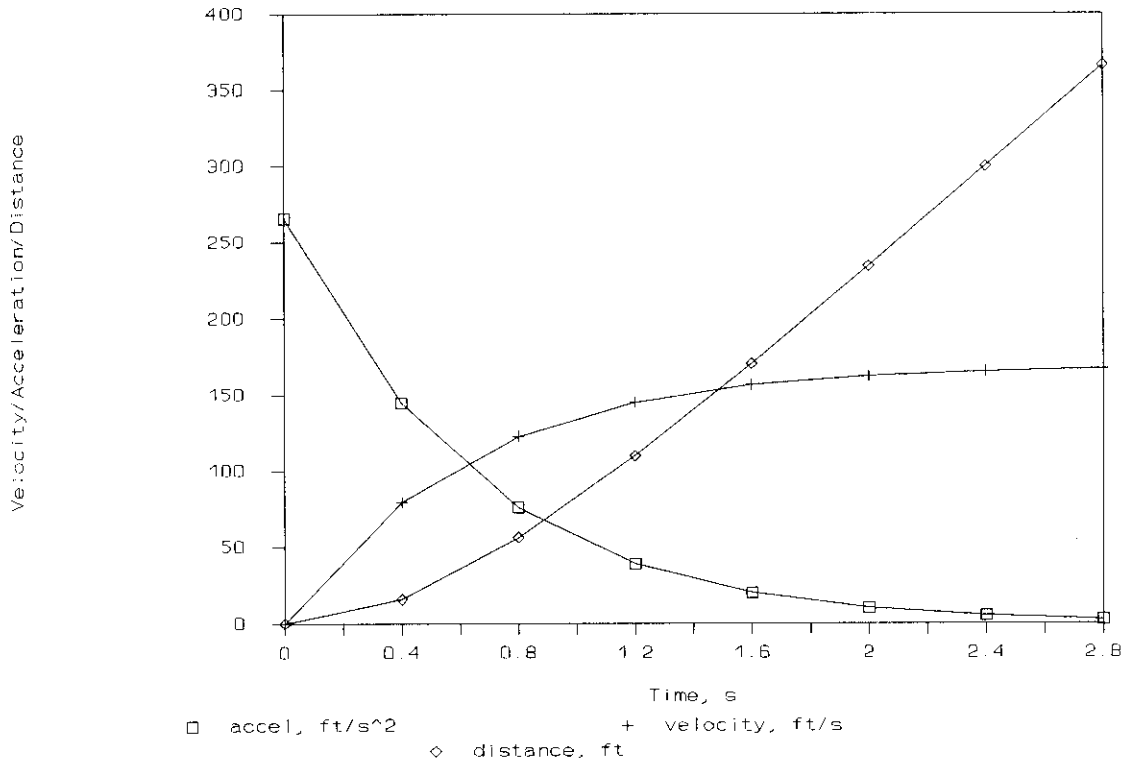
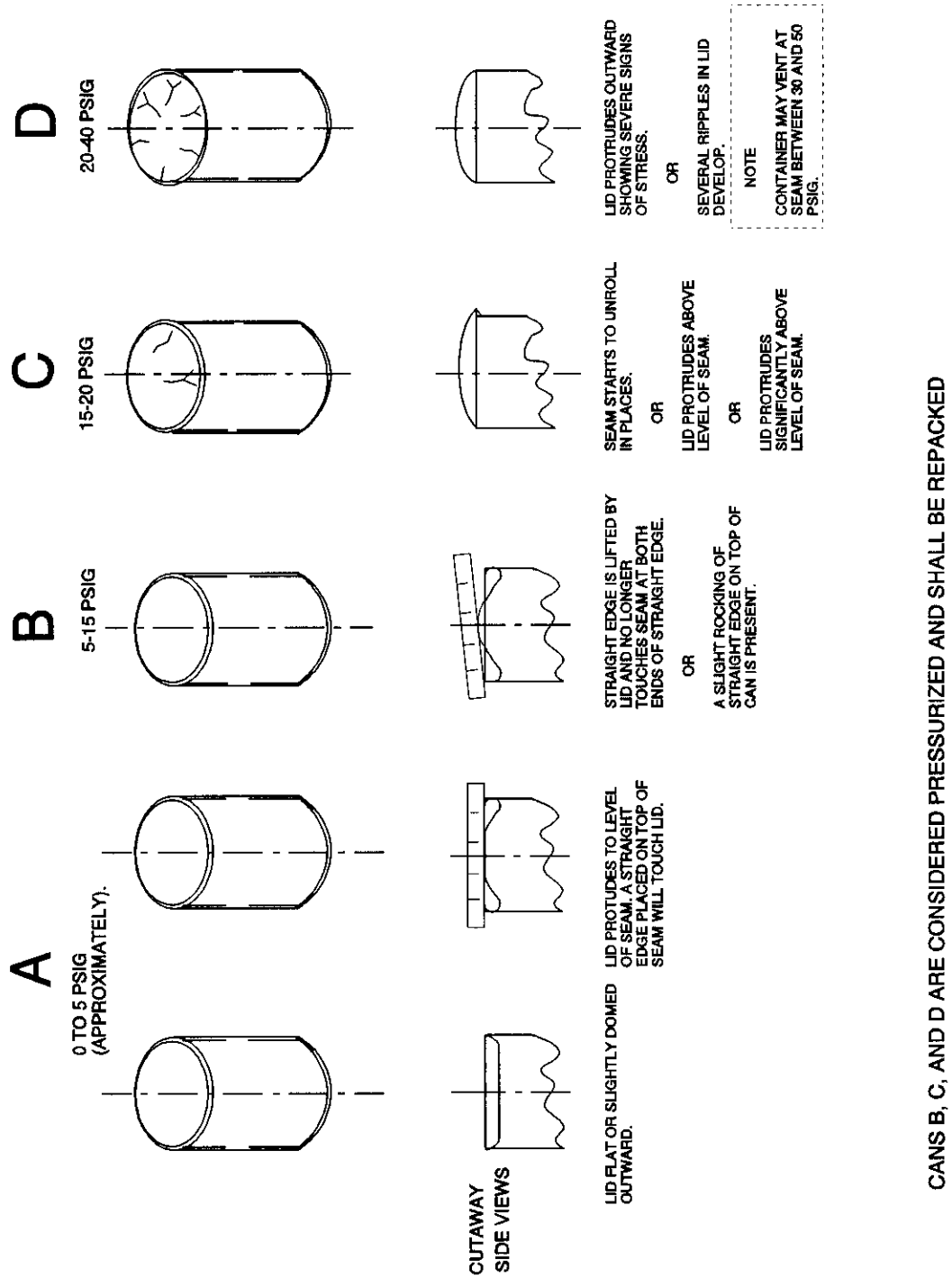


Figure 9-37. Stages of Pressurization of Pu Metal Containers



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APPENDIX 9A

PLUTONIUM FINISHING PLANT HAZARD EVALUATION

APPENDIX 9A

PLUTONIUM FINISHING PLANT HAZARD EVALUATION

This hazard evaluation systematically identifies and qualitatively assesses all hazards and potential accidents associated with active operations internal to the PFP facility, i.e., those associated with facility operation. The evaluation covers those operations and processes which were active at the time of preparation of the evaluation during Fiscal Year 1996. Subsequent to preparation of the hazard evaluation, two new processes were initiated within the PFP: 1) Plutonium-bearing solution stabilization using the Production Vertical Denitration Calciner (VDC) (operation not yet authorized), and 2) Reactive plutonium-bearing material stabilization (thermal stabilization) of "clean" plutonium oxide. The hazard evaluation for operation of the Production VDC is provided in Appendix 9D and the hazard evaluation for reactive material stabilization is provided in Appendix 9F. In addition to these two new processes, the Laboratory Prototype Calciner has been activated for stabilizing plutonium-bearing solutions. The hazard evaluation for the laboratory calciner is provided in the Laboratory Prototype Calciner addendum to this FSAR. The laboratory calciner sections of Appendix 9A (primarily in Table 9A.1.3) are superseded by the Laboratory Prototype Calciner addendum.

Throughout the hazard evaluation process, preventive and mitigative structures, systems and components (SSCs) and pertinent elements of programmatic and administrative features are identified. The identification establishes functional requirements for SSCs and the essential basis for the development of safety programs. An evaluation of the expected consequences and an estimation of the likelihood of accidents are included to identify abnormal events and accidents, and to facilitate the selection of a limited subset of internal accidents to undergo accident analysis in Section 9.2. This subset of accidents are those accidents that bound the envelope of accident conditions to which the operation would be subjected.

External events (both man-made and natural phenomena) are addressed in Section 9.2. These were determined to have significant impact on the public, therefore requiring quantitative analysis to determine the acceptable safety envelope. External events analyzed arise from two sources: natural phenomena and (seismic events, extreme winds and floods) technological (or man-made) hazards. An aircraft crash is the only man-made external hazard evaluated.

Conventional industrial hazards (i.e., hazards of the type and magnitude encountered and accepted by the public) are addressed through safety management programs as required by DOE Orders and the Occupational Safety and Health Administration (OSHA) and are not addressed in this appendix. The safety programs that mitigate conventional industrial hazards meet the requirements of DOE Orders, federal regulations, and industrial standards.

Methodology

The preliminary step in this evaluation was hazard identification. A hazard is a characteristic or an inherent feature of a system or operation that represents a potential for an uncontrolled release of hazardous material. The hazard evaluation identifies the material, system, process, and plant characteristics that can produce undesirable consequences and assesses the

associated hazards. A qualitative consequence evaluation was performed to determine the adequacy of plant preventive and mitigative features used to control these hazards.

The segmentation and selection of functional areas within the PFP was based on the independent nature of operations and the physical separation of the buildings. The hazards evaluation for the PFP was performed for specific operational hazards associated with the systems/activities within a defined functional area (e.g., analytical laboratories, thermal stabilization, storage vaults).

The hazard evaluation consisted of the following steps:

1) Identify the systems and activities in the functional area

2) Assess the failure modes of the systems and their associated equipment, and activities

3) Determine potential unmitigated consequences

4) Identify features (engineered, administrative, or both) required to prevent or mitigate the consequences of a specific hazard event

5) Qualitatively assess the risk of each event, giving consideration to the effectiveness of the preventive and mitigative features.

The effectiveness of hazard controls will be demonstrated through this hazard evaluation. Absolute risk cannot be determined; however, safety perspective and insights provided by this evaluation can be a basis for determining that the risk associated with operation of the PFP is acceptable. A detailed description of each step of the evaluation is given below.

System Identification. A variety of information was systematically reviewed in order to identify all hazardous and radioactive materials present in the facility and all energy sources associated with the facility. To facilitate the system identification, each facility and/or operation was divided into segments using facility layout drawings. The segment may be a subarea, a subsystem/activity, a function, a piece of equipment, or a step in an operation.

Failure Characterization. The identified system was then subjected to a characterization process that identified the failure modes that directly result in, or contribute significantly to, an abnormal event or an accident. The possible causes of operational deviations and the consequential accident scenarios were then determined.

The consequences of the various failure modes were assessed, assuming no mitigation. The level of detail necessary to sufficiently evaluate a hazard event is dependent upon its severity. If the unmitigated consequence of a hazard event was determined to be minor (see Table 9A-1 for consequence classification), qualitative risk evaluation performed in the hazard evaluation was sufficient. Hazard events with moderate or high unmitigated consequences may need to be analyzed in further detail in subsequent accident analyses.

The consequences were estimated based on the physical and/or chemical behavior of the pertinent process and the plant elements under upset conditions (certain components have malfunctioned and/or certain abnormal process deviations are assumed to have taken place).

TABLE 9A-1. Qualitative Severity Classification (DOE-STD-3009-94).

Descriptive word	Description
No (or none)	Negligible onsite or offsite impact on people or the environs.
Low	Minor onsite and negligible offsite impact on people or the environs.
Moderate	Considerable onsite impact on people or the environs; only minor offsite impact.
High	Considerable onsite and offsite impacts on people or the environs.

Identification of Preventive and Mitigative Features. Preventive features are those that would prevent a hazard event from occurring under normal operating conditions. Preventive features include both engineered safety features and administrative controls. Items such as pressure-relief valves, gloveboxes, circuit breakers, process controls and monitors are considered engineered features. Administrative controls include requirements to physically separate certain chemicals and fissile material for storage, limiting the quantity of chemicals and fissile material in an area, proper handling and segregation procedures for dangerous or toxic materials, and proper procedures for operating equipment.

Mitigative features are those that minimize the impact of a hazard event once it has occurred (e.g., fire protection systems, filters, barriers, and curbs). Mitigative features also include those that are procedural (evacuation of personnel in the event of a release of a toxic substance, instruction in proper use of fire extinguishers, and first aid).

Qualitative Risk Evaluation. Consequence severity and probability of occurrence were qualitatively assessed for each postulated event. A brief qualitative discussion is provided of the probability of the event and the potential consequence if it were it to occur, taking into consideration the PFP preventive and mitigative features. Risk involves both the consequence and the probability of an occurrence (likelihood) of an event. The consequences can be stated as severity of injuries, releases to the environment, etc. The classification of consequences is shown in Table 9A-1.

Each hazard event has a basic frequency of occurrence that reflects how often (on an average) a particular incident may occur to initiate the hazard sequence that causes the identified effect or harm (injury, damage, or exposure). The probability of occurrence for a given event is based, in part, on past plant experience. In other instances, engineering judgment was used to assess the likelihood of event occurrence. The classification of probability of occurrence is given in Table 9A-2.

TABLE 9A-2. Qualitative Likelihood Classification (DOE-STD-3009-94).

Descriptive word	Estimated annual likelihood of occurrence	Description
Anticipated	$10^{-1} \geq p > 10^{-2}$	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur)
Unlikely	$10^{-2} \geq p > 10^{-4}$	Incidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this probability class include: Uniform Building Code-level earthquake, 100-yr flood, maximum wind gust, etc.
Extremely unlikely	$10^{-4} \geq p > 10^{-6}$	Incidents that will probably not occur during the life cycle of the facility. This class includes the design basis accidents.
Beyond extremely unlikely (incredible)	$10^{-6} \geq p$	All other incidents.

The initial consequence screening used simplified criteria to determine the magnitude of the potential consequences of a hazard. These criteria provided a consistent method of determining the relative consequences of a hazard event, and addressed both radiological and toxicological effects.

Presentation of Hazard Evaluation. A tabular format is used to present the hazard evaluation results for each identified functional area of the facility. The tables are divided into eleven columns in order to present the results of the hazard evaluation in a systematic and understandable format. A brief description of the information presented in each column of the table is provided below.

Column 1 -- the numeric or alpha-numeric hazard identifier

Column 2 -- the system/equipment being evaluated

Column 3 -- a subsystem/activity of the system being evaluated

Column 4 -- the description of the function of the system/subsystem/activity

Column 5 -- failure mode of the system/subsystem/activity

Column 6 -- description of the potentially unmitigated consequences resulting from the failure

Column 7 -- the preventive/mitigative engineered features that may exist

Column 8 -- the preventive/mitigative administrative features that may exist

Column 9 -- relative risk (qualitative) associated with hazard events, taking into consideration the preventive and mitigative features.

Column 10 -- the location of a representative analysis

Column 11 -- pertinent remarks concerning the hazard evaluated.

The information in these eleven columns is organized into five top-level columns according to purpose. Columns 1-4 identify the system being evaluated, columns 5 and 6 characterize the failure, columns 7 and 8 present the preventive/mitigative features for the hazard event, columns 9 and 10 present the qualitative screening of the event, and column 11 provides pertinent remarks concerning the event. Figure 9A-1 presents the format of the hazard evaluation tables.

The hazard evaluations performed for the PFP are grouped into major PFP buildings as follows:

Appendix 9A.1 --The 234-5Z Building

- 9A.1.1 RMA/RMC Line
- 9A.1.2 PFP AL
- 9A.1.3 PPSL
- 9A.1.4 Radiochemical standards laboratory
- 9A.1.5 LI/LO
- 9A.1.6 Storage vaults
- 9A.1.7 Miscellaneous areas

Appendix 9A.2--The 2736-Z Building; Support/Storage Complex

- 9A.2.1 The 2736-Z Building
- 9A.2.2 The 2736-ZA Building
- 9A.2.3 The 2736-ZB Building
- 9A.2.4 The 2736-ZC Building
- 9A.2.5 The 2736-ZD Building
- 9A.2.6 The 2721-Z Building

Appendix 9A.3--The 236-Z Building; PRF

Appendix 9A.4--The 241-Z Building; Waste Storage and Treatment Facility

Appendix 9A.5--The 232-Z Building; Waste Incinerator Facility

Appendix 9A.6--The 243-Z Building; LLWTF

Figure 9A-1. Sample Hazard Evaluation Table.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	

[a]Hazard identifier
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.7--The 291-Z Building; Exhaust fan house

Appendix 9A.8--The 242-Z Building.

The Hazard Evaluation tables for the PFP follow. Each Hazard Evaluation table is preceded by a short description of the building operations. The barriers in the building to contain hazardous materials are discussed, as is the confinement system (if the building has one) designed to mitigate the release of hazardous material should a barrier faliure occur. The confinement system discussion includes a description of the building ventilation system(s). In addition, areas of the building not evaluated within the tables and services/utilities to the building are discussed.

APPENDIX 9A.1

HAZARD EVALUATION

The 234-5Z Building

Appendix 9A.1 provides the hazards evaluation performed for the various processes/operations within the 234-5Z Building. The radiological processes authorized for the 234-5Z Building are reactive material stabilization (by thermal processes) in gloveboxes HC-21C and HA-21I, with gloveboxes HC-18M, HC-18BS, HC-21A, HC-2, HA-28, HC-4, HC-3, and 235-B-5 supporting this process; laboratory functions; and SNM shipping, receiving, sorting, and storage. Other production gloveboxes are used for storage and handling operations.

The 234-5Z Building and its internal walls and equipment function as barriers that provide containment of hazardous materials. The primary barrier in the 234-5Z Building is a process enclosure (e.g., glovebox HA-21I), a process vessel within an enclosure, or a SNM storage or transportation container. The secondary barrier serves to enclose the area containing the primary barrier. An example is the internal building walls defining room 235B, which contains glovebox HA-21I. The 234-5Z Building structure in combination with the building ventilation systems forms a confinement system designed to mitigate the release of hazardous materials upon barrier failure.

The ventilation systems complete the confinement system by providing a controlled, continuous flow of air from the environment into the various building areas and process enclosures, and then back to the environment after HEPA filtration. The ventilation supply air is provided by supply fans located within the 234-5Z Building. The flow of supply air within the building is from uncontaminated areas to potentially contaminated areas (zone 3), and then to normally contaminated areas (zone 4). The air pressure in both zone 3 and zone 4 is normally negative relative to the atmosphere to prevent the movement of airborne material out of the building. The ventilation exhaust systems, designated as E-3 and E-4 for zones 3 and 4, respectively, route the exhaust air to rooms containing banks of HEPA filters. The E-3 exhaust is routed to rooms 311 through 316 and room 318, while the E-4 exhaust is routed to rooms 309 and 310. The E-3 and E-4 systems provide single- and two-stage filtration, respectively. The ventilation system exhaust is discharged to the atmosphere via the 291-Z stack by the 291-Z exhaust fans.

The hazard evaluation for the 234-5Z Building has been divided into seven segments as follows:

9A.1.1 RMA/RMC Process Line
9A.1.2 PFP AL
9A.1.3 PPSL
9A.1.4 Radiochemical standards laboratory
9A.1.5 LI/LO
9A.1.6 Storage vaults
9A.1.7 Miscellaneous areas.

No hazard evaluation was performed for offices, corridors, or maintenance shops as these areas are considered to have hazards that are

normally encountered and accepted by the general public. No hazard evaluation was performed for those operations that are inactive and not authorized for production operations (rooms 166, 169, and 170). These operations are not expected to be placed in operation again and will eventually undergo D&D.

A summary of the active processes/operations within the 234-5Z Building is provided below.

Remote Mechanical A and Remote Mechanical C Lines. The RMA and RMC Lines were used for the plutonium conversion of chemical process systems. This process is inactive and is not authorized for operation. However, all gloveboxes are authorized for interim storage of plutonium-bearing material. In addition, some of the gloveboxes within the RMA and RMC Lines have been converted for use in the thermal stabilization process. The thermal stabilization process is used to reduce the inventory of unstable plutonium-bearing materials that do not meet the criteria for secure, interim storage. Thermal stabilization will be performed in gloveboxes HC-21C and HA-21I in rooms 230A and 235B, respectively. Other gloveboxes, as discussed previously, will be used to support this process.

PFP Analytical Laboratory. The PFP AL, located in rooms 131 through 157A of the 234-5Z Building, is provided for analytical and physical test analyses of plutonium samples to support process control, product quality verification, and nuclear material accountability.

Plutonium Process Support Laboratories. The PPSL is located in the southwest corner of the 234-5Z Building in rooms 179 through 191 and room 202. The laboratory is chartered to operate chemical demonstration facilities involving both nonradioactive and radioactive materials.

Standards Laboratory. The standards laboratory in rooms 221C, 221D, and 221E is devoted to the formulation, verification, packaging, and distribution of actinide-containing standards needed in the laboratories for destructive and nondestructive analysis.

Load-In/Load-Out. Room 227 houses hood HC-227T and glovebox HC-227S. The hood and glovebox are used in the LI/LO and SNM-bearing nitrate solutions blending processes. The hood can accommodate either PR cans or L-10 polyethylene bottles transported in their outer containers. This room may also be used to load feed-grade nitrate into PR cans. Chemicals used for LI/LO are supplied by rooms 336 and 337.

Storage Vaults. The function of the storage vaults is to provide safe and secure storage for SNM. The activities associated with the storage vault operations are the storage, handling, and inspection of SNM containers.

Miscellaneous Areas. The miscellaneous areas include waste drum storage, radioactive mixed waste storage, trash compactor, NDA drum counting and the chemical preparation room. Facilities in rooms 336 and 337 were used to prepare and supply chemicals to the RMC Line and may be used to prepare chemical solutions needed for PFP operations.

A summary of all the rooms within the 234-5Z Building and the general usage of each room is given below.

Room number	Room function/usage
80-90	PPSL Offices
100 - 126	Office areas
127 - 130	Room numbers not used
131 - 157[2]	PFP AL[2]
158 - 164	Office areas/ instrument shop
165, 167, 168	Office areas
166, 169, 170	To undergo D&D
171	Corridor
172[6]	PR can storage[6]
173 - 175[6]	SNM storage vaults[6]
176 - 178	Room numbers not used
179 - 191[3]	PPSL[3]
192, 193[6]	SNM storage vaults[6]
194	Nonradioactive storage
195	Room number not used
196[7]	Waste drum storage[7]
197[7]	Radioactive mixed[7] waste storage
198 - 200	Maintenance shops
201	Nonradioactive storage
202[3]	PPSL[3]
203, 204	Room numbers not used
210 - 216	Material control area
217 - 218	Office areas
219, 220	Room numbers not used
221A, B,	Radiological Control Organization Office and Storage
221C, D, E[4]	Standards laboratory[4]
222, 223	Room numbers not used
224	Corridor
225[6]	PFP AL vault[6]
226	Room number not used
227[5]	LI/LO[5]
228 - 230, 232 and 235[1]	Thermal stabilization process[1]
231	Room number not used
233	RMA Line control room
234[7]	Trash compactor[7]
234A	NDA equipment
236[7]	PR/L-10 storage vault[7]
237 - 244	Room numbers not used
245	Corridor
246 - 249	Room numbers not used

Room number	Room function/usage	Room number	Room function/usage
205 - 209	Office areas	250 - 254	Office areas

[1] Hazard evaluation performed for these areas in Table 9A.1.1
[2] Hazard evaluation performed for these areas in Table 9A.1.2
[3] Hazard evaluation performed for these areas in Table 9A.1.3
[4] Hazard evaluation performed for these areas in Table 9A.1.4
[5] Hazard evaluation performed for these areas in Table 9A.1.5
[6] Hazard evaluation performed for these areas in Table 9A.1.6
[7] Hazard evaluation performed for these areas in Table 9A.1.7

Appendix 9A.1.1

RMA/RMC LINE PROCESS

The RMA and RMC Lines were used for the plutonium conversion chemical process systems. This process is inactive and is not authorized for operation. However, gloveboxes not designated as inactive (see table 9.2.4-1) are authorized for interim storage of plutonium-bearing material. The RMC Line is located approximately in the center of the first floor of the 234-5Z Building. The RMA Line, used in the past for converting plutonium nitrate to shippable plutonium metal and oxide powder, is also located in the 234-5Z Building (in the vicinity of the RMC Line). The line is inactive, but some of the equipment is used for other processes. The thermal stabilization process uses some of the gloveboxes located in rooms 230A, 230B, 235B, and 235C that were formerly used for RMA and RMC Line operations. The primary mission of this process is to reduce the inventory of unstable plutonium bearing materials that do not meet the criteria for safe and secure long-term storage.

Plutonium bearing materials are sealed into glovebox HC-21A, removed from the package, weighed, placed into a container called a boat, and then transferred via the conveyor system to glovebox HC-21C or HA-21I. The boat is placed into a muffle furnace and the appropriate temperature controller program is started. The controller ramps and holds the furnace temperature specifically for the type of material being processed. The material is cooled, ground, blended, and sampled to verify that < 1% of the volatiles remain. The processed material is then packaged for long-term storage.

There are three categories of SNM that are thermally stabilized in gloveboxes HC-21C and HA-21I. The furnaces in HC-21C stabilize chemically reactive plutonium sludge residues (which include centrifuge, PRF glovebox, and canyon sludges), oxides (which include plutonium fluoride, plutonium oxide, plutonium oxalate, and plutonium oxycarbonate), and incinerator ash (ash from the RFP incinerator and the 232-Z incinerator). The furnaces in HA-21I will primarily be used to thermally stabilize low fired oxide materials from the 2736-Z Building vault inventories.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	RMA/RMC Line areas, general	A. Container handling inside of rooms, but outside of gloveboxes.	To safely handle SNM containers as necessary to support operations.	(1) Dropped container	Potential release of SNM to the room. Potential entrainment in the E-3 ventilation exhaust system and release to the environment.	SNM containers resistant to gross failures as a result of a drop. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered E-3 exhaust system.	Packaging requirement for double containment. Procedure governing operator response to a spill. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to sections 9.1.1, "Radioisotope-Bearing Liquid Spills," and 9.1.3 "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Inadequate container spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency.	Lard cans and food pack cans are transported in fixed array wagons. Drums are moved one at a time using drum barrel hand trucks. CAS to detect a criticality and to activate criticality alarms.	Procedure governing the transportation of SNM. Procedure governing operator response to a criticality alarm.	Inadequate spacing is an anticipated event. There is judged to be no consequence.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005
		B. Ventilation supply system	In conjunction with the E-3 exhaust system, provides airflow to maintain the correct DP between zones.	(1) Insufficient supply airflow	Potential increased DP between zones 3 and 1.	Five operating and three backup supply fans. Pressure sensors/alarms and dampers monitor and control the supply airflow to each zone. Safety interlocks between supply and exhaust fans.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7F, "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow	Potential loss of DP between zones 3 and 1. Potential release of SNM to zone 1 areas and to the environment.	Pressure sensors/alarms and dampers monitor and control the airflow to each zone. E-3 exhaust to maintain DP. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization - 234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		C. E-3 exhaust system	In conjunction with ventilation supply system, provides airflow to maintain the correct DP between zones.	(1) Insufficient exhaust flow	Potential loss of DP between zones 3 and 1. Potential spread of contamination to zone 1 areas.	Four operating and three backup exhaust fans. Pressure sensors/alarms and dampers monitor and control the exhaust flow from each zone. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization - 234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	RMA/RMC Line areas, general (continued).	C. E-3 exhaust system (continued).	To provide airflow to maintain the correct DP between zones. (continued)	(2) Excessive exhaust flow	Potential increased DP between zones 3 and 1.	Pressure sensors/alarms and dampers monitor and control the exhaust flow from each zone.	Procedure governing operator response to a ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7F, "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005
		D. E-3 exhaust system HEPA filters.	To filter room exhaust through a single-stage of HEPA filtration before it is discharged to the environment.	Loss of HEPA filtration.	Potential release of SNM to the environment.	Seven parallel HEPA filter banks located in seven filter rooms; any three are in use simultaneously with the remainder on standby. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing HEPA filter maintenance and testing. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
2	RMA/RMC Line gloveboxes, general	A. Glovebox enclosure	Confinement of SNM	Loss of confinement.	Potential release of SNM to the room. Potential entrainment in the exhaust ventilation system and release to the environment.	Steel glovebox with shatter-resistant Lexan™ windows. E-4 exhaust ventilation system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a CAM alarm. Procedure governing inspection and maintenance of glovebox.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	The hazard analyses for "Gloveboxes, General" are typical for all gloveboxes. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Ventilation supply system (inleakage through inlet HEPA filters)	In conjunction with the E-4 exhaust system, provides airflow to maintain the correct negative DP between zones 3 and 4.	(1) Insufficient supply airflow	Potential excessive negative pressure. Potential loss of confinement, release of SNM to the room, and entrainment in the ventilation exhaust system.	Dry air system provides supply airflow to glovebox. Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow	Potential pressurization of the glovebox and loss of confinement. Potential release of SNM to the room and entrainment in the exhaust ventilation system. Potential release to the environment.	Two-stage HEPA-filtered E-4 exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm.	This event is very unlikely. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Spill."	Interconnection of RMA/RMC line gloveboxes minimizes the effects of pressure excursions. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		C. Ventilation supply system, glovebox inlet HEPA filters	To filter glovebox exhaust in the event of a flow reversal in order to mitigate the release of SNM.	Loss of filtration	Potential release of SNM to the room. Potential entrainment in the exhaust ventilation system and release to the environment.	Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust system (E-3).	Procedure governing operator response to CAM alarm. Procedure governing operator response to glovebox DP outside of operating limits.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	RMA/RMC Line gloveboxes, general (continued)	D. Dry air system (note: dryers are not functional)	In conjunction with the E-4 exhaust system, provides airflow to maintain the correct negative DP between zones 3 and 4.	(1) Insufficient supply airflow	Potential excessive negative DP. Potential loss of confinement and release to the room. Potential entrainment in the ventilation system and release to the environment.	Two-staged HEPA-filtered E-4 exhaust system. Glovebox outlet HEPA filter. Air flows through a self-governing regulating valve rated at 250 $stdft^3$/min. Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm. Procedure governing operator response to glovebox DP outside of operating limits.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	Gloveboxes HC-7, HC-60 and HC-235-B-2 are not supplied by the dry air system. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow	Potential glovebox pressurization. Potential loss of confinement and release of SNM into the room. Potential entrainment in the ventilation exhaust system and release to the environment.	CAMs to detect airborne contamination and to activate alarms. Two-staged HEPA-filtered E-4 exhaust system. Sufficient exhaust flow to remove full-open supply air. Glovebox pressure monitored in power control room and alarms if pressure exceeds -0.3 in w.g. PRV on glovebox air supply.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. Dry air gloveboxes are equipped with self-actuating supply valves that reduce the supply air flow to maintain the proper glovebox pressure. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		E. Glovebox exhaust HEPA filters	To filter the glovebox exhaust in order to mitigate the release of SNM.	Loss of filtration.	Potential entrainment of SNM in the exhaust ventilation system. Potential release to the environment.	HEPA filter DP gauge on glovebox outlet HEPA filters. Two-stage HEPA-filtered E-4 exhaust system. 291-Z-1 stack CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to HEPA filter DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		F. E-4 exhaust system	In conjunction with the supply systems, provides airflow to maintain the correct negative DP between zones 3 and 4.	(1) Excessive exhaust flow	Potential excessive negative DP. Potential loss of confinement and release to the room. Potential entrainment in exhaust system and release to the environment.	Glovebox outlet HEPA filter. Glovebox DP gauge. HEPA-filtered ventilation exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Insufficient exhaust airflow	Potential glovebox pressurization and loss of confinement. Potential release of SNM to the room and entrainment in the exhaust system.	Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	RMA/RMC Line gloveboxes, general (continued)	G. E-4 exhaust system HEPA filters.	To filter the glovebox exhaust through two stages of HEPA filtration before it is discharged to the environment.	Loss of filtration.	Potential release of SNM to the environment.	Glovebox outlet HEPA filters. E-4 exhaust system has one operating and one standby filter bank room (each containing 128 filters). 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing maintenance and testing of HEPA filters. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
3	Room 228, glovebox HC-1 (houses the conveyor system).	A. Conveyor	Automated transport of materials between RMA and RMC Line gloveboxes.	(1) Loss of automated transport.	Material must be transferred by hand using the HC-1 gloveports, resulting in increased extremity and whole body exposures to operators.	–	–	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
		B. Handling and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	(1) Inadequate container spacing.	Potential criticality resulting in high levels of radiation within the room and a release of fission products to the atmosphere. Potential release of SNM to the room and entrainment in the exhaust system.	CAS to detect a criticality and to activate criticality alarms. HEPA-filtered ventilation exhaust system. CAMs to detect airborne contamination and to activate alarms.	Double-contingency principle. CPS posted on glovebox specifies allowable spacing. Procedure governing operator response to a criticality alarm. Procedure governing operator response to a CAM alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Dropped container/ container failure	Potential spill of SNM within the glovebox. Potential airborne release and entrainment of plutonium in glovebox ventilation system.	Glovebox confinement. Two-stage HEPA-filtered exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to a spill of SNM. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
4	Room 228A, gloveboxes HC-7, HC-9B, HC-10, and HC-11.	Repackaging and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to items 3B.	Refer to item 3B.	Glovebox HC-7 is not supplied by the dry air system. Supply air is from room through two inlet HEPA filters. The glovebox is authorized for interim storage and repackaging of SNM. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
5	**Room 228A, gloveboxes HC-7 and HC-9B.**	Criticality drain	To drain liquid from the glovebox in order to prevent the accumulation of a critical volume of solution.	Failure to adequately drain liquid.	Potential criticality that results in high levels of radiation within the room and a release of fission products to the atmosphere.	Drains are protected from plugging by large mesh screens. CAS to detect a criticality and to activate criticality alarms.	Double-contingency principle. Procedure governing operator response to nonfunctional criticality drain. Procedure governing operator response to criticality alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-008
6	**Room 228B, gloveboxes HC-12S, HC-13MD, HC-15ABC, HC-16CC**	Repackaging and storage SNM-bearing containers	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.
7	**Room 228C, gloveboxes HC-5, HC-17-SBB, HC-17DC, HC-17P, HC-18BS, and HC-18M.**	Repackaging and storage of plutonium-bearing containers	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.
8	**Room 228C, glovebox HC-5 (houses conveyor system).**	Conveyor	Automated transport of materials between RMA and RMC Line gloveboxes.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	
9	**Room 228C, glovebox HC-18M (contains TGA)**	A. E-4 exhaust	To remove the heat generated by the TGA.	Buildup of heat.	Potential loss of glovebox confinement. Potential release of SNM to the room and entrainment in the ventilation exhaust system.	Four operating and three backup exhaust fans. Pressure sensors and dampers monitor and control the exhaust flow from each zone. Two exhaust fans connected to backup power. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. TGA	Used in Loss-on-ignition (LOI) analysis to determine the amount of volatiles remaining in the product.	(1) Excessive temperature	Potential loss of the TGA.	The TGA high-temperature alarm switch and associated thermocouple. The alarm switch is designed to cut TGA power when the high temperature limit is exceeded.	Procedure governing operator response to TGA high-temperature alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 228C, glovebox HC-18M (contains TGA) (continued)	B. TGA (continued)	Used in Loss-on-ignition (LOI) analysis to determine the amount of volatiles remaining in the product. (continued)	(2) Low temperature	Potential incomplete removal of volatiles resulting in potentially invalid LOI results. Potential storage of reactive material in the vaults.	Temperature/time regimes are computer-controlled.	Procedure governing LOI analysis. Procedure governing maintenance and calibration of TGA system.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	Refer Appendix 9A.2.1 "2736-Z -- Vault storage of SNM" and Appendix 9A.2.2 "2736-ZA -- Exhaust ventilation and filtration of 2736-Z."
				(3) Temperature ramps up too quickly	Potential loss of the TGA.	Temperature/time regimes are computer-controlled.	Procedure governing LOI analysis. Procedure governing maintenance and calibration of TGA system.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
				(4) Insufficient time at temperature	Potential incomplete removal of volatiles resulting in potentially invalid LOI results. Potential storage of reactive material in the vaults.	Temperature/time regimes are computer-controlled.	Procedure governing LOI analysis. Procedure governing maintenance and calibration of TGA system.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	Refer to Appendix 9A.2.1 "2736-Z -- Vault storage of SNM" and Appendix 9A.2.2 "2736-ZA -- Exhaust ventilation and filtration of 2736-Z"
		C. Hydraulic fluid reservoir (basement level of glovebox)	Supplies hydraulic fluid to pump that operated several rams in the RMC Line (hydraulic rams are no longer used).	Leak from reservoir or pressurized leak from hydraulic lines in the basement level or beneath other RMC Line gloveboxes (if hydraulic pump inadvertently operated).	Operational upset (glovebox activity halted until spill cleaned up). - Non-fire case. Fire in Glovebox HC-18M basement if hydraulic fluid spill heated above its flashpoint and an ignition source is present. Potential loss of glovebox confinement with minor contamination spread to Room 228C.	Glovebox HC-18M basement airspace is not common with RMC Line airspace. Separate Halon fire suppression system in Glovebox HC-18M basement. E-3 ventilation system filters mitigate release to environment of radiological material released from glovebox. CAMs to detect airborne contamination and to activate alarms.	Spill response procedure. Procedure governing operator response to CAM alarm. RMC Line process is in standby status. No reason for hydraulic pump to be operated. Hanford fire department response.	Spill/leak without fire is anticipated. Spill with subsequent fire is extremely unlikely. The consequence is judged to be low.	Refer to section 9.2.2A "Remote Mechanical C Line Fire" as bounding case.	Actuators are outside gloveboxes. Hydraulic lines do not penetrate into RMC Line gloveboxes. The hydraulic fluid is in lines and equipment below the areas where it could contact radioactive materials or other residues; therefore, a leak would not cause a reactive chemical hazard. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-010 WHC-SD-CP-SDD-011
10	**Room 228C, glovebox HC-18BS**	Storage rack	To maintain container separation for the purpose of criticality safety.	Loss of container separation.	Potential criticality and release of fission products to the atmosphere. Potential entrainment of SNM in the exhaust system and release to the environment.	CAS to detect a criticality and to activate criticality alarms. Two-staged HEPA-filtered exhaust system.	Double-contingency principle. Procedure governing operator response to a criticality alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
11	**Room 228C, gloveboxes HC-17-SBB, HC-17DC, and HC-17P**	Repackaging and storage of SNM-bearing containers	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.
12	**Room 230, gloveboxes HC-2, HC-3, and HC-4 (houses the conveyor system).**	Conveyors	Automated transport of materials between RMC Line gloveboxes	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	
13	**Room 230, glovebox HC-4**	Criticality drain	To drain liquid from the glovebox in order to prevent the accumulation of a critical volume of solution.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.
14	**Room 230A, glovebox HC-21C (contains two muffle furnaces with CO, purge, and two desiccators)**	A. Material handling	To safely handle material as necessary to support operations.	(1) Inadequate container spacing.	Refer to item 3B(1).	Refer to item 3B(1).	Refer to item 3B(1).	Refer to item 3B(1).	Refer to item 3B(1).	Refer to item 3B(1).
				(2) Contact with hot surfaces	Potential breach of glovebox gloves. Potential release of SNM to the room. Potential entrainment in the exhaust system and release to the environment.	Furnace door interlock designed to cut power to the furnace when the door is opened. Glovebox temperature is monitored by three thermocouples. Glovebox high temperature alarms. Furnace power is cut when the glovebox temperature exceeds operating limit. CAMs to detect airborne contamination and to activate alarms. Fire suppression system. HEPA-filtered exhaust system.	Procedure governing required protective equipment (i.e., heat-resistant gloves). Procedure governing furnace operations. procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 230A, glovebox HC-21C (continued)	A. Material handling (continued)	To safely handle material as necessary to support operations. (continued)	(3) Overfill or dropped boat during insertion in or removal from furnace.	Potential spill within the glovebox. Potential entrainment of SNM in the exhaust ventilation system.	Glovebox confinement. Two-stage HEPA-filtered E-4 exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to a spill of SNM within the glovebox. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		B. Halon system	To contain Halon until necessary to suppress a fire within the glovebox.	(1) Failure to suppress the fire.	Potential loss of confinement. Potential release of SNM to the room and entrainment in the ventilation system. Potential release to the environment.	Portable fire extinguishers. Halon system interlocked with the RMC Line emergency exhaust fire damper. HEPA-filtered exhaust ventilation systems (E-3 and E-4). CAMs to detect airborne contamination and to activate alarms.	Procedure governing inspection of the Halon system. Procedure governing operator response to a fire. Procedure governing operator response to a CAM alarm. Response of the HFD.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.2C, "Glovebox HA-21I Fire."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-010 WHC-SD-CP-SDD-011
				(2) Accidental discharge of the Halon fire system.	Potential pressurization of the glovebox relative to the room. Potential loss of confinement and a release of SNM into the room. Potential entrainment in the ventilation exhaust system and release to the environment.	E-4 ventilation system designed to maintain negative DP of glovebox during discharge of Halon system.	Procedure governing inspection of the Halon system. Procedure governing operator response to Halon system discharge.	This event is unlikely. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-010
		C. Glovebox muffle furnace	Controlled heating of reactive SNM in order to stabilize it for long-term storage.	(1) Excessive temperature	Potential loss of the furnace. Potential generation of a ceramic-like product.	High-temperature alarm switch and associated thermocouple to monitor furnace temperature. The alarm switch is designed to cut power to the furnace if the high temperature limit is exceeded.	Procedure governing operator response to high temperature alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed	
				(2) Low temperature	Potential incomplete removal of volatiles. Potential storage of reactive material in the vaults. Potential loss of containment event in the vaults.	Temperature regime is computer-controlled.	Procedure governing the LOI analysis used to verify volatiles have been removed.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	Refer to Appendix 9A.2.1 "2736-Z -- Vault storage of SNM" and Appendix 9A.2.2 "2736-ZA -- Exhaust ventilation and filtration of 2736-Z."

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 230A, glovebox HC-21C (continued)	C. Glovebox muffle furnace (continued)	Controlled heating of reactive SNM in order to stabilize it for long-term storage. (continued)	(3) Temperature ramps up too quickly	PRF sludge: potential accumulation of butene gas to flammable concentrations. Potential ignition and loss of confinement. Potential release of SNM to the room and entrainment in the ventilation system.	Temperature regimes are computer-controlled. An audible alarm and a window in the annunciator panel lights when the temperature in the furnace deviates from the set point. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust system.	Procedure governing organic content limit of feed material. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.1C, "Deflagration in Glovebox HA-21I."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
					Oxide/ash: potential rapid oxidization of carbon to both CO and CO_2. Potential CO accumulation flammable concentrations.	Temperature regimes are computer-controlled. An audible alarm and a window in the annunciator panel lights when the temperature in the furnace deviates from the set point.	--	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.1C, "Deflagration in Glovebox HA-21I."	Plutonium oxide is simply dried with no chemical reactions taking place and H_2O the only offgas expected. WHC-SD-CP-SDD-005
					RMC Line oxycarbonate type items: potential spill of material onto furnace bottom due to foaming. Potential plugging of offgas line and filter. Potential accumulation of high temperature offgas in glovebox and loss of confinement.	Furnace baffles designed to prevent material from entering exhaust system. Temperature regime is computer-controlled. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust system.	--	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(4) Insufficient time at temperature	Refer to item 14C(2).	Refer to item 14C(2).	Refer to item 14C(2).	Refer to item 14C(2).	Refer to item 14C(2).	Refer to item 14C(2).
				Loss of containment	Potential ignition of combustible materials and loss of glovebox confinement. Potential release of SNM to the room and entrainment in the exhaust system.	Glovebox thermocouples monitor temperature and activate alarm when temperature exceeds set-point. Power to furnace cut when the glovebox temperature exceeds the setpoint limit. Halon fire suppression system. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust system.	Procedure governing operator response to high temperature alarm. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be moderate.	Refer to section 9.2.2C, "Glovebox HA-21I Fire."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-010 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 230A, glovebox HC-21C (continued)	D. 26-in.-Hg vacuum system	To remove the offgas from the furnace.	(1) Insufficient vacuum	PRF sludge: Potential butene CO gas concentration in excess of LFL. Potential ignition and breach of glovebox. Potential release of SNM to the room and entrainment in the exhaust system.	Temperature/time regimes computer-controlled to assure that all of the TBP has decomposed before reaching auto ignition temperature of butene. CO_2 flow. Glovebox ventilation. CAMs to detect airborne contamination. HEPA-filtered exhaust system.	Procedure governing organic content limit of feed material. Procedure governing operator response to loss of vacuum. Procedure governing verification of exhaust flow rate. Procedure governing operator response to CAM alarm.	This event is unlikely. The consequences are judged to be moderate.	Refer to section 9.2.1C, "Deflagration in Glovebox HA-21I."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
					Oxide/ash: Potential entry of hot offgases into glovebox. Potential loss of containment and release of SNM to the room. Potential entrainment in the exhaust system and release to the environment.	E-4 exhaust ventilation system. Temperature/time regimes computer-controlled. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
					RMC Line oxycarbonate: Potential entry of offgases into glovebox. Potential loss of containment and release to the room. Potential entrainment in the ventilation system and release to the environment.	Refer to item above.	Refer to item above.	Refer to item above.	Refer to item above.	Refer to item above.
				(2) Excessive vacuum	Potential entrainment of flighty material into the offgas filters. Potential plugging of filters and pressurization of the furnace with a release of hot offgases to the glovebox. potential loss of confinement and entrainment in the ventilation system.	E-4 exhaust system maintains glovebox at a negative DP relative to the room. Screen placed over the boat containing SNM. CAMs to detect airborne contamination and to activate alarms.	Procedure governing verification of offgas flow rate. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 230A, glovebox HC-21C (continued)	E. Muffle furnace CO_2 system (used only during the processing of PRF sludge)	Provides CO_2 covergas to the furnace.	(1) Insufficient CO_2 cover gas.	Potential concentration of butene gas or CO in excess of the LFL. Potential ignition and breach of the glovebox. Potential release of SNM to the room and entrainment in the exhaust system.	Two 384-lb CO_2 bottles are manifolded such that the system automatically switches to the second bottle when the first one empties. Liquid level indicators. An audible alarm activates when the manifold switches. CAMs to detect airborne contamination. HEPA-filtered exhaust system.	Procedure governing operator verification of the offgas/CO_2 flow rate settings. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be moderate.	Refer to section 9.2.1C, "Deflagration in Glovebox HA-21I."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excess CO_2	Potential entrainment of flighty material in offgas and plugging of the filters. Potential pressurization of the furnace and the glovebox with a release of SNM into the room. Potential entrainment in the exhaust system.	CO_2 flow is controlled by a rotameter that acts as an orifice to limit the maximum flow into the glovebox. 26-in. mercury vacuum system. E-4 ventilation exhaust system. Screen on top of boat containing SNM.	Procedure governing operator verification of the offgas/CO_2 flow rate settings.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005
		F. CO_2 gas cylinders	To safely store liquid CO_2.	Leak or cylinder damage due to handling accident.	Potential cryogenic burns to operators. Potential asphyxiation hazard to operators. Pressurization of Room 230A from vaporized gas released from cylinder.	Cylinder restrained within storage cabinet. Cylinders vent approximately 2 lb of CO_2 per day to reduce buildup of pressure. Ring at top of cylinder protects supply valve from damage. Room ventilation flow dilutes carbon dioxide evaporating off spill. Room vents from near floor. Safety relief valve prevents cylinder from failing due to overpressurization.	Procedure governing transportation of gas cylinders. Special liquid cylinder hand trucks used to transport cylinders.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization - 234-5Z"	Carbon dioxide is in liquid phase and not under high pressure. Heat transfer limits evaporation rate. WHC-SD-CP-SDD-005
		G. Line containing CO_2 gas.	To transport CO_2 from the cylinder to the HC-21C glovebox muffle furnaces.	Line break in one of the flexible hoses.	Potential breach of the glovebox and a release of SNM into the room. Potential entrainment in the exhaust system and release to the environment.	Pressure-reducing valve at CO_2 cyliner. Two-stage HEPA-filtered E-4 exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a CAM alarm.	This event is unlikely. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	Flowrate into glovebox through breached hose is limited to sonic velocity. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.1
The 234-5Z Building
RMA and RMC Lines
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 230A, glovebox HC-21C (continued)	H. E-4 exhaust system	To remove the heat generated by the muffle furnace.	Buildup of heat.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.
15	**Room 230B, glovebox HC-21A (houses a grinder, a V-blender, a storage rack, a mortar and pestle, and a balance).**	A. Loading and unloading SNM in the grinder or blender.	To safely move SNM to and from the blender.	Dropped container	Potential spill of SNM. Potential entrainment of SNM in the exhaust ventilation system and release to the environment.	Glovebox enclosure and exhaust HEPA filter. Two-stage HEPA-filtered E-4 exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to a spill. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		B. Grinder, blender	To contain SNM during grinding and mixing operations used to break up and mix large chunks of dried, stabilized material to ensure a representative sample is obtained for LOI analysis.	(1) Loss of containment	Excessive airborne PuO_2 dust within the glovebox. Potential release to the room and entrainment in the ventilation system.	Glovebox enclosure. Two-stage HEPA-filtered E-4 exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Incomplete mixing	Potential for LOI sample to be nonrepresentative of material. Potentially invalid LOI analysis and storage of reactive material in the vaults.	--	Procedure governing grinding and mixing operations.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	Refer to Appendix 9A.2.1 for analysis of storage of reactive material.
16	**Room 230C, glovebox HC-60**	Handling and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Not supplied by the dry air system. Supply air is by inleakage through two inlet HEPA filters. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
17	**Room 232, glovebox HA-46/ Cell 46**	--	Glovebox is not currently in use.	--	--	--	--	--	--	Contains the KOH scrubber system which is no longer in use. No activities planned at this time.

Table 9A.1.1
The 234-5Z Building
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(Rooms 228, 230, 232, and 235).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
18	Room 235, gloveboxes HA-28 and HC-4 (houses the conveyor system).	Conveyor	Automated transport of material between RMA/RMC Line gloveboxes.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.
19	Room 235B, C glovebox HA-19 feed/lag storage awaiting to be processed.	Handling and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.
20	Room 235B, C glovebox HA-20MB	Handling and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.
21	Room 235B, C glovebox HA-21I (contains three muffle furnaces).	A. E-4 exhaust system	To remove the heat generated by the muffle furnace.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.
		B. Glovebox muffle furnace	To provide controlled heating of reactive SNM in order to stabilize it.	Refer to item 14C (except 14C(3), PRF Sludge).	Refer to item 14C (except 14C(3), PRF Sludge).	Refer to item 14C (except 14C(3), PRF Sludge).	Refer to item 14C (except 14C(3), PRF Sludge).	Refer to item 14C (except 14C(3), PRF Sludge).	Refer to item 14C (except 14C(3), PRF Sludge).	Refer to item 14C (except 14C(3), PRF Sludge).
		C. Glovebox dry chemical fire system.	To extinguish a fire should it occur inside the glovebox.	Failure to extinguish the fire.	Potential loss of glovebox confinement. Potential release of SNM to the room and entrainment in the ventilation system.	Two-stage HEPa-filtered exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a CAM alarm. Manual fire extinguishers. HFD.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.2C, "Glovebox HA-21I Fire."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-010 WHC-SD-CP-SDD-011
		D. 5-in.-Hg vacuum system	To remove the offgas from the furnace.	Refer to item 14D (except 14D(1), PRF Sludge).	Refer to item 14D (except 14D(1), PRF Sludge).	Refer to item 14D (except 14D(1), PRF Sludge).	Refer to item 14D (except 14D(1), PRF Sludge).	Refer to item 14D (except 14D(1), PRF Sludge).	Refer to item 14D (except 14D(1), PRF Sludge).	Refer to item 14D (except 14D(1), PRF Sludge).
22	Room 235B, C glovebox HA-23S (feed/lag storage awaiting to be processed).	A. Handling and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.

Table 9A.1.1
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 235B, C, glovebox HA-23S (continued)	B. Criticality drain	To drain liquid from the glovebox in order to prevent the accumulation of a critical volume of solution.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.	Refer to item 5.
23	**Room 235B, C glovebox 235-B-2 (repackaging glovebox).**	Repackaging of 55-gal TRU waste and LLW drums for compliance with Hanford and WIPP criteria.	--	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Not supplied by the dry air system. Supply air is from room through three inlet HEPA filters. Refer to item 3B.
24	**Room 235B, glovebox 235-B-5 (space available for feed preparation and a balance, a commercial grade electric can opener).**	Handling and storage of SNM-bearing containers.	To safely handle containers as necessary to support operations.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.	Refer to item 3B.

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.1.2

PFP ANALYTICAL LABORATORY

The PFP AL, located in the southeast corner of the 234-5Z Building in rooms 131 through 157, is used to perform analytical and physical test analyses on plutonium samples supporting process control, product quality verification, and nuclear material accountability. The samples come from the plant operations within the PFP, the research laboratory within the PFP, and a few special test samples from other locations.

Laboratory analysis is performed in rooms 131 through 157 on samples received from the PFP Operations, or others. Measurements include fissile material content, impurities, isotopic content, specific gravity, density, and LOI for oxide powders. Some of the gloveboxes contain argon, thus there is a potential for an argon release to the room and throughout the laboratory. There are fire suppression systems in the laboratory, therefore an earthquake could result in a release of water to the laboratory.

To ensure the safe storage of plutonium bearing materials, it is important to determine the amount of volatiles within the oxide material. By weighing the sample before and after heating, the weight loss or LOI can be calculated. This method was adopted for measuring the weight loss of any solid material. The muffle furnace used can be programmed for heating at any temperature up to 1000 °C for several hours. A controlled rate of heating will allow the temperature to increase at a constant rate (degrees per minute) until the desired setting is reached. A standard is used to provide a check against improper weighing. If the volatile content of a sample is high (1.0% or higher), the sample is reheated to ensure the volatiles are driven off.

The PFP AL contains 33 gloveboxes (two of which are inactive) and 38 hoods. An administrative limit of 5.25 kg of plutonium, of which not more than 2.25 kg is >10% ^{240}Pu, has been established. This material, in the form of a powder or a solution, could be located within gloveboxes, hoods, or both.

The samples received and analyzed in the PFP AL represent process control, material accountability, and product analysis. Both chemical analyses and physical tests are performed. The samples may be liquids, solids (metal and oxide), or substrate captured (filter media).

The PFP AL is located in rooms 131 through 157 of the 234-5Z Building, with quality control standards being formulated and dispensed from rooms 221-C, -D, and -E. The NDA drum counting activities in rooms 192 and 234A are also part of the PFP AL operations.

All laboratory activities are governed by appropriate procedures. The activities are performed by trained personnel and their performance is monitored by a quality control program that includes analysis of standards, compliance overchecks, and audits.

The PFP AL uses common scientific instruments and equipment in an approved manner. The samples analyzed are highly radioactive and have the potential for impacting the safety of personnel.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.1.2
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	PFP AL, general	A. Transportation of SNM	To safely move SNM within the PFP AL.	(1) Inadequate container spacing	Loss of a single contingency for criticality safety. Potential criticality should an additional contingency be lost.	Lard cans and food-pack cans are transported in fixed array wagons. 30- to 55-gal drums are moved one at a time using drum barrel hand trucks. CAS to detect criticality and to activate criticality alarms.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing transportation of SNM. Procedure governing operator response to criticality alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3 "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
				(2) Dropped container	Potential breach of SNM container. Potential release of respirable plutonium to the room and environment through the room ventilation system.	Carriers (drum barrel hand truck, fixed array wagon, lard can wagon) are designed for specific operation. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation exhaust system (E-3).	Procedure governing transportation of SNM. Packaging requirements call for double containment. Procedure governing operator response to a spill. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to sections 9.1.1 and 9.1.3 on radioisotope-bearing spills (liquid and powder).	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system	In conjunction with E-3 exhaust system, provides airflow to maintain the DP between zones.	(1) Insufficient supply airflow	Potential increased DP between zones 3 and 1.	Five supply fans normally operating, three fans provide backup. Pressure sensors/alarms and dampers monitor and control the supply airflow to each zone. Single-stage HEPA filtered ventilation exhaust system (E-3).	Procedure governing operator response to a ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005
				(2) Excessive supply airflow	Potential loss of DP between zones 3 and 1. Potential spread of contamination to zone 1 areas and release to the environment.	Pressure sensors/alarms and dampers monitor and control the supply airflow to each zone. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a ventilation system upset. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization - 234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.2
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	PFP AL, general (continued)	C. E-3 ventilation exhaust system	In conjunction with the ventilation supply system, provides airflow to maintain the DP between zones.	(1) Insufficient exhaust airflow	Potential loss of DP between zones 3 and 1. Potential spread of contamination to zone 1 areas and release to the environment.	Four exhaust fans normally operating, three fans provide backup. Pressure sensors and dampers monitor and control the exhaust airflow from each zone. Two electric exhaust fans connected to backup power. Supply fans to the facility are automatically shutdown on high pressure in the exhaust plenum. Zone 1 exhaust fans shutdown or shutdown of the Zone 3 supply fans. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a ventilation system upset. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization - 234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive exhaust airflow	Potential increased DP between zones 3 and 1.	Pressure sensors and dampers monitor and control the exhaust airflow from each zone.	Procedure governing operator response to a ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7F "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005
		D. E-3 ventilation exhaust system HEPA filters.	To filter the room exhaust air through a single-stage of HEPA filtration before it is discharged to the environment.	Loss of HEPA filtration.	Potential release of SNM to the environment.	Seven parallel HEPA filter banks located in seven filter rooms; any three are in use simultaneously with the remaining on stand-by. Testable HEPA filters. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing HEPA filter maintenance and testing. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
2	PFP AL, gloveboxes: general	A. Glovebox enclosure	Confinement of SNM.	Loss of confinement.	Potential release of SNM to the room. Potential entrainment in the ventilation exhaust system and release to the environment.	Glovebox is of steel construction with Lexan™ windows. Lexan™ will not shatter upon strong impact. E-4 exhaust ventilation system maintains glovebox at a negative DP relative to the room. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm. Procedure governing glovebox maintenance.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	The hazard analyses for "Gloveboxes, general" are typical for all gloveboxes. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.2
The 234-5Z Building
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	PFP AL, gloveboxes: general (continued)	B. Ventilation supply system (inleakage through inlet HEPA filters)	In conjunction with the E-4 exhaust system, provides airflow to maintain the correct negative DP between zones 3 and 4.	(1) Insufficient supply airflow	Potential excessive negative DP. Potential breach of confinement. Potential release of SNM to the room and entrainment in the ventilation exhaust system.	Glovebox DP gauge. Five operating and two backup supply fans. HEPA-filtered ventilation exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow	Potential pressurization of the glovebox. Potential release of SNM to the room and entrainment in the E-3 ventilation exhaust system. Potential release to the environment.	E-4 exhaust system will maintain glovebox DP negative relative to the room. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a CAM alarm.	This event is incredible because supply air is provided by inleakage from the room through inlet HEPA filters.	Refer to section 9.1.9, Glovebox Glove Breach."	WHC-SD-CP-SDD-005
		C. Ventilation supply system inlet HEPA filters	To filter the glovebox exhaust in the event of a flow reversal in order to mitigate the release of SNM from the glovebox.	Loss of filtration.	Potential release of SNM to the room. Potential entrainment in the ventilation exhaust system and release to the environment.	Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust ventilation system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		D. Glovebox exhaust HEPA filters	To filter the glovebox exhaust to mitigate the release of SNM from the glovebox.	Loss of filtration	Potential increased ventilation exhaust system contamination. Potential release of SNM from the ventilation exhaust system to the environment.	HEPA filter DP gauge. Two-stage HEPA-filtered ventilation exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to HEPA filter DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
		E. E-4 ventilation exhaust system	In conjunction with the supply system, provides airflow to maintain the correct negative DP between zones 3 and 4.	(1) Excessive exhaust airflow	Potential excessive negative DP. Potential loss of confinement and entrainment of any loose SNM into the ventilation exhaust system.	Glovebox outlet HEPA filter. Glovebox DP gauge. HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits.	This event is incredible because the E-4 exhaust fans draw air into the glovebox from the room.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Insufficient exhaust airflow	Potential glovebox pressurization, loss of confinement, release of SNM into the room, and entrainment in the E-3 exhaust system.	Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust ventilation system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	PFP AL, gloveboxes: general (continued)	F. E-4 exhaust system HEPA filters	To filter the E-4 ventilation exhaust before it is discharged to the environment.	Loss of filtration.	Potential release of SNM to the environment.	Glovebox outlet HEPA filters. Two E-4 ventilation exhaust system filter bank rooms (one in operation and the other on standby) containing 128 filters each. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing testing and maintenance of HEPA filters. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
3	**Room 131 chemical assay laboratory, glovebox (three sections used for dissolution and analysis of product quality plutonium).**	A. Handling of SNM	To safely handle SNM as necessary to support operations.	Inadequate container spacing.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional criticality.	CAS to detect a criticality and to activate criticality alarms.	Double-contingency principle. CPS posted on glovebox specifies the mass, volume, and spacing limits. Procedure governing operator response to a criticality alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3 "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
4	**Room 131 (continued), glovebox section 1 (contains a muffle furnace).**	A. Glovebox enclosure	Confinement of SNM and serves as airlock.	Loss of confinement	Potential release of SNM to the room. Potential entrainment in the ventilation exhaust system and release to the environment.	Glovebox DP gauge. Single-stage HEPA-filtered E-3 ventilation exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Material handling	--	(1) Contact with hot surfaces	Potential loss of confinement (glove breach). Potential release of SNM to the room and entrainment in the exhaust ventilation system.	Furnace door interlock cuts power when the door is opened. CAMs to detect airborne contamination and to activate alarms. High temperature interlock cuts power to the furnace when the glovebox temperature exceeds the allowable limit. Glovebox high temperature alarm. HEPA-filtered ventilation exhaust system. Fire suppression system.	Procedure governing required protective equipment (i.e., heat-resistant gloves). Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[1]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[2]	Engineered	Administrative	Relative probability/consequence discussion[3]	Representative analysis location[4]	
	Room 131, glovebox section 1 (continued)	B. Material handling (continued)	--	(2) Dropped or overfilled container.	Potential spill of SNM within the glovebox. Potential airborne release and entrainment of SNM in the exhaust ventilation system.	Glovebox confinement. Two-stage HEPA-filtered E-4 exhaust ventilation system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to spill. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills".	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		C. E-4 exhaust ventilation system	To remove the heat generated by the furnace.	No heat removal.	Potential heat rise within the glovebox. Potential loss of confinement and release of SNM to the room. Potential entrainment in the E-3 exhaust ventilation system.	Four operating and three backup exhaust fans. Pressure sensors and dampers monitor and control the exhaust flow from each zone. Two exhaust fans connected to backup power. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust ventilation system.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		D. Glovebox muffle furnace	Provides controlled heat for fusing PuO_2 samples.	(1) Excessive temperature	Potential furnace failure. Potential generation of ceramic-like product.	Furnace is equipped with a thermocouple to monitor furnace temperature and an alarm switch that cuts power to the furnace should the temperature exceed 1050 °C.	Procedure governing operator response to temperature alarm switch activation.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
				(2) Low temperature	Potentially invalid LOI results. Potential storage of reactive material within storage vaults.	Temperature control is computer-controlled.	Procedure governing LOI analysis. Procedure governing maintenance and calibration of the furnace.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	Refer to hazard tables in Appendix 9A.2.1 "2736-Z – Vault storage of SNM" and Appendix 9A.2.2 "2736-ZA – Exhaust ventilation and filtration of 2736-Z"
				(3) Temperature ramps up too quickly	Potential furnace failure.	Temperature control is computer-controlled.	Procedure governing maintenance and calibration of the furnace.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	

Table 9A.1.2
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 131, glovebox section 1 (continued)	D. Glovebox muffle furnace (continued)	Provides controlled heat for fusing PuO_2 samples.	(4) Insufficient time at temperature	Potentially invalid LOI results. Potential storage of reactive material within storage vaults.	Temperature control is computer-controlled.	Procedure governing LOI analysis. Procedure governing maintenance and calibration of the furnace.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	Refer to Appendix 9A.2.1 "2736-Z -- Vault storage of SNM" and Appendix 9A.2.2 "2736-ZA -- Exhaust ventilation and filtration of 2736-Z"
5	**Room 131, glovebox section 2**	Dissolving, heating, and titration of samples.	--	(1) Spill	Potential airborne release and entrainment in the E-4 ventilation exhaust system.	Glovebox enclosure. Two-stage HEPA-filtered E-4 ventilation exhaust system. Glovebox exhaust HEPA filter. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to spill. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005
				(2) Excessive temperature	Potential glovebox glove breach. Potential release of SNM to the room. Potential entrainment in the E-3 exhaust system and release to the environment.	CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation exhaust system (E-3). Glovebox fire suppression system.	Procedure governing use of hot plate. Combustibles in the glovebox are kept to a minimum. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
6	**Room 131, glovebox section 3 (contains a argon-purged balance).**	A. Reagents	Safe concentrations are used in analytical procedures involving plutonium.	Detonable reagent concentration.	Potential detonation. Potential loss of confinement and release of SNM to the room. Potential entrainment of SNM in the E-3 exhaust system.	The E-4 exhaust ventilation system. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered E-3 exhaust system.	Procedure governing allowable quantity of reagent. Procedure governing operator response to CAM alarm.	This event extremely unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Argon supply	Used to purge balance.		Potential asphyxiation of operators.	Rotameter on argon supply acts as an orifice to limit flow. E-3 and E-4 ventilation exhaust systems.	Procedure governing operation and maintenance of argon supply equipment.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005.
7	**Room 132, mass spectrometer laboratory.**	Nitrogen supply for mass spectrometer.	Used to cool the spectrometer.	(1) Leak	Potential asphyxiation of operators.	E-3 and E-4 ventilation exhaust system. Nitrogen supply control system.	Procedure governing operation and maintenance of nitrogen supply equipment.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
				(2) No flow.	Potential overheating of mass spectrometer.	--	Procedure governing operation and maintenance of nitrogen supply equipment.	This event is unlikely. The consequence is judged to be low.	Not specifically analyzed.	
8	**Room 133, dark room**		Used to develop film.	--						No radioactive materials are allowed in the room.

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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
9	**Rooms 134 and 135, mass spectrometry sample preparation: hoods 1 through 4**	A. E-4 ventilation exhaust system	To provides exhaust airflow for the removal of the fumes generated by operations in the hood.	(1) Insufficient exhaust airflow	Potential release of hazardous fumes into the room.	Four operating and three backup exhaust fans. Pressure sensors and dampers monitor and control the exhaust flow from each zone. Hood DP gauge.	Procedure governing verification of adequate exhaust flow rate.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.2.8, "Toxic Chemical Release."	WHC-SD-CP-SDD-005
				(2) Excessive exhaust airflow	Potential entrainment of loose material into the ventilation exhaust system and release to the environment.	Hood exhaust HEPA filters. Two-stage HEPA-filtered exhaust ventilation system.	--	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spill."	WHC-SD-CP-SDD-005
		B. Hood exhaust HEPA filters	To filter exhaust air from the hood before it is discharged to the E-4 exhaust system.	Loss of filtration.	Potential release of SNM to the E-4 ventilation exhaust system. Potential release to the environment.	HEPA filter DP gauge. Two-stage HEPA-filtered E-4 exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to HEPA filter DP outside of operating limits.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spill."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		C. Preparation of samples for mass spectrometer.	To safely prepare samples for analysis.	Spill	Potential generation of airborne contaminants. Potential entrainment in the exhaust system and release to the environment.	Hood enclosure. Hood exhaust HEPA filters. Two-stage HEPA-filtered E-4 exhaust system.	Procedure governing operator response to a spill.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005
10	**Rooms 136 and 137, glovebox (one per room). Glovebox is divided into three sections. Section 1 contains a muffle furnace**	A. Material handling	To safely handle material as necessary to support operations.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	WHC-SD-CP-SDD-005
		B. E-4 exhaust system	To remove the heat generated by the furnace.	Buildup of heat.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	Refer to items 4C.	WHC-SD-CP-SDD-005
		C. Muffle furnace	Controlled heating of plutonium nitrate and oxide samples.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	

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Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
11	**Rooms 136 and 137, section 2**	Glovebox enclosure.	Confinement of SNM during preparation and weighing of sample electrodes.	Spill	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	WHC-SD-CP-SDD-005
12	**Rooms 136 and 137, section 3 (sample electrodes are shot in a moist argon/oxygen atmosphere).**	Argon supply system.	Used to supply argon for an argon/oxygen mixture that is used to support a small arc in the quantimeter.	Leak	Potential asphyxiation of operators.	Rotameter acts as an orifice to limit the flow of argon. Glovebox exhaust ventilation system.	Procedure governing inspection and maintenance of argon supply system.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005.
	Room 139, plutonium oxide sample receiving/ storage (contains a train of 6 gloveboxes).		Contains six interconnected gloveboxes used to process and store all PuO_2 and plutonium metal received by the laboratory for analysis.							Storage is in 5 or 10 mL vials. The racks are metal and the vials are supported on the bottom by a metal plate and at mid-height by another metal plate.
13	**Glovebox 1**	Transferring items into and out of airlock.	To safely move items to and remove items from the glovebox train.	Spill.	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
14	**Room 139, gloveboxes 2 and 3**	Weighing of plutonium metal and PuO_2 samples for analysis.	Confinement of plutonium.	Loss of confinement.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	WHC-SD-CP-SDD-005
15	**Room 139, glovebox 4**	A. V-Blender	To contain and completely mix the stabilized material in order to ensure a representative sample for analysis.	(1) Loss of containment.	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills"	WHC-SD-CP-SDD-005
				(2) Incomplete mixing.	Potentially nonrepresentative sample used for analysis. Potentially invalid analysis.	--	Procedure governing mixing operation.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 139, glovebox 4 (continued)	B. Loading and unloading plutonium containing materials in V-blender.	--	Overfill or dropped container.	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	Refer to item 4B(2).	WHC-SD-CP-SDD-005
16	**Room 139, glovebox 5**	Storage glovebox containing 50 racks, each capable of holding up to forty-two 15-35 mL sample bottles per tray.	To maintain container separation distance for the purpose of criticality safety.	Loss of container separation.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional criticality.	CAMs to detect airborne alpha contamination and to activate alarms. Two-stage HEPA-filtered ventilation exhaust system. CAS to detect criticality and to activate criticality alarms.	Procedure governing operator response to CAM alarm. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm.	The failure of the storage rack is unlikely. The consequences are judged to be low.	Refer to section 9.2.3 "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
17	**Room 139, glovebox 6 (contains two balances and a programmable furnace used for LOI analysis).**	A. Material handling	To safely handle material as necessary to support operations.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	WHC-SD-CP-SDD-005
		B. E-4 exhaust system	To remove the heat generated by the furnace.	Buildup of heat.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	WHC-SD-CP-SDD-005
		C. Muffle furnace	Used for performing LOI analysis.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D. Hood is equipped with a limited-volume sprinkler head system.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	WHC-SD-CP-SDD-005
18	**Room 139, hoods 1 and 2**	A. --	To capture contaminated air and direct it into the exhaust ventilation system.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to item 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Solution makeup to support projects being performed in the radioactive laboratories.	To safely prepare solutions.	Chemical spill	Potential chemical burns to operator. Potential release of toxic fumes to the room and entrainment in the E-3 exhaust system.	Hood enclosure. E-4 exhaust system.	Procedure governing operator response to a spill.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.8, "Toxic Chemical Spill."	WHC-SD-CP-SDD-005

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 139, hoods 1 and 2 (continued)	C. Hot plates\ muffle furnace	Controlled heating and dissolving of samples.	Excessive temperature	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	WHC-SD-CP-SDD-005
19	**Room 142, vented storage cabinets (4). Used to store up to 250 g plutonium (oxide, metal, and nitrate) and/or ^{235}U per shelf.**	A. –	To maintain container separation distance for the purpose of criticality safety.	Loss of container separation.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of SNM from storage containers.	CAMs to detect airborne alpha contamination and to activate alarm(s). Two-stage HEPA-filtered ventilation exhaust system to mitigate the release of SNM to the environment. Same as above. CAS to detect criticality and to activate criticality alarms.	Double-contingency principle. Procedure governing operator response to criticality alarms. Procedure governing operator response to CAM alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Cabinet ventilation supply.	Provides airflow for the removal of the heat generated by the decay of SNM.	Insufficient supply airflow.	Potential additional thermal loading and pressurization of SNM storage containers. Potential loss of SNM from storage container(s) and entrainment in the ventilation system.	Five operating and two backup supply fans. CAMs to detect airborne alpha contamination and to activate alarm(s). Two-stage HEPA filtered exhaust ventilation system.	Procedure governing packaging requirements for SNM. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		C. Cabinet E-4 ventilation exhaust.	Provides airflow for the removal of the heat generated by the decay of SNM.	Insufficient exhaust airflow.	Potential additional thermal loading and pressurization of SNM storage containers. Potential loss of SNM from storage container(s) and release to the room.	Four operating and three backup exhaust fans. Two exhaust fans connected to backup power. CAMs to detect airborne alpha contamination and to activate alarm(s). Single-stage HEPA-filtered ventilation exhaust system.	Procedure governing packaging requirements for SNM. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
	Room 143, waste process		Used for handling of liquid waste not compatible with the waste recovery system and disposal of low-level waste to the D-8 tank in 241-Z.							
20	**Hoods 1, 2, and 3**	A. –	To capture contaminated air and direct it into the exhaust ventilation system.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 143, hoods 1, 2, and 3 (continued)	B. Waste handling/storage operations.	--	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005
		C. Hot plates	Controlled heating and dissolving of samples.	Excessive temperature	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	WHC-SD-CP-SDD-005
21	Room 143, glovebox 4	Glovebox enclosure	Confinement of SNM.	--	--	--	--	--	--	Glovebox is no longer used.
	Room 144, plutonium chemistry laboratory		The work performed in this room provides the primary analytical support for plutonium samples.							Storage is in polyjars inside tubes with taped-on tops.
22	Room 144, hoods 1-3 and 5-9; glovebox 4	A. --	To capture contaminated air and direct it into the exhaust ventilation system.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	Refer to item 9A.	All hoods and glovebox exhaust to the E-4 exhaust system. No HEPA filters on hoods. WHC-SD-CP-SDD-005
		B. Support operations for plutonium sampling and storage of samples.	--	(1) Spill	Refer to item 5(1).	Refer to item 5(1).	Refer to item 5(1).	Refer to item 5(1).	Refer to item 5(1).	WHC-SD-CP-SDD-005
				(2) Inadequate container spacing	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.
		C. Hot plates	Controlled heating and dissolving of samples.	Excessive temperature	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Sane as item 5(2).	Refer to item 5(2).
23	Room 144, hood 1	Heating of sample disks.	--	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
24	**Room 144, hoods 3 and 9**	26-in. mercury vacuum system	--	(1) Excessive vacuum	Potential entrainment of liquid waste into the 26-in. mercury vacuum system.	The 26-in. mercury vacuum system equipped with a vacuum trap.	Procedure governing operator verification of functionality of vacuum system.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	
				(2) Insufficient vacuum	Potential accumulation of gases. Potential explosion if organic solvents reach LFL/LEL.	Hood E-4 exhaust system.	Procedure governing operator verification of functionality of vacuum system.	This event is considered very unlikely. The consequences are judged to be moderate.	Refer to section 9.2.1C, "Deflagration in Glovebox HA-211."	WHC-SD-CP-SDD-005
25	**Room 144, hood 6 (contains a uranium analyzer used to determine uranium concentration).**	Uranium analysis by laser-induced kinetic phosphorimetry.	--	Exposed laser beam.	Potential exposure of operator to laser beam.	Designed such that there is no laser radiation accessible to operator. Interlocks on instrument door and cover prevent laser and photomultiplier tube voltage actuation unless door is closed and latched, and the cover is in place.	Procedure governing operation of uranium analyzer.	This event is considered extremely unlikely. The consequences are judged to be low.	Not specifically analyzed.	
26	**Room 145, glovebox.**	Glovebox contains a sintering furnace.	This glovebox is inactive.	--	--	--	--	--	--	
27	**Room 145-A, stockroom**	--	Stores supplies routinely used in the laboratory.	--	--	--	--	--	--	
28	**Room 146, general**	--	Used for waste repackaging and analyzing percentage organic samples.	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
29	**Room 146, hoods 1 through 4**	A. --	To capture contaminated air and direct it into the exhaust system.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	
		B. Sample analysis and storage.	To safely test and store samples.	(1) Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Inadequate spacing/too many containers	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.	Refer to item 3A.

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
30	**Room 146, glovebox (hood 5)**	Waste repackaging.		Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C. CPS limits glovebox to 150 g of plutonium.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005
31	**Room 147, office**	--	Room 147 is used as an office.	--	--	--	--	--	--	--
32	**Room 148, sample dissolution**		Used as the laboratory chemical satellite storage area.	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	The two hoods in room have been cleaned out. Hoods exhaust through HEPA filters to the E-4 exhaust system. WHC-SD-CP-SDD-005
33	**Room 149, glovebox**	Glovebox enclosure	Confinement of SNM.	Loss of confinement.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	Refer to item 4A.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
34	**Room 149, hood**	--	To capture contaminated air and direct it into the exhaust system.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
35	**Room 150, counting room (count solution CT vials for americium and plutonium).**	A. 90% argon/10% methane gas supply	Used in counting instrument.	Leak	Potential personnel asphyxiation.	E-3 ventilation system.	Procedure governing inspection and maintenance of equipment.	This event is unlikely to extremely unlikely. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
		B. Nitrogen supply	Liquid nitrogen used for cooling the Ge-Li detector.	Leak	Potential personnel asphyxiation.	E-3 ventilation system.	Procedure governing inspection and maintenance of equipment.	This event is unlikely to extremely unlikely. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
36	**Room 151, shift office**	--	Room 151 serves as the shift office.	--	--	--	--	--	--	--
37	**Room 152, waste laboratory for storing liquid wastes, hood 551**	A. --	To capture contaminated air and direct it into the exhaust system.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 152, hood 551 (continued)	B. Waste sampling for H+ and plutonium analysis; visually inspected for organic content.	--	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005
38	Room 152, glovebox 552	--	This glovebox is inactive.	--	--	--	--	--	--	
39	Room 153, hoods 1 through 4	A. --	To capture contaminated air and direct it into the exhaust system.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	Refer to items 9A and 9B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Process samples for analysis and storage.	To safely handle samples as necessary to support operations.	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005
40	Room 153, glovebox 5	--	This glovebox is inactive.	--	--	--	--	--	--	Glovebox contains inlet/outlet HEPA filters.
41	Room 154, product specification analysis: glovebox section 3 (partitioned into three sections).	A. Material handling	To safely handle SNM as necessary to support operations.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	Refer to item 4B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. E-4 ventilation exhaust system	To remove the heat generated by the furnace.	Buildup of heat.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	Refer to item 4C.	WHC-SD-CP-SDD-005
		C. Furnace	Controlled heating of plutonium samples for analysis purposes.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	Refer to item 4D.	WHC-SD-CP-SDD-005

Table 9A.1.2
The 234-5Z Building
PFP AL
(Rooms 131-137, 139, and 141-157).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
42	**Room 155, hoods 1 through 4**	A. Preparation of samples for mass spectrometer and analysis of specific samples for organic content using the infrared spectrometer.	--	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005
		B. Hot plates	Heating and dissolution of samples.	Excessive temperature	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).	Refer to item 5(2).
43	**Room 156, glovebox**	--	Glovebox is no longer in use.	--	--	--	--	--	--	Glovebox is HEPA-filtered and exhausts to the E-4 exhaust system.
44	**Room 156, hoods 3 and 4**	--	Used for specific ion analyses of fluoride and chloride.	Spill	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	Refer to item 9C.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
45	**Room 157, gloveboxes 1 and 2**	--	Gloveboxes have been sealed and are no longer in service.	--	--	--	--	--	--	
46	**Room 157, gloveboxes 3 and 4**	Equipment used for particle size determination.	Gloveboxes are not in use.	--	--	--	--	--	--	These gloveboxes are new and have not been used. Future use would be for temporary storage.

[a]Event category and hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.1.3

PLUTONIUM PROCESS SUPPORT LABORATORIES

The PPSL are located in the southwest corner of the 234-5Z Building in rooms 179 through 191 and room 202. These laboratories provide flowsheet verification, flowsheet enhancement, and prototype development studies for the PFP, other Hanford Site facilities, and offsite customers.

The PPSL are chartered to operate nonradioactive and radioactive chemical-oriented demonstration laboratories and equipment to support numerous programs across the Hanford Site and, on occasion, other DOE sites. The PPSL facilities include necessary connections to essential building services, including ventilation, drains, vacuum, electricity, water, distilled water, and compressed air. The PPSL support processing facilities flowsheet evaluation, troubleshooting, new technology implementation, and process demonstration. The above activities are performed on both bench- and pilot-plant scales. The PPSL also perform analyses of nonroutine samples for process support and develop new methods that are transferred to other organizations when the methodology is well established and the need becomes routine. The PPSL also process limited quantities of SNM to demonstrate processes whenever the PPSL have exclusive expertise.

The PPSL contain eight gloveboxes (two of which are inactive) and eight hoods (three of which are inactive). An administrative limit of 6.0 kg of plutonium, of which not more than 2,250 g is >10% ^{240}Pu, has been established. This material, in the form of a powder or a solution, could be located within gloveboxes, hoods, or both.

The gloveboxes in the rooms are used to support bench-scale (mostly wet) chemical procedures to support process development. Examples of these procedures are dissolution, reclamation of plutonium from scrap, extraction, and small scale plutonium work.

Rooms 179 through 188 contain gloveboxes operated by the PPSL. There are no processes in these gloveboxes having a potential for an explosion hazard. These gloveboxes (like the PFP AL gloveboxes) are always open to the introduction of a wide variety of chemicals. The type of support work performed tends to use larger quantities of material than is used in the PFP AL, but less than is used in the production gloveboxes. Room 202 is the nonradioactive pilot-plant laboratory and contains one walk-in hood and two large countertop areas for general chemistry projects. Rooms 81 through 90, 205, 250, and 251-A are used as offices. Room 80 and vault 201 are used for equipment storage.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM

detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
(187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	PPSL, general	A. Handling of SNM containers	To safely handle SNM within the PPSL as necessary to support operations.	(1) Inadequate container spacing	Potential criticality which results in high levels of radiation in room. Potential release of fission products to the atmosphere.	Lard cans and food pack cans are transported in fixed array wagons. 30- to 55-gal drums are moved one at a time using drum barrel hand trucks. CAS to detect criticality and to activate alarms. Single-stage HEPA-filtered ventilation exhaust system.	Procedure governing movement of SNM. Double contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm.	Inadequate spacing of containers is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3 "Criticality"	Potentially severe consequences to workers in proximity of a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005
				(2) Dropped container	Potential release of SNM to the room. Potential entrainment of SNM in the ventilation system and release to the environment.	Carriers (drum barrel hand truck, fixed array wagon, lard can wagon) are designed for specific operation. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust system.	Procedure governing movement of SNM. Packaging requirements call for double containment. Procedure governing operator response to a spill. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1,"Radioisotope-Bearing Liquid Spills", and section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system	To provide airflow to maintain the correct DP between zones.	(1) Insufficient supply airflow	Potential increased DP between zones 3 and 1 and decreased DP between zones 3 and 4.	Five supply fans normally operating, three fans provide backup. Pressure sensors and dampers used to monitor and control the supply airflow to each zone.	Procedure governing operator response to ventilation system upset.	This event is anticipated. Flow will be from areas of no contamination (zone 1) to areas of potential contamination (zone 3). The consequence is judged to be low.	Refer to section 9.1.7F "Building Depressurization-All PFP Operating Buildings."	WHC-SD-CP-SDD-005
				(2) Excessive supply airflow	Potential loss of DP between zones 3 and 1. Potential release of SNM to zone 1 areas and entrainment in the ventilation exhaust system.	Pressure sensors and dampers used to monitor and control the supply airflow to each zone. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation exhaust.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization--234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
(187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	PPSL, general (continued).	C. E-3 ventilation exhaust system	To provide airflow to maintain the correct DP between zones.	(1) Insufficient exhaust airflow	Potential loss of DP between zones 3 and 1. Potential release of SNM to zone 1 areas and entrainment in the ventilation exhaust system.	Four exhaust fans normally operating, three fans provide backup. Pressure sensors and dampers used to monitor and control the exhaust airflow from each zone. Two exhaust fans connected to backup power. Supply fans to the facility automatically shut down on high pressure reading in the exhaust plenum. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization--234-5Z."	WHC-SD-CP-SDD-005
				(2) Excessive exhaust airflow	Increased DP between zones 3 and 1.	Pressure sensors and dampers used to monitor and control the exhaust airflow from each zone.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7F, "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005
		D. E-3 ventilation exhaust HEPA filters.	To provide single-stage HEPA filtration of room exhaust.	Loss of HEPA filtration	Potential release of SNM to the environment.	Single-stage HEPA filtration provided by filters in seven filter rooms; any three rooms are in use simultaneously with the remaining on standby. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing maintenance and testing of HEPA filters. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Not Specifically Analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
2	PPSL, gloveboxes (general)	A. Glovebox enclosure	Confinement of SNM	Loss of confinement	Potential release of SNM to the room. Potential entrainment of SNM in the ventilation system and release to the environment.	Glovebox is of steel construction with Lexan™ windows. Lexan will not shatter upon strong impact. E-4 exhaust ventilation system maintains negative DP in glovebox relative to the room. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm. Procedure governing glovebox inspection and maintenance.	This event is anticipated. Historical events have resulted in minor worker uptake. Thus, the consequence is judged to be low.	Refer to section 9.1.9 "Glovebox Glove Breach."	The hazards analysis for "Gloveboxes, general" are typical for all gloveboxes. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.1.3
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	PPSL, gloveboxes; general (continued)	B. Ventilation supply system (inleakage via inlet HEPA filters)	To provide airflow to maintain correct DP between zones 3 and 4.	(1) Insufficient supply airflow	Potential excessive negative DP in glovebox relative to room. Potential breach of confinement.	Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow	Potential pressurization of glovebox relative to the room. Potential release of SNM to the room and entrainment in the E-3 ventilation system.	E-4 exhaust system will maintain negative DP of glovebox relative to the room. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Inlet HEPA filters	To filter glovebox exhaust air should a flow reversal occur.	Loss of filtration	Potential release of SNM to the room. Potential entrainment in the ventilation system and release to the environment.	E-4 exhaust system will maintain glovebox at negative DP relative to the room. Room CAMs provided to detect airborne contamination and to activate alarms. HEPA-filtered exhaust ventilation system.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. E-4 ventilation exhaust system	To provide airflow to maintain correct DP between zones 3 and 4.	(1) Excessive exhaust airflow	Potential excessive negative DP in glovebox. Potential breach of containment. Potential entrainment of loose material into ventilation duct.	Glovebox DP gauge. Glovebox outlet HEPA filter. Two-stage HEPA-filtered exhaust ventilation system.	Procedure governing operator response to glovebox DP outside of operating limits.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Insufficient exhaust airflow	Potential glovebox pressurization. Potential loss of confinement. Potential release of SNM to the room and entrainment in the exhaust ventilation system.	Glovebox DP gauge. Room CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust ventilation system.	Procedure governing operator response to glovebox DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.1.3
The 234-5Z Building: PPSL (Rooms 179, 180, 182, 183) (187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	PPSL, gloveboxes; general (continued)	E. E-4 exhaust system HEPA filters.	To filter exhaust ventilation air prior to atmospheric discharge in order to mitigate the release of SNM to the environment.	Loss of filtration.	Potential release of SNM to the environment.	Glovebox outlet filters. Testable E-4 exhaust HEPA filters. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing testing of HEPA filters. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
3	**Room 179, process support lab (the room is used for working with plutonium and other TRU isotopes).**	Gas cylinders (helium and air)	To provide safe storage of pressurized gases.	High-velocity cylinder projectile due to high-pressure release.	Potential equipment damage from cylinder impact. Potential minor to severe injury to operators. Potential breach of glovebox and release of SNM to the room.	Restraints used on gas bottles. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation exhaust system.	Procedure governing transport of pressurized gas bottles. Procedure governing operator response to CAM alarm.	This event is extremely unlikely. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
4	**Room 179, glovebox 1 (houses the TGA system).**	A. E-4 exhaust system	To remove the heat generated by the TGA.	Failure to remove heat.	Potential increased temperature within glovebox. Potential loss of glovebox confinement and release of SNM to the room. Potential entrainment of SNM in the ventilation system and release to the environment.	Four exhaust fans normally operating; three fans provide backup. Pressure sensors and dampers monitor and control the exhaust airflow from each zone. Two exhaust fans are provided with backup power.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005
		B. TGA system	Used in LOI analysis to determine the amount of volatiles remaining in the SNM.	(1) High temperature	Potential damage to the heating elements of the TGA. Potentially invalid LOI results.	The TGA is equipped with a thermocouple and a high temperature alarm switch. The alarm switch is designed to cut power to the furnace. Audible and visible alarms.	Procedure governing operator response to high temperature alarm.	This event is anticipated. The consequence is considered low.	Not specifically analyzed.	
				(2) Low temperature	Potentially invalid LOI results. Potential storage of reactive material in vaults.	TGA is computer-controlled.	Procedure governing LOI analysis.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 179, glovebox 1 (continued)	B. TGA system (continued)	Used in LOI analysis to determine the amount of volatiles remaining in the SNM.	(3) Temperature ramps up too quickly	Potential damage to the TGA heating elements resulting in the loss of the TGA.	TGA is computer-controlled.	Procedure governing LOI analysis.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
				(4) Insufficient time at temperature	Potentially invalid LOI results. Potential storage of reactive material in vaults.	TGA is computer-controlled.	Procedure governing LOI analysis.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	
5	Room 179, gloveboxes 4, 6, 9, 10, and 12.	A. E-4 exhaust system	To remove the heat generated by hot plates/furnaces.	Failure to remove heat.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.
		B. Hot plates/furnaces	To safely heat samples as necessary to support operations.	Excessive temperature.	Potential ignition and melting of glovebox gloves. Potential release of SNM to the room. Potential entrainment in the ventilation system and release to the environment.	Glovebox temperature monitored by thermocouples. Fire suppression system activation. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation system.	Procedure governing protective clothing (i.e., heat-resistant gloves) requirements. Procedure governing allowable amount of combustibles in glovebox.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
6	Room 179, gloveboxes 10 and 12	Criticality drain	To drain liquid from the glovebox in order to prevent it from accumulating to a depth sufficient for a criticality.	Liquid accumulation sufficient for a criticality.	Loss of a single contingency for criticality safety. Potential criticality should there be the loss of an additional contingency.	The CAS to detect a criticality and to activate alarms.	Double-contingecny principle. Procedure governing functionality of criticality drains. Procedure governing operator response to criticality alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-008
7	Room 179, hoods 2 and 3	A. Airlock access leading into the glovebox.	To capture contaminated air and direct it into the E-4 exhaust ventilation system.	Loss of exhaust ventilation.	Potential release of contamination from the glovebox to the room. Potential entrainment in the E-3 ventilation exhaust system.	Four exhaust fans normally operating, three fans provide backup. Pressure sensors and dampers to monitor and control the exhaust airflow from each zone. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust system.	Procedure governing operation of airlock. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.1.3
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 179, hoods 2 and 3 (continued)	B. Handling of SNM containers.	--	Inadequate container spacing or too many containers.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency.	CAS to detect a criticality and to activate alarms.	CPS posted on the hood limits the mass, volume, and spacing. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to a criticality alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
8	Room 179, hood 11	Airlock access leading into gloveboxes 10 and 12.	To capture contaminated air and direct it into the E-4 exhaust ventilation system.	Loss of exhaust ventilation	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.
9	Room 180, glovebox (houses the TGA system).	A. E-4 exhaust system	To remove the heat generated by the TGA.	Failure to remove heat.	Potential temperature rise within glovebox. Potential loss of confinement. Potential release of SNM to the room and entrainment in the ventilation system.	Four exhaust fans normally operating, three fans provide backup. Pressure sensors and dampers monitor and control the exhaust airflow from each zone. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust ventilation system.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. TGA system	To perform LOI analysis in order to determine the percentage of volatiles within the SNM.	(1) High temperature	Potential failure of the TGA.	Thermocouple to monitor TGA temperature and a alarm switch to cut power upon excessive temperature.	Procedure governing operator response to TGA high temperature alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
				(2) Low temperature	Potentially invalid LOI results. Potential storage of reactive SNM within vaults.	The TGA is computer-controlled.	Procedure governing LOI analysis.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005
				(3) Temperature ramps up too quickly	Potential failure of the TGA.	The TGA is computer-controlled.	Procedure governing LOI analysis.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005

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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 180, glovebox (continued)	B. TGA system (continued)	To perform LOI analysis of SNM.	(4) Insufficient time at temperature	Potentially invalid LOI results. Potential storage of reactive SNM within vaults.	The TGA is computer-controlled.	Procedure governing LOI analysis.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005
10	**Room 180, argon cylinder**	Pressurized argon and nitrogen cylinders (cylinders located in 2734-ZA).	To provide containment for pressurized gases.	(1) High-velocity cylinder projectile due to high-pressure release.	Potential equipment damage. Potential minor to severe injury to operators. Potential rupture of glovebox and release of SNM. Potential release of SNM to the environment.	Gas bottles moved on hand trucks. Restraints used on stored gas bottles.	Procedure governing transport and storage of pressurized gas bottles.	This event is extremely unlikely. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Loss of containment.	Potential release of argon/nitrogen into the room. Potential asphyxiation of personnel.	High pressure is physically limited by pressure-relief valves on supply system. E-4 exhaust ventilation system.	Procedure governing equipment maintenance.	This event is unlikely. The consequences are judged to be low.	Not Specifically Analyzed.	
11	**Room 182, process support lab microscope**	–	Houses the scanning electron microscope	–						
12	**Room 183, specialized processing**	–	Used for liquid scintillation counting and storage of waste drums prior to removal from the building.	Spill	Potential release of SNM to the room. Potential entrainment in the ventilation exhaust system.	CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust ventilation system.	Procedure governing transportation of waste drums. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
13	**Room 186, laboratory chemical storage**	–	To safely store chemicals used in the PPSL.	Spill	Potential release of chemicals to sanitary sewer. Potential exposure of operators to hazardous chemicals.	Exhaust ventilation system.	Procedure governing operator response to chemical leak.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
14	**Room 187, laboratory open-faced hoods, 1 through 5**	A. E-4 exhaust ventilation system	To remove fumes generated by operations conducted within the hood.	(1) Insufficient exhaust airflow	Potential operator exposure to toxic fumes.	Four exhaust fans normally operating; three fans provide backup. Two exhaust fans are connected to backup power (1 of 2 operates on loss of normal power). Hood flowmeter.	Procedure governing operator response to exhaust flowrate outside of operating limits. Procedure governing operator response to release of toxic fumes.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.8, "Toxic Chemical Release."	WHC-SD-CP-SDD-005

Table 9A.1.3
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SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 187, hoods 1 through 5 (continued).	A. E-4 exhaust ventilation system (continued)	To remove fumes generated by operations conducted within the hood.	(2) Excessive exhaust flow	Potential entrainment of loose material into E-4 ventilation exhaust system.	Hood exhaust HEPA filter prevents loose material from entering the ventilation duct.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005
		B. Hood exhaust HEPA filters	To remove particulates from the hood exhaust flow.	Loss of filtration.	Potential entrainment of SNM in the E-4 ventilation system. Potential release of SNM to the environment.	291-Z-1 exhaust stack CAM. HEPA filter DP gauge. Two-stage HEPA-filtered exhaust ventilation system (E-4).	Procedure governing operator response to HEPA filter DP outside of operating limits.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
15	**Room 188, glovebox 188-1 (houses the calciner system).**	A. Handling and storage of plutonium-bearing containers	–	(1) Inadequate container spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency.	CAS to detect a criticality and to activate alarms.	Double-contingency principle. Gloveboxes are labeled per CPSs as to the allowable limits on plutonium quantities, container volumes and minimum spacing. Procedure governing operator response to criticality alarms.	Inadequate spacing of containers is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
16	**Room 188 glovebox 188-1 (continued)**	A. Material Handling (continued)	–	(2) Contact with hot surfaces	Potential loss of confinement. Potential release of plutonium-bearing materials to the room.	Thermocouples to monitor glovebox temperature. Power to the calciner is cut automatically when the glovebox temperature exceeds the operating limit. Fire suppression system. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation exhaust system.	Procedure governing protective clothing requirements (i.e., heat-resistant gloves). Procedure governing combustible loading of glovebox.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. E-4 ventilation exhaust system	To remove the heat generated by the calciner.	Failure to remove heat.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.	Refer to item 2D.
		C. Criticality drain	To drain liquid from the glovebox in order to prevent it from accumulating to a depth sufficient for a criticality.	Liquid accumulation sufficient for a criticality.	Potential criticality resulting in high levels of radiation within the room. Potential release of fission products to the room and to the atmosphere.	Drains are protected from plugging by large mesh screens. CAS to detect criticality and to activate criticality alarms.	Double-contingency principle. Procedure governing operator verification of drain functionality. Procedure governing operator response to criticality alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-008

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Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
17	Room 188, calciner	--	To contain and stabilize plutonium nitrate solutions via controlled heating.	(1) Excessive temperature	Potential failure of the calciner. Potential loss of confinement and entrainment of SNM in the ventilation system.	Thermocouple probe measures calciner temperature and activates interlock to cut off power to the calciner upon excessive temperature. Local high temperature alarm. HEPA-filtered ventilation exhaust system.	Procedure governing operator response to high temperature alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.2, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005
				(2) Low temperature	Potential incomplete removal of volatiles. Potential flooding of the calciner and the formation of paste in the material bed.	Temperature is computer controlled. Interlock prevents feed pump from operating when temperature is < 700 °C. Calciner contained within glovebox.	An LOI analysis is used to verify volatiles have been removed.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005
				(3) Insufficient time at temperature	Potential incomplete removal of volatiles. Potential storage of reactive material in vaults.	Temperature/time are computer controlled.	An LOI analysis is used to verify volatiles have been removed.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005
				(4) Temperature ramps up too quickly	Potential failure of the calciner due to excessive thermal stress.	Temperature/time are computer controlled. Calciner contained within glovebox.	--	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.2, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005
				(5) Insufficient mixing	Potential incomplete removal of volatiles. Potential storage of reactive material in vaults.	Calciner equipped with an agitator.	An LOI analysis is used to verify volatiles have been removed.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005
		A. Calciner $PuNO_3$ feed	To introduce $PuNO_3$ into the vertical calciner in a controlled process.	(1) Excessive flow	Potential pressurization of the calciner. Potential violation of criticality limit. Potential incomplete removal of volatiles and storage of reactive material in the vaults.	Feed pumps are interlocked with a master stop switch. Feed pump is disabled by the temperature controller when the temperature in the calciner is < 700 °C.	An LOI analysis is used to verify that all of the volatiles have been removed.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.2, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005

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Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 188, calciner (continued)	A. Calciner $PuNO_3$ feed (continued)	To introduce $PuNO_3$ into the vertical calciner in a controlled process.	(2) Inadequate flow	No product or insufficient product produced by calciner. Potential plugging of the feed tube.	Feed tube designed to be easily replaced. Cleanout rod to clear blockage.	Procedure governing operation and maintenance of calciner.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.2, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005
				(3) High organic feed solution	Potential filter blockage and pressurization of the calciner.	Filter blow-back system designed to dislodge any accumulated material from the filter surface.	Procedure governing sampling of feed solution for organics before calcination.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.2, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005
				(4) High plutonium content feed solution	Potential criticality resulting in high levels of radiation in the room and a potential release of fission products to the atmosphere.	The calciner is engineered to be inherently critically favorable under any conditions. CAS to detect criticality and to activate alarms.	Double-contingency principle. Procedure governing operator response to criticality alarm.	High plutonium content feed solution is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-003
		B. Calciner $PuNO_3$ feed pump transfer line	To provide containment of $PuNo_3$ as it is transferred from the feed tank to the calciner.	Loss of containment.	Potential excessive $PuNO_3$ solution in glovebox. Potential criticality and resulting high levels of radiation within the room. Potential release of fission products to the atmosphere.	Glovebox 188-1 is equipped with a criticality drain. CAS to detect criticality and to activate alarms.	Procedure governing operator response to leak from feed line. Double contingency principle. Procedure governing operator response to criticality alarm.	A line leak is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-008
		C. Calciner process air supply	To insulate the liquid feed from the hot baseplate and to provide some cooling.	Inadequate airflow	Potential boiling of feed solution. Potential degradation of the feed port. Potential flow of plutonium nitrate solution through air line and into the process air system.	Interlock installed to shut down feed pump when air pressure falls below 60 lb/in^2. The feed tube is designed to be easily replaced.	Procedure governing operator response to feed pump shut down.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
(187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 188, calciner (continued)	D. Calciner offgas filter sintered ceramic filter elements	To remove particulates from the calciner offgas.	Failure to remove particulates.	Potential release of plutonium into offgas system and contamination of scrubber solution. Potential contamination of cooling water. Potential criticality and release of fission products to the atmosphere.	High filter DP indicator light. Two-stage HEPA-filtered E-4 ventilation system. Cooling water is pressurized and the scrubber shell is under vacuum, reducing the potential for contamination of the cooling water. Scrubber designed to operate with constant overflow, thus limiting plutonium buildup. CAS to detect a criticality and to activate criticality alarms.	Procedure governing operator response to HEPA filter DP high pressure warning light. Procedure governing operator response to criticality alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005
		E. Calciner offgas scrubber	To cool the calciner offgas and to neutralize the acidic vapors.	(1) Insufficient cooling.	Potential entrainment of hot acidic gases into the 26-in mercury vacuum and offgas systems. Potential failure of equipment.	Caustic solution is metered continuously into the scrubber to maintain the desired caustic concentration.	Procedure governing addition of caustic solution to maintain the proper pH.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	In the production version, a pH analyzer/controller will maintain scrubber pH.
				(2) No neutralization of acidic vapors.	Potential failure of vacuum system line due to corrosion.	The pH is manually maintained by adjusting the caustic makeup feed pump flow rate to match feed acidity, salt nitrate, and feed rate.	Procedure governing maintenance of proper solution pH.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	Refer to above.
				(3) Loss of scrubber confinement.	Potential flow of sodium hydroxide solution and hot acidic offgas into the glovebox. Potential breach of glovebox and release of SNM to the room. Potential release of SNM to the environment.	Two-stage HEPA-filtered E-4 ventilation exhaust system to remove acidic offgas. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to loss of scrubber confinement.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		F. 26-in. mercury vacuum system	To provide the motive force necessary for removing the calciner offgas.	(1) Insufficient vacuum	Potential buildup of gases inside the calciner. Potential exhaust of excess gases through the pressure relief valve into the glovebox.	Glovebox enclosure. Two-stage HEPA-filtered E-4 ventilation exhaust system removes gases from the glovebox.	Procedure governing operator response to actuation of calciner pressure relief valve.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.2, "Radioisotope-Bearing Pressurized Liquid Container."	WHC-SD-CP-SDD-005.

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
(187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 188, calciner (continued)	F. 26-in. mercury vacuum system	Provides the motive force necessary to remove the calciner offgas.	(2) Excessive vacuum	Potential intrusion of scrubber solution into the vacuum system. Potential criticality and release of fission products to the atmosphere.	Two-phase separators to separate gas/liquid mixture into liquid and gas. Vacuum trap ensures separation of liquid and gas phase and inhibits the overflow of liquid into the vacuum system. Float in trap seal vacuum. Vacuum trap alarms and interlock with feed pumps. CAS to detect a criticality and to activate criticality alarms.	Procedure governing operator response to liquid intrusion in the vacuum trap. Procedure governing operator response to criticality alarm.	This event is considered unlikely. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-008
18	**Room 189**	This room contains an ion chromatograph to examine non-radioactive samples.	--	--	--	--	--	--	--	--
19	**Room 190, radioactive material storage vault**	A. SNM storage containers.	To provide primary containment of SNM within the vault.	(1) Loss of containment.	Potential release of SNM into the vault. Potential entrainment of SNM in the ventilation system.	Containers restrained within storage rack to prevent inadvertent movement from storage location. CAMs to detect airborne contamination and to activate alarm(s). Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	OSD requires SNM stored in the vaults to be packaged with a minimum of two containment barriers. LOI performed on material before it is stored in the vault. Procedure governing operator response to CAM alarm. Procedure governing operator response to detection of SNM container anomaly during required (by OSD) monthly inspection.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Inadequate spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of SNM to the environment.	SNM storage containers. SNM container storage rack. CAS to detect criticality and to activate criticality alarms.	Double-contingency principle. Procedure governing operator response to criticality alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
(187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 190, radioactive material storage vault (continued).	B. E-3 ventilation supply system.	Provides airflow for removal of heat generated by decay of the SNM within the vault and for maintaining correct negative DP control of the vault.	(1) Insufficient supply airflow	Potential excessive negative pressure within the vault if the exhaust system continues to operate. Additional thermal loading of containers and resultant potential loss of containment.	Pressure sensors and dampers monitor and control the flow of supply air. Five supply fans normally operating; three are on standby. SNM contained within sealed storage containers. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	OSD requires SNM stored in the vault to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm. Procedure governing operator response to a ventilation system upset.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.7F, "Building Depressurization--All PFP Operating Buildings."	WHC-SD-CP-SDD-005 Whc-SD-CP-SDD-011
				(2) Excessive flow of supply air.	Potential pressurization of vault relative to corridor and release of SNM to corridor if there is any loose SNM within the vault.	Pressure sensors and dampers monitor and control the flow of supply air. Supply dampers are designed to fail closed. SNM contained within sealed storage containers. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	OSD requires SNM stored in the vault to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization, 234-5Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		C. E-3 ventilation exhaust system.	Refer to above.	(1) Insufficient exhaust airflow.	Additional thermal loading of SNM containers and resulting container pressurization could potentially result in loss of SNM from storage container(s). Potential pressurization of vault with respect to corridor if supply fans continue to operate could result in a release of SNM to the corridor.	Four operating exhaust fans and three on standby. SNM storage containers designed to withstand 100 lb/in^2 internal pressure before gross failure (Szempruch 1984). CAMs to detect airborne contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to above.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization, 234-5Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.3
The 234-5Z Building: PPSL
(Rooms 179, 180, 182, 183)
(187-191, and 202).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 190 (continued).	C. E-3 ventilation exhaust system (continued).	Provides airflow for removal of heat generated by decay of SNM within the vault and for maintaining correct negative DP control of the vault.	(2) High exhaust flow.	Potential excessive negative pressure within the vault.	Pressure sensors and dampers to monitor and control the flow of exhaust air. Four operating exhaust fans and three on standby. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F.1, "Building Depressurization-- All PFP Operating Buildings."	WHC-SD-CP-SDD-005
20	Room 191, process support cold lab, hoods 1 through 3	A. --	To capture contaminated air and direct it into the exhaust ventilation system.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	Refer to item 7A.	WHC-SD-CP-SDD-005.
		B. Solution makeup to support projects being performed in the radioactive laboratories.		Chemical spill	Possible chemical burns on hands and arms or other parts of the body. Localized injuries sustained if chemical touches body.	E-4 exhaust ventilation system prevents toxic fumes from entering the room.	Procedure governing personnel protective clothing requirements. Procedure governing operator response to chemical spill.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Toxic Chemical Release."	WHC-SD-CP-SDD-005
		C. Hot plates\ muffle furnace	Heating of samples.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	
21	Room 202, walk-in hood	A. Furnaces, hot plates	Heating of samples.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.	Refer to item 5B.
		B. --	Captures contaminated air and directs it into the exhaust duct system.	Loss of ventilation	Possible exposure to toxic fumes causing dizziness, headache, breathing difficulty.	Exhaust system removes fumes from work area. Ventilation system exhaust to the atmosphere through exhaust fan EM-15.	Chemicals are mixed in the hood with adequate exhaust ventilation to outside environment.	This event is anticipated. The consequence is low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
		C. EM-15 fans	Provides hood exhaust and removes fumes generated by operations in hood.	Insufficient exhaust flow	Potential release of toxic fumes into the room.	--	Procedure governing operator response to loss of exhaust flow.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.1.4

RADIOCHEMICAL STANDARDS LABORATORY

The radiochemical standards laboratory provided in rooms 221-C, 221-D, and 221-E is devoted to the formulation, verification, packaging, and distribution of the plutonium-containing standards needed in the PFP AL.

The standards laboratory contains NDA equipment, balances, blenders, etc. for the fabrication of standards. The plutonium is in liquid or oxide form, and is normally doubly contained (except for material in use).

The standards laboratory contains ten combination glovebox/hoods. An administrative limit of 1.2 kg of plutonium has been established for the laboratory. This material, in the form of a powder or solution, could be located within gloveboxes, hoods, or both.

- Room 221-C contains the fissile standards storage, PuO_2, and decontamination hoods plus a glovebox. Sheet standards for NDA are produced in this laboratory. The laboratory documentation center is also located in a walled-off area in the northeast corner.

- Room 221-D contains four hoods and a glovebox. The wet standard makeup is performed here. Standards containing uranium, neptunium, thorium, and plutonium are formulated and packaged. The analysis of plutonium stock solutions is performed. In-use acids and bases are stored in this room.

- Room 221-E contains three hoods that support the ampulization of low-level standards. The room is also used for preparation of low (radiation) level standards and as the storage area for the small amount of uranium and neptunium used in laboratory standards.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.1.4
The 234-5Z Building
Radiochemical Standards Laboratory
(Rooms 221C, 221D, and 221E).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Radiochemical standards laboratory, general**	A. Handling of SNM containers.	To safely handle SNM containers as necessary to support operations within the standards laboratory.	(1) Inadequate container spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of fission products to the atmosphere.	Lard cans and food-pack cans are transported in fixed array wagons. 30- to 55- gal drums are moved one at a time using drum barrel hand trucks. CAS to detect a criticality and to activate criticality alarms.	Procedure governing spacing requirements of transportation arrays. Double contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3 "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005
				(2) Dropped container	Potential release of SNM to the room. Potential entrainment in the ventilation exhaust system and release to the environment.	Carriers (drum barrel hand truck, fixed array wagon, lard can wagon) are designed for specific operation. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust ventilation system (E-3).	Procedure governing movement of SNM. Procedure governing operator response to a spill. Packaging requirements for double containment.	This event is anticipated. The consequences are judged to be low.	Refer to sections 9.1.1, "Radioisotope-Bearing Liquid Spills,", and 9.1.3 Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system	To provide airflow for maintaining the correct DP between zones.	(1) Insufficient supply airflow	Potential increased negative DP between zones 3 and 1. Potential loss of DP between zones 3 and 4.	Five supply fans normally operating, three fans provide backup. Pressure sensors and dampers monitor and control the supply airflow to each zone.	Procedure governing operator response to a ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005
				(2) Excessive supply airflow	Potential loss of negative DP between zones 3 and 1. Potential spread of contamination to zone 1 areas.	Pressure sensors and dampers monitor and control the supply airflow to each zone. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A "Excessive Building Pressurization--234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		C. E-3 ventilation exhaust system	To provide airflow for maintaining the correct DP between zones.	(1) Insufficient exhaust airflow	Potential loss of negative DP between zones 3 and 1. Potential spread of contamination to zone 1 areas.	Four exhaust fans normally operating; three fans provide backup. Pressure sensors and dampers monitor and control the exhaust airflow from each zone. Two exhaust fans are connected to backup power. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A "Excessive Building Pressurization--234-5Z."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.4
The 234-5Z Building
Radiochemical Standards Laboratory
(Rooms 221C, 221D, and 221E).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Radiochemical standards laboratory, general (continued).	C. E-3 ventilation exhaust system (continued).	To provide airflow for maintaining the correct DP between zones.	(2) Excessive exhaust airflow	Potential increased negative DP between zones 3 and 1.	Pressure sensors and dampers monitor and control the exhaust flow from each zone.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7F "Building Depressurization - All PFP Operating Buildings."	WHC-SD-CP-SDD-005
		D. E-3 ventilation exhaust system HEPA filters.	To filter room exhaust through a single-stage of HEPA filtration before it is discharged to the environment.	Loss of HEPA filtration.	Potential release to of SNM to the environment.	Seven parallel HEPA filter banks in seven filter rooms; any three are in service with the remainder on standby. Testable HEPA filters. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing HEPA filter maintenance and testing. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
2	**Room 221-B, radiological control organization storage**	Provides storage for portable NDA equipment and an equipment calibration area.		--						This room is dedicated for use by Radiological Control.
3	**Room 221-C, storage (contains a dry air glovebox used for the preparation of ultrapure PuO_2 standards for the AL): glovebox 1**	A. Glovebox enclosure	Confinement of SNM.	Loss of confinement.	Potential release of SNM to the room. Potential entrainment of SNM in the ventilation system and release to the environment.	Steel glovebox with Lexan™ windows. Lexan™ will not shatter upon strong impact. E-4 exhaust ventilation system maintains a negative DP in the glovebox relative to the room. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to a CAM alarm. Procedure governing inspection and maintenance of glovebox.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system (inleakage via inlet HEPA filters).	To provide airflow for maintaining the correct negative DP between zones 3 and 4.	(1) Insufficient supply airflow	Potential excessive negative DP within glovebox. Potential loss of confinement and release of SNM to the room. Potential entrainment of SNM in the E-3 ventilation exhaust system.	Additional supply air provided by the dry air supply system. Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.4
The 234-5Z Building
Radiochemical Standards Laboratory
(Rooms 221C, 221D, and 221E).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 221-C, glovebox 1 (continued).	B. Ventilation supply system (continued).	To provide airflow for maintaining the correct negative DP between zones.	(2) Excessive supply airflow	Potential pressurization of the glovebox relative to the room. Potential release of SNM to the room and entrainment in the ventilation system.	E-4 ventilation exhaust system will maintain negative DP of glovebox relative to the room. Glovebox DP gauge. Room CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		C. Inlet HEPA filters	To filter glovebox exhaust air in the event of a flow reversal in order to mitigate the release of SNM.	Loss of filtration.	Potential release of SNM to the room. Potential entrainment in the ventilation system and release to the environment.	Room CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust system (E-3).	Procedure governing operator response to CAM alarm. Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		D. Dry air supply system (note: dryers are not functional)	To provide airflow for maintaining the correct DP between zones 3 and 4.	(1) Insufficient supply airflow	Potential excessive negative DP within glovebox relative to the room.	Additional supply air provide by inleakage through inlet HEPA filters. Glovebox DP gauge.	Procedure governing operator response to glovebox DP outside of operating limits.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005
				(2) Excessive supply airflow	Potential pressurization of the glovebox and potential loss of confinement. Potential release of SNM into the room and entrainment in the E-3 ventilation exhaust system.	E-4 exhaust system has sufficient exhaust flow to remove full-open supply air. Glovebox DP gauge. Room CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		E. Glovebox exhaust HEPA filters	To filter glovebox exhaust air in order to mitigate the release of SNM.	Loss of filtration.	Potential increased ventilation system contamination, including E-4 HEPA filters. Potential release to the environment.	HEPA filter DP gauge. Two-stage E-4 exhaust HEPA filters. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to HEPA filter DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		F. E-4 ventilation exhaust system	To provide airflow for maintaining the correct DP between zones 3 and 4.	(1) Excessive exhaust airflow	Potential excessive negative DP within the glovebox. Potential loss of confinement. Potential entrainment of loose SNM in the ventilation exhaust system.	Glovebox DP gauge. Supply air provided by the dry air system and via inleakage through the inlet HEPA filter. Glovebox outlet HEPA filter. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.4
The 234-5Z Building
Radiochemical Standards Laboratory
(Rooms 221C, 221D, and 221E).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 221-C, glovebox 1 (continued)	F. E-4 ventilation exhaust system (continued)	To provide airflow for maintaining the correct DP between zones 3 and 4.	(2) Insufficient exhaust airflow	Potential glovebox pressurization and loss of confinement. Potential release of SNM into the room and entrainment in the E-3 ventilation exhaust system.	Glovebox DP gauge. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		G. E-4 exhaust system HEPA filters.	Provides two stages of HEPA filtration for glovebox exhaust system.	Loss of filtration.	Potential release of SNM to the environment.	Testable HEPA filters. Glovebox outlet HEPA filters remove particulates before flow to the E-4 exhaust system. Two stage E-4 HEPA filtration. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing testing and maintenance of HEPA filters. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		H. Use of blender/ grinder to produce quality control standards.	To provide containment of SNM during mixing/ grinding operations.	Loss of containment.	Dust generation within glovebox.	Grinder and blender are fully enclosed. CAMs to detect airborne contamination and to activate alarms. E-4 ventilation system will mitigate dust concentration within the glovebox.	Procedure governing operator response to excessive dust within the glovebox. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
4	**Room 221-C, hoods 1 and 2**	A. E-4 exhaust ventilation system.	To provide hood exhaust for the removal of fumes generated by hood operations.	(1) Insufficient exhaust airflow.	Potential release of toxic fumes to the room. Potential entrainment of fumes in the ventilation exhaust system.	Four exhaust fans normally operating and three fans provide backup. Pressure sensors and dampers monitor and control the exhaust flow from each zone.	Procedure governing operator verification of adequate exhaust flow rate.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.2.8, "Toxic Chemical Release."	WHC-SD-CP-SDD-005
				(2) Excessive exhaust airflow	Potential entrainment of loose SNM into the exhaust ventilation system.	Hood exhaust HEPA filter mitigates entrainment of SNM into the exhaust system. Two-stage HEPA-filtered ventilation exhaust.	Procedure governing operator verification of hood exhaust flow rate.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005

Table 9A.1.4
The 234-5Z Building
Radiochemical Standards Laboratory
(Rooms 221C, 221D, and 221E).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 221-C, hoods 1 and 2 (continued)	B. Hood exhaust HEPA filters	To filter hood exhaust before it enters the E-4 ventilation exhaust system.	Loss of filtration.	Potential entrainment of SNM in the E-4 ventilation system. Potential release to the environment.	HEPA filter DP gauge. Two-stage HEPA-filtered E-4 ventilation exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to HEPA filter DP outside of operating limits.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
		C. Handling and storage of plutonium-bearing containers within hoods.	To safely handle containers as necessary to support operations.	Inadequate spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of fission products to the atmosphere.	CAS to detect a criticality and to activate the criticality alarms.	CPS posted on hoods specifies the allowable mass, volume, and minimum spacing of SNM. Double- contingency principle. Procedure governing operator response to criticality alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
		D. Dilution of μCi level quantities of plutonium with HNO_3 and decontamination of glassware.	--	Spill	Potential release of airborne contaminants. Potential mixing of incompatible chemicals with HNO_3.	Hood exhaust HEPA filter. Two-stage HEPA-filtered E-4 exhaust ventilation system.	Procedure governing operator response to a spill. Procedure governing required protective equipment.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1 "Radioisotope-bearing Liquid Spills."	WHC-SD-CP-SDD-005
5	**Room 221-C, vented storage cabinet**	--	To maintain container separation distance for the purpose of criticality safety.	Loss of container separation.	Potential criticality and a resultant potential loss of SNM from the storage container(s). Potential entrainment of SNM in the ventilation exhaust system and release to the environment.	CAS to detect a criticality and to activate criticality alarms. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation exhaust system.	SNM is packaged with a minimum of two containment barriers. Double-contingency principle. Procedure governing operator response to criticality alarm. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		A. Cabinet ventilation supply system.	To provide airflow for the removal of the heat generated by the decay of SNM.	Insufficient supply air flow.	Potential additional thermal loading of SNM containers and resulting container pressurization could result in a loss of SNM from the storage container(s) and entrainment in the ventilation system.	Five operating and three backup supply fans. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	SNM packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.4
The 234-5Z Building
Radiochemical Standards Laboratory
(Rooms 221C, 221D, and 221E).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 221-C, vented storage cabinet (continued)	B. Cabinet E-4 ventilation exhaust system.	To provide air flow for the removal of the heat generated by the decay of SNM.	Insufficient exhaust air flow.	Potential additional thermal loading of SNM containers. Potential release of SNM from the containers and entrainment in the ventilation system.	Four operating and three backup exhaust fans. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system.	SNM packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
6	**Room 221-D, hoods 1 through 4**	--	Open-faced hoods used for pipetting of microcurie level quantities of SNM and plutonium nitrate characterization.	Refer to item 4.	Refer to item 4.	Refer to item 4.	Refer to item 4.	Refer to item 4.	Refer to item 4.	Hood exhaust is HEPA-filtered.
7	**Room 221-D, glovebox**	--	Glovebox is inactive. There is no equipment located within it.	--	--	--	--	--	--	Equipped with both inlet and outlet HEPA filters, and is exhausted through the building E-4 exhaust system.
8	**Room 221-E, hoods 1 and 2 (hood 1 contains an ultrasonic cleaner).**	Electric bunsen burners.	Used to seal glass ampules and for heating counting disks.	Excessive temperature.	Potential burn injury to operator.	--	Procedure governing required protective equipment.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
9	**Room 221-E, hood 3**	Heat lamps	Drying low-level sheet standards used in NDA techniques.	Excessive temperature.	Refer to item 8.	--	Refer to item 8.	Refer to item 8.	Not specifically analyzed.	

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.1.5

LOAD-IN/LOAD-OUT OPERATIONS

The LI/LO of $Pu(NO_3)_4$ solutions from PR cans and 10-L polyethylene bottles is accomplished in room 227 of the 234-5Z Building, in glovebox HC-227S and hood HC-227T. Highly concentrated plutonium solutions are handled in glovebox HC-227S and present a serious contamination hazard.

The LI/LO operations consist of vacuum transfer of solutions between PR cans and tanks. Hood HC-227T is primarily used for the vacuum transfer of 10-L bottles of solutions to tanks in glovebox HC-227S. Hood HC-227T is also used to load-out material and for venting PR cans. Glovebox HC-227S is used to blend and sample plutonium nitrate solutions and to transfer (via hood HC-227T) solutions to PR cans. The PR cans are then transferred to the PFP AL.

Plutonium nitrate solution from PR cans is transferred to batch tanks in glovebox HC-227S via open-faced hood HC-227T. Plutonium nitrate is loaded into tanks BT-1 and BT-2 from storage or shipping containers. It is then blended as one batch and sampled.

Once the transfer is complete, the batch tanks and load out tanks in glovebox HC-227S are flushed, and the floor of glovebox HC-227S is flushed and slurped. General cleanliness of the glovebox floor is maintained by flushing and slurping. Flushing of the tanks is done to keep solids buildup below CPS limits and for accountability purposes.

Solutions that are being down loaded into PR cans are blended and sampled for accountability reasons. Solutions loaded into glovebox HC-227S are blended and sampled if they are being transferred for processing.

Plutonium nitrate is loaded into tanks BT-1 and BT-2 from storage or shipping containers. It is then blended as one batch and sampled. Blending and sampling may be required after transferring solution to glovebox HC-227S from the PFP AL. Blending and sampling is also required before load-out for accountability purposes. Receiver tanks are used for miscellaneous solution handling.

Plutonium nitrate, chloride, and fluoride solutions are transferred from 10-L storage container polybottles to glovebox HC-227S via open-faced hood HC-227T. Solution is loaded into tank BT-3 from 10-L storage containers using a vacuum transfer. The transferred solutions are then blended as one batch and sampled. When analyses are complete, the solution is loaded into 4.2-L polyjugs and transferred to the PPSL.

Plutonium nitrate solution is loaded out from the loadout tank into PR cans and the PR cans are sealed. The PR cans are then placed in approved shipping or storage containers.

Plutonium-bearing solutions removed from poly-bottles (10-L, L-10, and FL-10 container types) are received only in tank BT-3. This material is blended in tank BT-3 using an air-driven, diaphragm pump. After blending, the homogeneous solution is sampled for material accountability and solution

characterization. Plutonium-bearing solution is loaded into tank BT-3 from poly-bottle storage and shipping containers. Solution and bottle rinse from one or more poly-bottles is blended as one batch (or sub-batch) and sampled. Blending and sampling is also required before solution seal-out/load-out for accountability purposes.

Solutions are transferred from tank BT-3 into 4.2-L polyjugs or 3-L containers depending on the concentration of plutonium. The filled polyjug will then be sealed out and transferred to the facility development labs (PPSL). Only one polyjug at a time may be filled and only in glovebox HC-227S. Sample bottles are sent to the PFP AL.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.1.5
The 234-5Z Building
LI/LO Operations (Room 227).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	Room 227, process LI/LO	A. Handling of SNM containers within rooms (outside gloveboxes).	To safely handle containers as necessary to support operations.	(1) Dropped container	Potential release of $Pu(NO_3)_4$ solution to areas occupied by personnel. Potential entrainment of plutonium in the ventilation system.	L-10 and FL-10 containers built to withstand public highway accidents without loss of integrity. Room CAMs alarm at prescribed airborne activity levels. Single-stage HEPA-filtered exhaust ventilation system.	Packaging requirements for double containment. Procedure governing movement of SNM. Procedure governing operator response to CAM alarm. Operator required to have supply air respirator. Housekeeping.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.1 "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Inadequate container spacing or too many containers.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of fission products to the atmosphere.	CAS to detect criticality and to activate criticality alarms. Single-stage HEPA-filtered ventilation system. CAMs to detect airborne contamination and to activate alarms.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm. The CPS limits the allowable volume, mass, and spacing of SNM. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to the criticality. A criticality resulting from inadequate spacing is not a credible event. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system.	To provide airflow to maintain the correct DP between zones.	(1) Insufficient supply airflow.	Potential increased DP between zones 3 and 1. Potential loss of DP between zones 3 and 4.	Five supply fans normally operating and three backup fans. Pressure sensors and dampers used to monitor and control the supply airflow to each zone. Single-stage HEPA-filtered ventilation system.	Procedure governing operator response to ventilation system upset.	This event is anticipated. Flow will be from areas of no contamination (zone 1) to areas of potential contamination (zone 3). Thus, the consequence is judged to be low.	Refer to section 9.1.7F, "Building Depressurization–All Plutonium Finishing Plant Operating Buildings."	WHC-SD-CP-SDD-005
				(2) Excessive supply airflow	Potential loss of DP between zones 3 and 1. Potential spread of contamination to zone 1 areas.	Five supply fans normally operating and three backup fans. Pressure sensors and dampers used to monitor and control the supply airflow to each zone. CAMs to detect airborne contamination and to activate alarms.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization 234-5Z."	WHC-SD-CP-SDD-005

Table 9A.1.5
The 234-5Z Building
LI/LO Operations (Room 227).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 227, process LI/LO (continued).	C. E-3 Exhaust ventilation system	To provide airflow to maintain the correct DP between zones.	(1) Insufficient exhaust airflow	Loss of DP between zones 3 and 1, possible spread of contamination to zone 1 areas.	Five exhaust fans normally operating, two fans provide backup. Pressure sensors and dampers used to monitor and control exhaust airflow from each zone. Building supply fans shut down when DP upstream of exhaust fans becomes > -3.5 in. w.g.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization 234-5Z."	Total loss of exhaust is unlikely since there will be a natural draft through the exhaust stack. WHC-SD-CP-SDD-005
				(2) Excessive exhaust airflow	Increased DP between zones 3 and 1.	Pressure sensors and dampers used to monitor and control exhaust airflow from each zone.	Procedure governing operator response to ventilation system upset.	This event is anticipated. Flow will be from areas of no contamination (zone 1) to areas of potential contamination (zone 3). Thus, the consequence is low.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	WHC-SD-CP-SDD-005
			Provides single-stage HEPA filtration of room exhaust.	Loss of HEPA filtration	Potential release of SNM to the environment if airborne contamination is present.	Single-stage HEPA filtration provided by filters in seven filter rooms; any three rooms are in service simultaneously with the remaining rooms on standby. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing maintenance and testing of HEPA filters. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Fire sprinkler system	To provide containment of water until necessary to suppress a fire.	Accidental discharge of water.	Potential criticality. Criticality results in high levels of radiation in the room with a potential release of fission products to the atmosphere.	Plutonium-bearing solutions contained within sealed containers. CAS to detect criticality and to activate criticality alarm. CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation system.	Procedure governing handling of SNM containers. Procedure governing operator response to fire sprinkler system activation. Procedure governing operator response to criticality alarm. Double-contingency principle precludes criticality as a result of a single failure.	The probability of this event occurring is unlikely. The consequence is judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.1.5
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LI/LO Operations (Room 227).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 227, process LI/LO (continued).	E. 26-in. mercury process vacuum.	Provides the motive force used to transfer solutions between glovebox HC-227S and hood HC-227T. Vents tanks during blending and sparging operations.	(1) Excessive vacuum	Potential contamination of 26-in. mercury vacuum system with plutonium-bearing solution. Potential criticality if solution reaches E-4 filter bank.	Vacuum trap conductivity probe activates alarm upon detection of liquid. Liquid detectors on inlet line to vacuum pumps before HEPA filters. Inlet line liquid detection system interlock shuts down vacuum pump, closes HEPA filter isolation valves, and activates alarm upon detection of liquid.	Procedure governing operator verification of vacuum trap liquid detection interlock system functionality. Procedure governing operator response to liquid detection alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-008
				(2) Insufficient vacuum	Loss of solution transfer capability and equipment cleanup capability.	Vacuum gauge above vacuum tank.	Procedure governing operator verification that 26-in. mercury vacuum system is operative.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
		F. Chemical addition tank.	To provide HNO_3 for flushing batch tanks, load-out tanks, and floor of glovebox HC-227S.	Excessive HNO_3	Potential spill of HNO_3 onto room floor. Potential release of HNO_3 fumes to the room and entrainment in the ventilation system.	NO_x monitor alarms when NO_x exceeds 3 ppm. Chemical addition tank high-level alarm. Single-stage HEPA-filtered ventilation exhaust.	Procedure governing operator response to spill of HNO_3.	This event is anticipated. Chemical addition tank only holds 3 L of solution, thus release would be small. The consequence is judged to be low.	Refer to section 9.2.8, "Toxic Chemical Release."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		G. E-4 ventilation exhaust system	Prevents gaseous release from entering room.	Loss of exhaust	Potential release of organic fumes to room. Potential exposure of operators to toxic fumes.	Protective clothing and supplied air. NO_x alarm. Single-stage HEPA-filtered ventilation exhaust system (E-3). Four operating exhaust fans and three on standby.	Procedure governing operator response to appearance of brownish vapors (NO_x).	This event is anticipated. The release would be small and confined within hood. Operators are required to wear protective clothing and supplied air. Thus, the consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005

Table 9A.1.5
The 234-5Z Building
LI/LO Operations (Room 227).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
2	**Room 227, glovebox HC-227S (houses the batch and load out tanks).**	A. Glovebox enclosure	Confinement of plutonium.	Loss of confinement.	Potential release of plutonium-bearing materials to areas occupied by personnel. Potential entrainment in the E-3 ventilation system.	Glovebox is of steel construction with Lexan™ windows. Lexan will not shatter upon strong impact. E-4 exhaust ventilation system maintains a negative DP in the glovebox relative to the room. CAMs to detect airborne contamination and to activate alarms at prescribed activity levels.	Procedure governing operator response to CAM alarm. Procedure governing glovebox maintenance (e.g., glove changeout).	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	Historical events have resulted in minor worker uptake. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Criticality drain	To drain liquid from the glovebox in order to prevent the accumulation of a critical volume of solution.	Failure to adequately drain liquid.	Potential criticality that results in high levels of radiation in room with a potential release of fission products to the atmosphere.	CAS to detect a criticality and to activate alarms.	Procedure governing functionality of criticality drains. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarms.	The probability of this event occurring is unlikely. The consequence is judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to the criticality. A second contingency (failure) would have to occur for a criticality to be possible. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-008
		C. Handling and storage of SNM containers.	To safely handle containers as necessary to support operations.	(1) Inadequate container spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of fission products to the atmosphere.	CAS to detect a criticality and to activate alarms.	CPS posted on glovebox specifies the allowable limits on plutonium quantities, container volumes, and minimum spacing. Double-contingency principle. Procedure governing operator response to criticality alarms.	The probability of inadequate spacing is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. Need failure of additional contingency for a criticality to be possible. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-011
				(2) Dropped container	Potential spill of SNM within glovebox. Potential airborne release and entrainment of plutonium in E-4 ventilation system.	Glovebox confinement. Glovebox outlet HEPA filter. Two-stage HEPA-filtered ventilation exhaust system. 291-Z-1 stack CAM to detect airborne contamination and to activate alarms.	Procedure governing operator response to spill of SNM. Procedure governing operator response to CAM alarm.	This event is anticipated. The release would be small and confined within the glovebox. Thus, the consequence is judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	Historical events has resulted in minor worker uptake. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.1.5
The 234-5Z Building
LI/LO Operations (Room 227).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 227, glovebox HC-227S (continued).	D. Blending/ sampling tanks	To contain solutions during blending/sampling operations.	(1) Leak/overflow of tanks	Potential criticality that results in high levels of radiation in room with a potential release of fission products to the atmosphere.	CAS to detect a criticality and to activate alarms. Glovebox criticality drain. Glovebox sump probe that alarms when liquid is detected.	CPS posted on glovebox specifies volume, mass, and spacing limits. CPS requires any spill in excess of accumulation limit to be cleaned up before operations. Procedure governing operator response to criticality alarm.	A leak/overflow from a tank is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-008
				(2) Excessive plutonium in tanks	Potential criticality which results in high levels of radiation in room with a potential release of fission products to the atmosphere.	CAS to detect criticality and to activate alarms. The tanks are of a critically safe geometry.	CPS posted on glovebox specifies volume, mass, and spacing limits. Double-contingency principle precludes the potential for a criticality as a result of a single failure.	Excessive plutonium in the tanks is an unlikely event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	A criticality could potentially result in severe consequences to the workers. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-008
				(3) H_2 buildup	Potential explosion with release of plutonium-bearing materials. Potential entrainment of material in the E-3 ventilation exhaust system.	CAMs to detect airborne contamination and to activate alarms. Single-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to CAM alarm.	This event is unlikely. The consequences are judged to be moderate.	Refer to section 9.1.8.4, "Hydrogen Accumulation."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		E. Supplied air	To provide air to the receiver tank sparger for sample blending.	(1) Excessive air	Potential pressurization of glovebox may cause a loss of glovebox confinement. Potential release of SNM to the room and entrainment in the E-3 ventilation exhaust system.	Glovebox E-4 ventilation exhaust system maintains glovebox at negative DP relative to the room. 26-in. mercury vacuum system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing verification of 26-in. mercury vacuum system functionality before sparging operation. procedure governing operator response to CAM alarm.	The probability of the event occurring is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Insufficient air	Solution not thoroughly mixed. Inadequate blending and sampling of nitrate solution sent to processing.	Two water cooled compressors supply process air.		The probability of the event occurring is anticipated. However, the consequence is low.	Not specifically analyzed.	
		F. E-4 exhaust ventilation system	To provide airflow to maintain correct negative pressure control of glovebox.	(1) Insufficient exhaust airflow	Potential loss of negative DP of glovebox relative to the room. Potential release of SNM into the room and entrainment in the E-3 exhaust system.	Glovebox DP gauge. Room CAMs provided to detect and alarm at prescribed airborne radioactivity levels.	Procedure governing operator response to glovebox DP outside of operating limits.	The probability of this event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.5
The 234-5Z Building
LI/LO Operations (Room 227).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 227, glovebox HC-227S (continued)	F. E-4 exhaust ventilation system (continued)	To provide airflow to maintain correct negative pressure control of glovebox.	(2) Excessive exhaust airflow	Potential increased negative DP in glovebox relative to the room may result in a loss of glovebox confinement. Potential entrainment of loose SNM in the E-4 exhaust system.	Glovebox outlet HEPA filter. Two-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to glovebox DP outside of operating limits.	The probability of this event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		G. Glovebox inlet/outlet HEPA filters.	To provide filtration of glovebox exhaust during normal and reverse flow conditions.	Loss of filtration	Potential release of plutonium-bearing materials to the room. Potential entrainment in the ventilation exhaust system and release to the environment.	Two parallel inlet HEPA filters. Two-stage HEPA-filtered E-4 exhaust system. CAMs provided to detect and alarm at prescribed airborne radioactivity levels. Outlet HEPA filter DP gauge. Glovebox DP gauge.	Procedure governing operator response to outlet HEPA filter or glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm.	The probability of this event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
3	**Room 227, hood HC-227T**	A. Hood enclosure	To capture contaminated air and direct it into the E-4 exhaust system.	Inadequate exhaust	Potential release of contaminants to the room. Potential entrainment in the E-3 ventilation exhaust system.	NO_x monitor located in room.	Procedure governing required protective equipment (e.g., respirators). Procedure governing operator response to NO_x alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	
		B. Container handling	To safely handle containers as necessary to support operations.	(1) H_2 build up	Potential explosion with release of plutonium-bearing materials to the room. Potential entrainment of SNM in the E-3 exhaust ventilation system.	HEPA-filtered exhaust ventilation systems. CAMs to detect airborne contamination and to activate alarms.	Procedure governing handling of containers during LI/LO operation.	This event is unlikely. The consequences are judged to be moderate.	Refer to section 9.1.8.4, "Hydrogen Accumulation."	Potentially severe consequences to workers in the vicinity of explosion. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Dropped container	Potential spill and flooding of the confinement structure. Potential criticality. Potential airborne release of SNM. Potential entrainment of SNM in the E-4 exhaust ventilation system.	HEPA-filtered exhaust ventilation systems. CAMs to detect airborne contamination and to activate alarms. Criticality drain to prevent accumulation of liquids. CAS to detect criticality and to activate criticality alarms. HEPA-filtered exhaust system.	Procedure governing inspection of hoist. Use of yoke or clamping device. Procedure governing operator protective equipment. Procedure governing operator response to a criticality alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.1.6

Storage Vaults

The function of the storage vaults is to provide safe and secure storage for SNM. The activities associated with the storage vault operations are the storage, handling, and inspection of SNM containers.

Rooms 172 and 173 provide floor storage for PR cans.

Rooms 174 and 175 are storage vaults containing cabinet (room 174) or pedestal (room 175) storage. Analysis shows that the containers in the storage cabinets could be overturned, but would remain in the cabinets on their respective trays. Analysis shows that the pedestals will not fail, the anchors to the wall and floor will not fail, and the container will not come out of the holder (Vollert 1987a, 1987b). Ventilation is needed in these storage areas. Loss of ventilation could result in container pressurization due to heat buildup.

Room 190 contains pedestal storage.

Rooms 192-B and 192-C contain pedestal storage of plutonium compounds, and, as such, are similar to room 175. Room 192-A has floor storage of FFTF fuel pins and bundles in shipping containers which will not be ruptured during a seismic event.

Room 225 is a storage vault. Fixed-array storage in cubicles is allowed for laboratory standards samples.

Table 9A.1.6
The 234-5Z Building: Storage Vaults (Rooms 172-175, 192A, 192B, 192C) (194, 201, 225, 236).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	Storage vaults	A. Vault storage cabinets (room 174) and pedestals.	To maintain container separation distance for the purpose of criticality safety.	Loss of container separation.	Potential criticality and release of fission products to the atmosphere. Potential release of SNM from the storage containers and entrainment in the ventilation system.	Analysis shows that pedestals will survive a DBE (Vollert 1987a, 1987b). CAS to detect a criticality and to activate criticality alarms. CAMs to detect airborne alpha contamination and to activate alarms. Two-stage HEPA-filtered ventilation exhaust system.	The OSD requires SNM stored in the vault to be packaged with a minimum of two containment barriers. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to a criticality alarm. Procedure governing operator response to CAM alarm.	Structural failure of the storage pedestals is not credible.	Refer to section 9.2.4A.2.1, "Accident Scenarios, 234-5Z Building."	There is no credible scenario that could challenge the integrity of the storage rack other than an earthquake. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		B. Vault ventilation supply system.	Provides airflow for the removal of heat generated by decay of the SNM within the vault and for maintaining correct negative DP control of the vault.	(1) Insufficient supply airflow.	Additional thermal loading of SNM containers and resulting container pressurization could potentially result in loss of SNM from storage container(s) and entrainment in the ventilation system.	Supply fan flow monitors activate alarm upon low flow condition. SNM containers designed to withstand 100 lb/in^2 internal pressure before gross failure (Szempruch 1984). CAMs to detect airborne alpha contamination and to activate alarms. Two-stage HEPA-filtered ventilation system.	OSD requires SNM stored in the vaults to be packaged with a minimum of two containment barriers. Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.8.6, "Vault Temperature Rise."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
					Potential excessive negative DP within the vault if the exhaust system continues to operate.	Five operating and two standby supply fans. Pressure sensors and dampers monitor and control the supply airflow to the vaults.	Procedure governing operator response to ventilation system upset.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	WHC-SD-CP-SDD-005
				(2) Excessive supply airflow.	Potential pressurization of vault relative to adjacent areas. Potential release of any loose SNM to adjacent areas.	Pressure sensors and dampers monitor and control the supply airflow to the vaults. SNM contained within sealed storage containers. CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system.	Procedure governing operator response to a ventilation system upset. Procedure governing operator response to a CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization, 234-5Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.6
The 234-5Z Building: Storage Vaults (Rooms 172-175, 192A, 192B, 192C) (194, 201, 225, 236).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Storage vaults (continued).	C. Vault ventilation exhaust system	Provides airflow for the removal of heat generated by the decay of SNM within the vault and for maintaining correct negative DP control of the vault.	(1) Insufficient exhaust airflow.	Potential additional thermal loading of SNM containers. Potential pressurization of SNM containers and release of SNM. Potential pressurization of vault relative to adjacent areas if supply fans continue to operate could result in a release of SNM to these areas.	Four operating exhaust fan and three on standby. Two exhaust fans are provided with backup power. Pressure sensors and dampers monitor and control the exhaust airflow from the vaults. SNM storage containers determined to withstand 100 lb/in^2 internal pressure before gross failure (Szempruch 1984). CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system.	Procedure governing operator response to a ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7A, "Excessive Building Pressurization, 234-5Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive exhaust airflow.	Potential excessive negative DP within the vault. Potential entrainment of any loose SNM in the exhaust ventilation system.	Pressure sensors and dampers monitor and control the exhaust flow from the vaults. CAMs to detect airborne alpha contamination and to activate alarms. Two-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F.1, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		D. Vault SNM storage containers	To provide primary containment of SNM within the vault.	Loss of containment.	Potential release of SNM into the vault. Potential entrainment of SNM in the ventilation system and release to the environment.	CAMs to detect airborne contamination and to activate alarms. Two-stage HEPA-filtered ventilation system.	OSD requires SNM stored in the vaults to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm. Procedure governing operator response to detection of SNM container anomaly during required (by OSD) monthly inspection.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills", and section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		E. Handling of SNM storage containers.	To safely move SNM containers to/from vault storage location as needed to support operations.	(1) Dropped SNM container.	Potential loss of containment and entrainment of SNM in the ventilation system.	Tests have shown that SNM containers dropped to a hard, unyielding surface do not suffer gross failures. CAMs to detect airborne alpha contamination and to activate alarms. Two-stage HEPA-filtered exhaust.	Procedure governing operator response to dropped container. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to item above.	Refer to item above.

Table 9A.1.6
The 234-5Z Building: Storage Vaults (Rooms 172-175, 192A, 192B, 192C) (194, 201, 225, 236).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Storage vaults (continued).	E. Handling of SNM storage containers (continued).	To safely move containers to/from vault storage location as needed to support operations.	(2) Inadequate spacing between container being handled and other containers.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency.	Same as above, except drop test information is not applicable. CAS to detect criticality and to activate criticality alarms.	Double contingency principle. Procedure governing operator response to criticality alarm. Procedure governing operator response to CAM alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to operators in proximity to a criticality. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		F. Inspection of SNM storage containers.	To detect SNM container anomalies (i.e., bulging, corrosion, dents, penetrations).	Failure to detect SNM container anomaly.	Potential loss of containment and entrainment of SNM in the ventilation system.	--	Procedure governing operator response to detection of SNM container anomaly.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		G. Shipping containers	To provide containment of SNM.	Loss of containment.	Potential release of SNM to the vault. Potential entrainment of SNM in the ventilation exhaust system and release to the environment.	CAMs to detect airborne alpha contamination and to activate alarms. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing storage of containers on floor of vault. Procedure governing operator response upon detection of container anomaly during required (by OSD) monthly inspection. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		H. Handling of shipping containers	To safely move shipping containers to/from the vault.	Refer to item 1E.	Refer to item 1E.	Refer to item 1E.	Refer to item 1E.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills", and section 9.2.3, "Criticality."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
		I. Inspection of shipping containers	To detect container anomalies (i.e., bulging, corrosion, dents, penetrations.)	Refer to item 1F.	Refer to item 1F.	--	Procedure governing operator response to detection of SNM container anomaly.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

[a]Event category and hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.1.7

Miscellaneous Areas

Miscellaneous operations include waste drum storage (room 196), PR can storage (room 172), radioactive mixed waste storage (room 197), trash compaction (room 234), NDA drum counting (room 234A), PR/L-10 storage vault (room 236), and the chemical preparation room (rooms 336 and 337).

Waste Drum and Radioactive Mixed Waste Storage.

Storage areas for TRU radioactive solid waste and TRU radioactive mixed waste in 55-gal drums.

Trash Compaction.

A trash compactor used to compact miscellaneous radioactive waste.

NDA Drum Counting.

Used for the NDA of containers of SNM to determine the total weight of isotopes by measuring the radioactive emissions and/or the heat output of plutonium bearing material in the package.

Chemical Prep Room.

Facilities in rooms 336 and 337 were used to prepare and supply chemicals to the RMC Line and are currently used to supply chemicals for glovebox HC-227S/hood HC-227T operations. Room 336 contains tanks stored under a ventilated hood that exhausts through roof exhausters. The room is equipped with safety showers, floor drains, and fire sprinklers. Motor controls for outside chemical pumps are located in room 337.

Dilute HNO_3 solution is made up in tanks located in room 336 by first adding the specified volume of water to the tank. Concentrated HNO_3 (57%) is then added by pump transfer from drums. The solution is agitated, sampled, and analyzed for HNO_3 molarity. The solution is piped by gravity-drain to glovebox HC-227S to be used for adjustment of process solution acidity and as a flush solution. One tank is valved in to the process while the second tank is being refilled or is on standby.

Table 9A.1.7
The 234-5Z Building
Miscellaneous Areas
(Rooms 172, 196, 197, 234)
(234A, 236, 336, and 337).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Room 196, waste drum storage**	A. Handling of waste drums.	To safely handle drums as necessary to support operations.	(1) Dropped container	Potential release of SNM to the room. Potential entrainment in the ventilation exhaust system and release to the environment.	Drum barrel hand trucks used to move drums. Single-stage HEPA-filtered E-3 exhaust system. CAMs to detect airborne contamination and to activate alarms.	Packaging requirement for double containment. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Inadequate spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency.	CAS to detect a criticality and to activate criticality alarm.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to a criticality alarm.	Inadequate spacing is an anticipated event. The consequence is judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
		B. Fire sprinkler system.	To contain water until necessary to discharge for suppression of a fire.	Accidental discharge of water.	Potential criticality that results in high levels of radiation in room and release of fission products to the atmosphere.	CAS to detect a criticality and to activate criticality alarm. Waste drum designed to resist moisture intrusion.	Double contingency principle. Procedure governing operator response to a criticality alarm. Packaging requirements limit the amount of fissile material.	This event is unlikely. The consequence is judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. Room is normally unoccupied. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-010
2	**Room 197, radioactive mixed waste storage**	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.	Refer to items 1A and 1B.
3	**Room 234, trash compactor**	A. Trash compactor	Confinement of radioactive materials during compaction process.	Loss of confinement.	Potential release of SNM to the room. Potential entrainment in the exhaust ventilation system and release to the environment.	Trash compactor is fabricated from metal. Exhaust ventilation system maintains a negative DP in the compactor relative to the room. CAMs to detect airborne contamination and to activate alarms. HEPA-filtered exhaust ventilation system.	Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.1.7
The 234-5Z Building
Miscellaneous Areas
(Rooms 172, 196, 197, 234)
(234A, 236, 336, and 337).

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	Room 234, trash compactor (continued).	B. E-4 exhaust system	To provide airflow to maintain negative DP of the compactor relative to the room.	(1) Insufficient exhaust airflow	Potential loss of negative DP between the compactor and the room. Potential release of SNM into the room and entrainment in the E-3 exhaust system.	CAMs to detect airborne contamination and to activate alarms. Four operating and three backup exhaust fans.	Procedure governing operator response to CAM alarm. Procedure governing operator response to a ventilation system upset (i.e., cessation of compactor operation).	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
				(2) Excessive exhaust airflow	Potential excessive negative DP between the compactor and the room. Potential entrainment of loose material into the exhaust system.	Two-stage HEPA-filtered E-4 exhaust system.	Procedure governing operator response to a ventilation system upset.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
4	**Room 234A, NDA drum counting**	NaI package counter	A. To measure the plutonium content of waste or scrap in different package forms.	Dropped container (55 gal drum or 50 lb slip lid cans)	Potential loss of containment. Potential release of SNM to the room and entrainment in the exhaust ventilation system. Potential release to the environment.	Drum barrel hand trucks have hook slides that go over the barrel outer ring to keep it from falling. Raised ring on NaI package counter table. HEPA-filtered exhaust system. CAMs to detect airborne contamination and to activate alarms.	Procedure governing movement of SNM. Procedure governing operator response to a spill. Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011
			B. Movement of SNM within the PFP AL.	Inadequate spacing	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency.	CAS to detect a criticality and to activate criticality alarms.	Double contingency principle. Procedure governing operator response to criticality alarm. Procedure governing transportation of SNM.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	Potentially severe consequences to workers in proximity to a criticality. WHC-SD-CP-SDD-003
5	**Room 336 and 337, chemical preparation room**	--	To prepare and supply chemicals to PFP.	Leak	Potential release of hazardous chemicals to the room. Potential generation of hazardous fumes. Potential entrainment of fumes in the ventilation exhaust system.	Sump around tanks to catch leaks and spills. Sump overflows to outside tank that alarms when full. Tanks in a hooded area and ventilates through roof exhausters.	Procedure governing operator response to a spill.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.2.8, "Toxic Chemical Release."	The rooms are used to provide acid to glovebox HC-227S in room 227. WHC-SD-CP-SDD-005

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.2

The 2736-Z Support/Storage Complex

The 2736-Z complex is comprised of six separate buildings that conduct several different operations in support of the current PFP mission. The buildings and their functions are listed below:

9A.2.1	2736-Z Building--Vault storage of SNM
9A.2.2	2736-ZA Building--Exhaust ventilation and filtration for the 2736-Z Building
9A.2.3	2736-ZB Building--Shipping/receiving/repackaging/NDA of SNM
9A.2.4	2736-ZC Building--All weather loading dock (attached to the 2736-ZB Building via enclosed corridor)
9A.2.5	2736-ZD Building--Currently stores three experimental breeder reactor (EBR) II casks containing irradiated metallic fuel rods. May store a maximum of seven casks.
9A.2.6	2721-Z Building--Backup electrical power (three diesel generators) for the PFP facilities.

Shipments of SNM are received at the 2736-ZC Building. A jib crane equipped with a chain hoist and drum handler unloads material containers from cargo restraint transporters. The cargo restraint transporters are stored within the 2736-ZC Building, while the material containers are transferred to the 2736-ZB Building. Once inside the 2736-ZB Building, the containers are inspected, weighed, and sorted. The 2736-ZB Building is used to repackage stable/shippable SNM as necessary, and to perform NDA of the fissile material content of material containers. Safe and secure storage of stable/shippable SNM containers in vaults is the function of the 2736-Z Building. The 2736-ZA Building provides exhaust ventilation and HEPA filtration for the 2736-Z Building (supply air is provided by the 2736-ZB Building.) The 2736-ZD Building stores three EBR II storage casks containing irradiated metallic fuel rods. The 2721-Z Building houses three diesel generators and the switching gear used to provide backup electrical power to the PFP facilities.

Appendix 9A.2.1

2736-Z Building

The only function of the 2736-Z Building is to provide safe and secure storage for stable/shippable SNM.

The 2736-Z Building has barriers designed to provide containment of hazardous materials. The primary barrier in the 2736-Z Building is a SNM storage or transportation container. The secondary barrier serves to enclose the area containing the primary barrier. An example is a concrete storage cubicle (within one of the vaults) that holds SNM storage containers. The 2736-Z Building structure and building ventilation system work together to form a confinement system designed to mitigate the release of hazardous material should a barrier fail.

The building ventilation system completes the confinement system by providing a controlled, continuous flow of air from the environment into the various building areas and then back to the environment after HEPA filtration. The ventilation supply air is provided by supply fans located in the 2736-ZB Building via an underground duct between the two buildings. The relative pressure of each building area is controlled independently by supply and exhaust dampers. The air pressure in each area is normally negative relative to the atmosphere to prevent the movement of airborne material out of the building. Ventilation exhaust airflow is provided by fans located in the 2736-ZA Building. The 2736-Z Building ventilation exhaust air moves to the 2736-ZA Building via an aboveground duct assembly. The exhaust air is filtered through two stages of HEPA filtration in the 2736-ZA Building and discharged to the environment through the 296-Z-6 stack.

Two rooms, separated by fire walls, are located on each side of the corridor. The rooms are designated as vault 1, vault 2, vault 3, and vault 4. Vaults 1, 3, and 4 contain storage cubicles having pedestal storage rings for SNM storage containers (two of the storage cubicles in vault 1 have shelf storage). Vault 2 contains metal storage racks having storage shelves for SNM storage containers and open floor storage space for larger items such as shipping containers.

Normal electrical power for the building is provided from the 291-Z Building, while backup power is provided by the three diesel generators in the 2721-Z Building and the diesel generator in the 2736-ZA Building.

The only authorized operations occurring within the 2736-Z Building are the storage, handling, and inspection of SNM containers. SNM containers are stored and inspected in each of the four vaults, while handling of containers occurs in each of the four vaults and the building corridor.

Vault 2, unlike the other three vaults, has water supplied for a sprinkler system.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded.

They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Vaults 1, 3, and 4.**	A. Vault storage cubicles/pedestal storage rings.	Provides shielding to reduce neutron interactions between SNM stored in adjacent cubicles and maintains container separation distance for the purpose of criticality safety.	Loss of shielding and container separation.	(1) Potential loss of SNM from storage container(s) and entrainment in the ventilation system.	Storage cubicles/pedestals determined to withstand DBE loads (Ocoma 1994). CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation exhaust system to mitigate the release of SNM to the environment.	The OSD requires SNM stored in the vault to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm.	Structural failure of the storage cubicles/pedestals is not credible.	Refer to section 9.2.4A.1.1, "Building Response During a Seismic Event."	There is no credible scenario that could challenge the integrity of the cubicles other than an earthquake. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
					(2) Potential criticality with a resultant potential loss of SNM from storage container(s) and entrainment in the ventilation system.	Same as above. CAS to detect criticality and to activate criticality alarm.	Same as above. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm .			
		B. Vault ventilation supply.	Provides air flow for removal of heat generated by decay of SNM within the vault and for maintaining correct negative pressure control of vault.	Insufficient supply air flow.	(1) Additional thermal loading of SNM containers and resulting container pressurization could potentially result in loss of SNM from storage container(s) and entrainment in the ventilation system. Potential release of SNM to the environment.	One operating supply fan and one on standby. Supply fan flow monitors activate alarm upon low flow condition. Cubicle/container temperature monitors. SNM containers designed to withstand 100 lb/in^2 internal pressure before gross failure (Szempruch 1984). CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to flow alarms and a pressure alarm for the 2736-Z Building. Procedure governing operator response to container temperature(s) outside allowable limits. OSD requires SNM stored in the vaults to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm.	Short term insufficient supply air is an anticipated event. The consequences are judged to be low. Long term insufficient supply air is an extremely unlikely event. The consequences are judged to be moderate.	Refer to section 9.2.4A.6.3.6.D, "Accident Analysis Calculations, 2736-Z Complex, Container Heatup."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Vaults 1, 3, and 4 (continued)**	B. Vault ventilation supply (continued)	Provides air flow for removal of heat generated by decay of SNM within the vault and for maintaining correct negative pressure control of vault.	Insufficient supply air flow	(2) Potential excessive negative pressure within the vault if the exhaust system continues to operate .	Building DP sensor activates alarm upon sensing abnormal pressure. Computer-controlled ventilation system designed to disable supply and exhaust fans upon sensing low-flow condition. SNM contained within sealed storage containers. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1B(1)	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	See Item 4 for analysis of the building ventilation system. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				High flow of supply air.	(3) Potential pressurization of vault with respect to building corridor and release of SNM to building corridor if there is any loose SNM within the vault.	Supply dampers are designed to fail closed. SNM contained within sealed storage containers. CAMs to detect airborne alpha contamination and to activate local alarms should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1B(1)	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.7D, "Excessive Building Pressurization, 2736-Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Vaults 1, 3, and 4 (continued)**	C. Vault ventilation exhaust.	Provides air flow for removal of heat generated by decay of SNM within the vault and for maintaining correct negative pressure control of vault.	Insufficient exhaust air flow.	(1) Refer to item 1B(1) and 1B(2)	Computer-controlled ventilation system designed to disable supply and exhaust fans upon sensing low flow condition. One operating exhaust fan and one on standby. Cubicle/container temperature monitors. SNM storage containers designed to withstand 100 lb/in^2 internal pressure before gross failure (Szempruch 1984). CAMs to detect airborne contamination and to activate alarm(s). Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1B(1)	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7D, "Excessive Building Pressurization, 2736-Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				High exhaust flow.	(2) Potential excessive negative pressure within the vault .	Computer controlled exhaust ventilation dampers. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1B(1)	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F.4, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	See item 4. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Vault SNM storage containers.	To provide primary containment of SNM within the vault.	Loss of containment.	Potential release of SNM into the vault. Potential entrainment of SNM in the ventilation system.	Vault safety and inventory system (VSIS) monitors storage containers for dimensional changes. Containers restrained within cubicles to prevent inadvertent movement from storage location. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	The OSD requires SNM stored in the vaults to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm. Procedure governing operator response to VSIS anomalies annunciated in rooms 104 and 306A of the 234-5Z Building.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Vaults 1, 3, and 4 (continued).**	E. Handling of SNM storage containers.	To safely move SNM containers to/from vault storage location.	(1) Dropped SNM container.	Potential loss of containment and entrainment of SNM in the ventilation system.	Tests have shown (Hammond 1976a) that food-pack cans (i.e., SNM containers) can be dropped from a height of 3 m without suffering a loss of containment. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation exhaust system to mitigate the release of SNM to the environment.	Same as above, except response to VSIS anomalies is not applicable.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Inadequate spacing between container being handled and other containers.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential loss of containment and entrainment of SNM in the ventilation system.	Refer to item above, except drop test information is not applicable. CAS to detect criticality and to activate criticality alarm horns.	Refer to item 1A(2)	Inadequate spacing is an anticipated event. The consequences are judged to be low.		A criticality could potentially result in severe consequences to the worker. A criticality due to inadequate spacing of containers is not a credible event. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		F. Vault safety and inventory system.	To remotely monitor SNM container temperature, ambient air temperature, dimensional changes of the container, container presence, and container identification number.	Failure to detect SNM container anomaly.	Potential loss of containment and entrainment of SNM in the ventilation system.	Refer to item 1D. VSIS anomalies annunciated in rooms 104 and 306A of the 234-5Z Building.	Refer to item 1D. Procedure governing operator response to VSIS anomalies annunciated in rooms 104 and 306A of the 234-5Z Building.	This event is anticipated. The consequence is judged to be low.	Refer to item 1D.	Refer to item 1D. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
2	**Vault 2**	A. Vault storage racks	To maintain container separation for the purpose of criticality safety.	Loss of container separation.	Refer to item 1A.	Storage racks determined to withstand seismic event (Ocoma 1994, and WHC-SD-CP-SA-026). Refer to item 1A except for seismic qualification of cubicles, which is not applicable.	Procedure governing operator response to CAM alarm.	Structural failure of the storage racks is not credible.	Refer to item 1A.	No credible scenario that could challenge rack integrity other than the seismic event. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
2	Vault 2 (continued).	B. Vault ventilation supply	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Vault ventilation exhaust	Refer to item 1C.	Refer to item 1C.	Refer to item 1C.	Refer to item 1C.	Refer to item 1C.	Refer to item 1C.	Refer to item 1C.	Refer to item 1C. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Vault SNM Storage containers	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Containers restrained within storage racks by chains to prevent fall from shelf. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to detection of SNM container anomaly during required (by OSD) monthly inspection. Procedure governing operator response to CAM alarm.	Refer to item 1D.	Refer to item 1D.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		E. Handling of SNM storage containers.	Refer to item 1E.	Refer to item 1E.	Refer to item 1E.	Hammond (1976b) showed that lard cans are resistant to failure when dropped from heights up to 80 in. Refer to item 2D., except restraint of containers is not applicable.	Refer to item 1E.	Refer to item 1E.	Refer to item 1E.	Refer to item 1E. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		F. Inspection of SNM storage containers.	To detect SNM container anomalies (i.e., bulging, corrosion, dents, penetrations).	Refer to item 1F.	Refer to item 1F.	--	Procedure governing operator inspection of containers for anomalies.	Refer to item 1F.	Refer to item 1F.	Refer to item 1F. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		G. Shipping containers.	To provide containment of SNM.	Refer to item 1D.	Refer to item 1D.	SNM contained within sealed metal containers inside of shipping container. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing storage of containers on floor of vault. Procedure governing operator response upon detection of container anomaly during required (by OSD) monthly inspection. Procedure governing operator response to CAM alarm.	Refer to item 1D.	Refer to item 1D.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
2	**Vault 2 (continued).**	H. Handling of shipping containers.	To safely move shipping containers to/from the vault.	Refer to item 1E.	Refer to item 1E.	Refer to item above. Containers designed to withstand fall from 30 ft without a loss of containment.	Procedure governing handling of shipping containers using drum barrel hand trucks.	Refer to item 1E.	Refer to item 1D.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		I. Inspection of shipping containers.	To detect container anomalies (i.e., bulging, corrosion, dents, penetrations).	Refer to item 1F.	Refer to item 1F.	--	Refer to item 2F.	Refer to item 1F.	Refer to item 1F.	Refer to item 1F. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		J. Vault water supply system.	To supply water to the vault sprinkler system.	Flooding of vault with water.	Potential criticality as a result of flooding and dislodgement of containers from shelf storage positions.	Containers are designed to resist moisture intrusion. Containers on shelves are restrained within cubicle by chains. Room has scuppers 1/2 in. above the floor to discharge water to the corridor of the building, which has a sealed drain.	Procedure governing operator response to water intrusion within vault. Double contingency principle precludes the potential for a criticality as a result of a single failure.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.4A.2.11.A, "Accident Scenario-Criticality, Vaults."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-010 WHC-SD-CP-SDD-011
3	**Vault corridor**	A. Handling of SNM storage containers	Refer to item 1E.	Refer to item 1E.	Refer to item 1E.	Refer to item 1E. SNM is transported through corridor in fixed-array wagon.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to item 1D.	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Sprinkler system	To contain water until necessary to suppress a fire occurring within the corridor.	Water leak from sprinkler system.	Potential flooding of vault corridor. Potential flooding of vaults.	Corridor has a sealed drain.	Procedure governing operator response to water intrusion within corridor.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-010
4	**Building ventilation system**	A. Exhaust HEPA filters (located in the 2736-ZA Building; see Table A.2.2)	To filter exhaust ventilation air before atmospheric discharge in order to mitigate the release of SNM to the environment.	Loss of exhaust air filtration.	Potential release of SNM to the environment if a loss of containment event occurs concurrently.	296-Z-6 stack CAM to detect airborne alpha contamination and to activate alarm(s) if alarm set point is exceeded. HEPA filter DP gauges. Backup two-stage HEPA-filtration system on standby.	Procedure governing operator response to inappropriate HEPA filter DP value. Procedure governing operator response to the CAM alarm for the 296-Z-6 stack.	This event is anticipated. The consequences are judged to be low because there is normally no loose contamination in the building.	Not specifically analyzed.	Loss of filtration is analyzed in Table A.2.2 for the 2736-ZA Building because it houses the exhaust HEPA filters for the 2736-Z Building. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.1
2736-Z Complex: 2736-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**Building ventilation system (continued)**	B. Exhaust interface duct assembly (connecting the 2736-Z Building to the 2736-ZA Building)	To provide confinement of exhaust ventilation air flowing from the 2736-Z Building to the 2736-ZA Building.	Loss of confinement due to shear-tearing of a light-gauge sheet metal portion of the duct as a result of differential building motion in an earthquake.	Potential release of SNM to the environment if the 2736-Z Building is overpressurized and there is either a loss of confinement of a storage container or there is SNM present in the duct as holdup.	--	Procedure governing operator response to shut down the ventilation system for the 2736-Z Building in the event of an earthquake of large enough magnitude to potentially compromise the integrity of the duct.	This event is unlikely. The release from this flowpath is negligible compared to the releases from other PFP facilities as a result of a seismic event.	Refer to section 9.2.4A.6.3.6.E., "Accident Analysis-Calculations, 2736-Z Complex, Storage Container Failure."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Ventilation supply system (supply fans located in the 2736-ZB Building, room 602)	To provide air flow for (1) removal of heat generated by decay of SNM within vaults and (2) maintaining correct negative pressure control of vaults.	Refer to item 1B.	Refer to item 1B.	Ventilation system has backup equipment on standby with backup power provided by the 2721-Z Building. Computer-controlled ventilation system designed to disable fans upon low flow. Cubicle/container temperature monitors.	Procedure governing operator response to flow alarms and the pressure alarm for the 2736-Z Building (located in room 714 of the 234-5Z Building) Procedure governing operator response to cubicle/container temperature(s) outside allowable limits.	This event is anticipated. The consequences are judged to be low.	Refer to item 1B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Ventilation exhaust system (exhaust fans located in the 2736-ZA Building)	Refer to item 4C.	Refer to item 1C.	Refer to item 1C.	Refer to item 4C.	Refer to item 4C.	This event is anticipated. The consequences are judged to be low.	Refer to item 1C.	Building modified to withstand the pressurization due to a 175 mi/h tornado (Giller 1990). WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
5	**Normal electrical power supply system (provided by the 291-Z Building).**	--	To provide electrical power for the building electrical requirements.	Loss of electrical power.	Potential loss of ventilation system control that could result in the release of SNM to the environment if a loss of containment occurs concurrently; potential loss of function of monitoring and alarm systems.	Backup power is provided by the 2721-Z Building and an uninterruptible power supply system. Ventilation system designed to fail to a state that will maintain confinement. Sealed containers provide primary SNM containment.	Procedure governing operator response to loss of electrical power event.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.8, "Loss of Ventilation."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
6	**Air sample vacuum system (supplied by the 291-Z Building).**	--	Provides the motive force (vacuum) necessary to operate the room CAMs.	Loss of vacuum.	Potential inoperability of room CAMs. Potential failure to detect airborne contamination within the building.	CAM failure alarm. Backup systems (e.g., portable CAMs) are available for use.	Procedure governing operator response to CAM failure.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.2.2

2736-ZA Building

The 2736-ZA Building consists of two rooms (designated rooms 649 and 650) and the 296-Z-6 stack. The function of the building is to provide exhaust airflow for the 2736-Z Building, and to provide HEPA filtration of the exhaust air before it is discharged to the environment.

The 2736-ZA Building structure and exhaust ventilation system form a confinement system designed to mitigate the release of hazardous material to the environment in the event of a barrier failure in the 2736-Z Building.

Room 650 contains two exhaust fans that provide ventilation exhaust for the 2736-Z Building, and four HEPA filters arranged in series (two groups of two) that provide two stages of filtration for the ventilation exhaust air before discharge to the atmosphere through the stack. Room 650 also houses a small compressor that provides backup instrument air for the 2736-Z and 2736-ZA Buildings.

Normal electrical power is provided to the building by two separate sources in the 234-5Z Building. Backup power is provided by the diesel-generators in Building 2721-Z.

Instrument air and air sample vacuum are provided to the building by equipment located in the 291-Z Building.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.2.2
2736-Z Complex: 2736-ZA Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ Activity	Function	Failure Mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Room 650, ventilation system**	A. Exhaust HEPA filters	To filter exhaust ventilation air from the building and the 2736-Z Building before atmospheric discharge in order to mitigate the release of radioactive particulates to the environment.	Loss of exhaust air filtration.	Potential release of SNM to the building and to the environment.	CAMs (room and stack) to detect airborne alpha contamination and to activate alarm(s) if alarm set point is exceeded. HEPA filter DP gauges. Backup two-stage HEPA filtration system on standby.	Procedure governing operator response to off normal HEPA filter DP value. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Not specifically analyzed.	Normally there is no loose SNM in either the 2736-Z Building or the 2736-ZA Building. Therefore, for a release of SNM to the environment to occur there must also be a loss of containment event in the 2736-Z Building. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system.	Provides airflow for cooling of room as necessary.	Insufficient supply airflow.	Potential for excessive temperature inside of room.	Two supply fans available to provide filtered outside air for room. Two temperature controllers to activate motor-controlled dampers to allow filtered outside air into room.	--	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	
		C. Ventilation exhaust system.	Provides exhaust airflow for the 2736-Z Building and the 2736-ZA Building.	Insufficient exhaust airflow.	(1) Potential loss of pressure control for the 2736-Z Building, and (2) potential increased temperature of SNM storage containers in 2736-Z. See Table A.2.1 for the hazard analysis of these events for the 2736-Z Building.	Two exhaust fans; one operating and one on standby. Computer-controlled ventilation system activates alarm upon sensing low flow condition.	Procedure governing operator response to low flow alarm.	This event is anticipated. The consequences in the 2736-ZA Building are low.	Not specifically analyzed.	Insufficient exhaust airflow has minimal impact on the 2736-ZA Building. However, the exhaust system also provides exhaust airflow for the 2736-Z Building. See Table A.2.1 for the hazard analysis of the ventilation exhaust system for the 2736-Z Building. WHC-SD-CP-SDD-005

Table 9A.2.2
2736-Z Complex: 2736-ZA Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ Activity	Function	Failure Mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
2	**Room 650, instrument air (provided from room 501 of the 291-Z Building.)**	--	Provides air for use in instrument controls for the ventilation system.	Failure to provide air.	Potential loss of ventilation system control. Loss of ventilation system control could lead to loss of ventilation for the building and the 2736-Z Building. See Item 4, Table A.2.1 for the consequences of a loss of ventilation event in the 2736-Z Building.	Backup instrument air system located in room 650 designed to start automatically should the instrument air pressure drop below 80 psig.	--	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
3	**Room 650, air sample vacuum (ASV) system (provided from room 501, the 291-Z Building.)**	--	Provides the motive force (vacuum) necessary to operate the room CAMs and the 296-Z-6 stack sampler and monitor.	Loss of vacuum.	Potential inoperability of room CAMs and stack sampler and monitor. Potential failure to detect airborne contamination within building and/or within stack effluents.	CAM failure alarm. Backup systems [e.g., portable CAMs] available.	Procedure governing operator response to CAM failure alarm.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.2.3

2736-ZB Building

The 2736-ZB Building has facilities that enable it to ship and receive, store, repackage, and NDA containers of SNM.

The 2736-ZB Building and its internal walls and equipment function as barriers to contain hazardous material. The primary barrier in the 2736-ZB Building is a process enclosure (e.g., glovebox 636) or a SNM storage or transportation container. The secondary barrier serves to enclose the area containing the primary barrier. An example is the internal building walls defining room 636, which contains glovebox 636. The 2736-ZB Building structure also functions as a barrier.

The 2736-ZB Building structure operates with the building ventilation systems to form a confinement system that is designed to mitigate the release of hazardous material should a barrier fail. The building ventilation systems complete the confinement system by providing a controlled, continuous flow of air from the environment into the various building areas, through HEPA filters, and then back to the environment. Ventilation supply air is provided for the building by equipment located in room 602. The flow of supply air within the building is from uncontaminated areas to potentially contaminated areas (zone 2). Air is supplied to zone 1 (glovebox 636) by a dedicated dry-air system. The air pressure in both zone 2 and zone 1 is normally negative relative to the atmosphere to prevent the movement of airborne material out of the building. The ventilation exhaust air flows to room 600 where it is filtered through two stages of HEPA filtration before being exhausted to the environment through the 296-Z-5 stack. Room 637, the NDA laboratory, has dedicated supply/exhaust fans and HEPA filters that are also located in rooms 600 and 602. Ventilation of room 637 is separate from the rest of the building until the filtered exhausts are combined in the exhaust plenum leading to the 296-Z-5 stack.

The building includes 49 areas designated as separate rooms and the 296-Z-5 stack. The room designations begin with room 600 and end with room 646. Two additional rooms are designated as rooms 638A and 641A. Many of the rooms simply provide administrative or service facilities used to support the primary operations conducted within the building and have no significant radiological or toxicological hazards associated with them. A listing of these rooms, grouped by general function, is provided below.

- Offices--rooms 603 through 607, 610, 611, 631, and 634
- Airlocks--rooms 608, 615, 621, and 646
- Corridors--rooms 601, 609, 617, and 624
- Janitor closets--rooms 613 and 626
- Water heater--room 612
- Restrooms--rooms 614, 618, 627, and 628

- Changerooms--rooms 616, 619, and 622
- Lunchroom--room 620
- UPS room--room 623
- Mardix--room 629
- Decontamination facility--room 630
- Operator ready room--room 635
- Supply room--room 640
- Personnel entry zone III--room 643
- Material passageway--room 644
- Supply air--room 602
- MUX (security system for the 2736-Z Building)--room 641A
- Applied Technology Chemistry--room 632.

Room 636 contains glovebox 636, which is used for storing, inspecting, and repackaging containers of SNM. Room 637 contains the equipment (e.g., large-table Segmented Gamma Scan Assay System (SGSAS), calorimetry pre-equilibration bath) used for the NDA of various containers of SNM. Room 638 (including rooms 638A, 639 and 640) contains the necessary equipment (e.g., can sealers, storage rack) for the staging, recanning, and storage of SNM. Room 641 provides a storage area for 55-gal drums waiting for analysis or shipment. The equipment necessary (e.g., portable NDA equipment) to support International Atomic Energy Agency (IAEA) surveillance activities of SNM is contained in room 642. In addition, corridors 625 and 633 and room 644 are used for transporting containers of SNM within the building.

The building provides its own normal electrical power from a pad-mounted transformer. Backup power is provided by the 2721-Z Building.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is

generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	Rooms 636, 637, 638, 638A, 639, and 642; corridors 625 and 633.	A. Handling of SNM storage containers.	To safely handle SNM containers within the building as necessary to support operations.	(1) Dropped SNM storage container.	Potential release of SNM from storage container to room or corridor. Potential plutonium metal/scrap fire in container. Potential entrainment of SNM in the ventilation system.	SNM is contained within sealed metal containers. Tests have shown (Hammond 1976a) that food pack cans are able to survive a drop of 3 m without a loss of containment. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation exhaust system to mitigate the release of SNM to the environment.	OSD requires SNM (except polycubes) to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm. Procedure governing operator response to a plutonium metal/scrap fire outside of a glovebox.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Inadequate spacing between SNM containers.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential loss of SNM from storage container(s) to room or corridor and entrainment in the ventilation system.	Same as above, except drop test information is not applicable. CAS to detect criticality and to activate criticality alarm horns.	Same as above. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to CAS criticality alarm horns.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality", subsection 9.2.3.4.4, "Transport and Storage, Probability."	A criticality due to inadequate spacing of containers during handling could potentially result in serious consequences to the worker. However, it is not a credible event. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. SNM storage containers.	To provide containment of SNM.	Loss of containment.	Release of SNM from storage container to room or corridor and potential entrainment in the ventilation system.	SNM is contained within sealed metal containers. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	OSD requires SNM (except polycubes) to be packaged with a minimum of two containment barriers. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.4, "Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
2	Rooms 637, 638, 641, and 644; corridors 625 and 633.	A. Handling waste drums and shipping containers.	To safely handle waste drums/shipping containers within the building as necessary to support operations.	(1) Dropped waste drum/shipping container.	Potential breach of waste drum/shipping container. Potential release of SNM to room or corridor. Potential entrainment of SNM in the ventilation system.	Waste drums designed to withstand drop from 4 ft, shipping container from 30 ft, without loss of containment. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-Stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing movement of SNM using drum barrel hand truck. Packaging requirement for double containment of waste. SNM in shipping containers typically has four levels of containment. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.4, Radioisotope-Bearing Pressurized Powder Container."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Inadequate spacing between drums/containers.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of SNM to the room or corridor. Potential entrainment of SNM in the ventilation system.	Same as above, except drop height information not applicable. CAS to detect criticality and to activate criticality alarm horns.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm horn. Packaging requirement limiting the amount of fissile material in drum/container. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality", subsection 9.2.3.4.4, "Transport and Storage, Probability."	A criticality could potentially result in severe consequences to the worker, but it is not credible for a criticality to occur as a result of inadequate spacing. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Waste drums/shipping containers.	To provide containment of SNM.	Loss of containment.	Potential release of SNM to the room or corridor. Potential entrainment in the ventilation system.	Waste drums have vents to relieve internal pressure. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Waste drums packaging requirements for double containment, limiting volatile organic compounds, and for incompatible materials. Packaging requirements for shipping containers of SNM. Procedure governing operator response to CAM alarm.	This is an anticipated event. The consequences are judged to be moderate.	Refer to section 9.2.2D, "Waste Drum Fire."	An energetic loss of containment (i.e., waste drum explosion) could potentially result in severe consequences to the worker. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
3	Room 636, Glovebox 636	A. Glovebox enclosure.	To provide confinement of SNM for various operations (i.e., repackaging, inspection, storage) conducted within glovebox.	Loss of confinement.	Potential release of SNM from the glovebox to the room. Potential entrainment of SNM in the ventilation system.	Glovebox determined to withstand DBE loads (Ocoma 1994). Glovebox maintained at negative pressure relative to room. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to CAM alarm. CPS, which limits the form and quantity of SNM inside the glovebox, is posted on the exterior of the glovebox.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Glovebox ventilation dry-air supply system.	(1) Provides airflow for maintaining correct negative pressure control of glovebox.	(1) Insufficient supply airflow.	Potential excessive negative pressure within the glovebox. Potential loss of glovebox confinement.	Dry-air system has backup equipment. Magnehelic gauge to verify glovebox pressure is within operating limits. DP (between glovebox and room) monitor activates alarm if pressure is off normal. CAMs to detect airborne alpha contamination and to activate alarms should the alarm set point be exceeded. Two-stage HEPA- filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to glovebox pressure outside operating limits. Procedure governing operator response to pressure alarm. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	See item 5. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High flow of supply air.	Potential pressurization of the glovebox relative to the room. Potential release of SNM to the room and entrainment in the ventilation system.	Same as above.	Same as above.	Same as above.	Same as above.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
			(2) Provides dry air to maintain glovebox dew point more negative than operating limit.	Glovebox dew point more positive than operating limit.	Potential uptake of moisture by the SNM exposed to the glovebox atmosphere, which could potentially result in the storage of unstable SNM within room 638 or in the 2736-Z Building. Storage of unstable SNM could potentially result in a loss of containment.	Dry-air system components have backup units. Glovebox dry-air monitor and alarm light. Dry-air receiver tank stores a 5 min reserve of dry air.	Procedure governing operator verification of dry-air monitor alarm light status. Procedure governing operator response to glovebox dew point more positive than operating limit.	This event is anticipated. Refer to Item 1B. for consequences of loss of containment in room 638.	Refer to section 9.1.4, "Radioisotope Bearing Pressurized Powder Container."	Refer to Item 1D. in Table A.2.1 for hazard analysis of loss of containment event in the 2736-Z Building. WHC-SD-CP-SDD-005

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
3	**Room 636, glovebox 636 (continued).**	C. Glovebox ventilation exhaust.	Provides airflow for maintaining correct negative pressure control of glovebox.	(1) Insufficient exhaust airflow.	Potential pressurization of the glovebox relative to the room. Potential release of SNM from the glovebox to the room. Potential entrainment of SNM in the ventilation system.	Magnehelic gauge to verify glovebox pressure is within operating limits. DP (between glovebox and room) monitor activates alarm if pressure is off normal. One operating exhaust fan and one on standby. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to glovebox pressure outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High exhaust airflow.	Potential excess negative pressure in glovebox relative to the room. Potential loss of glovebox confinement.	Magnehelic gauge to verify glovebox pressure is within operating limits. DP (between glovebox and room) monitor activates alarm if pressure is off normal. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to glovebox pressure outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Glovebox HEPA filters.	To filter any discharges of air from the glovebox in order to minimize the release of radioactive airborne particulates.	Loss of filtration.	Potential release of SNM from the glovebox. Potential entrainment of SNM in the ventilation system.	Glovebox exhaust HEPA filter DP gauge. Exhaust system designed to maintain glovebox at negative pressure relative to room. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered exhaust ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator verification that glovebox exhaust HEPA filter DP is within operating limit. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Same as above.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
3	Room 636, glovebox 636 (continued).	E. Glovebox argon supply.	To provide flow of argon for use during repackaging plutonium metal (one form of SNM).	(1) Insufficient flow of argon.	Packaging of plutonium metal in container with non-inert atmosphere. Potential storage of unstable SNM in room 638 or the 2736-Z Building. Storage of unstable material could potentially result in a loss of containment event.	Pressure gauge on argon supply bottle.	Procedure governing operator verification of argon bottle pressure prior to repackaging operation. Procedure governing operator verification of argon flow into glovebox.	This event is anticipated. Refer to Item 1B. for the consequences of a loss of containment in room 638.	Refer to section 9.1.4, "Radioisotope Bearing Pressurized Powder Container."	Refer to Item 1D. in Table A.2.1 for hazard analysis of loss of containment event in the 2736-Z Building.
				(2) Excessive flow of argon.	Potential pressurization of the glovebox relative to the room. Potential release of SNM to the room and entrainment in the ventilation system.	Rotameter orifice limits the maximum flow of argon to the glovebox. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered exhaust ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator verification of argon flow into glovebox. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		F. Inspection, repackaging and storage of SNM containers.	--	(1) Inadequate spacing of containers within glovebox.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of SNM from the glovebox to the room. Potential entrainment of SNM in the ventilation system.	CAS to detect criticality and to activate criticality alarm horns. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	CPS, specifying mass limit of SNM and spacing requirements, is posted on the glovebox. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to CAS horn. Procedure governing operator response to a CAM alarm.	Inadequate spacing is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality."	A criticality could potentially result in severe consequences to the worker. A criticality due to inadequate spacing is not credible. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Dropped SNM storage container.	Potential release of SNM from storage container to the glovebox. Potential plutonium metal/scrap fire. Potential entrainment of SNM in the ventilation system.	Glovebox maintained at negative DP relative to the room. MgO sand, empty metal can/fire cover, and dry chemical fire extinguisher to suppress fire. CAMs to detect airborne contamination and to activate alarm(s). Two-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to plutonium metal/scrap fire inside of glovebox. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.2C, "Glovebox HA-211 Fire."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
3	**Room 636, glovebox 636 (continued).**	F. Inspection, repackaging and storage of SNM containers (continued).	--	(3) Improper repackaging.	Potential release of SNM from the storage container to the glovebox or to the room. Potential entrainment of SNM in the ventilation system.	Glovebox maintained at negative pressure relative to room. CAMs to detect airborne alpha contamination and to activate alarm(s) if the alarm set point is exceeded. Two-stage HEPA- filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator inspection of can seam. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
4	**Room 637, NDA laboratory.**	A. Monorail and manual hoist.	Used to safely move waste drums to/from the large table SGSAS.	Failure to move drum safely.	Potential breach of drum. Potential loss of containment of SNM and release to the room. Potential entrainment of SNM in the ventilation system.	Hoist is physically restricted (by the height of the monorail) from lifting a drum higher than 4 ft. Waste drums are designed to withstand a fall from 4 ft. without a loss of containment. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Packaging requirement for double containment. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	Since the hoist can not lift the drum higher than 4 ft, there is minimal potential for a drum to be breached. Thus, the only hazard would be a dropped load with potentially minor consequences to the worker. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Large table SGSAS turntable.	Used to safely elevate and rotate waste drums for SGSAS analysis purposes.	Drum dislodged from turntable while at fully elevated position.	Same as above.	Same as above, except drum can fall greater than 4 ft.	Same as above.	Same as above.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	When the turntable is fully elevated, the drum is approximately 5 ft above the floor. Thus, there is a potential for the drum to be breached in a fall. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**Room 637, NDA laboratory (continued).**	C. Calorimetry pre-equilibration bath.	To safely bring containers of SNM to thermal equilibrium before calorimetry assay.	Inadequate spacing of containers in bath.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of SNM from storage container(s) and entrainment of SNM in the ventilation system.	SNM containers are placed inside measurement adapters having tops loaded with copper shot before insertion in bath. Measurement adapters within bath tubes are separated by thermal spacers. CAS to detect criticality and to activate criticality alarms. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release to the environment.	CPS, which limits container size and mass, is posted on bath. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm horn. Procedure governing operator response to CAM alarm.	This event is extremely unlikely. The consequences are moderate.	Refer to section 9.2.3, "Criticality."	A criticality could potentially result in severe consequences to the worker. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Ventilation supply system (fans located in room 602).	Provides airflow for maintaining correct negative pressure control of room.	(1) Insufficient supply airflow.	Potential excessive negative DP in room relative to atmosphere.	Ventilation system has backup fan. Flow and pressure control alarms. Computer-controlled ventilation system designed to disable supply and exhaust fans upon sensing off normal condition. SNM is contained within sealed storage containers or waste drums. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to flow and pressure alarms. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.8, "Loss of Ventilation", subsection 9.1.8.7, "Buildings 2736-Z and 2736-ZB."	There is normally no loose SNM in room 637. The potential for entrainment of SNM in the ventilation system as a result of insufficient or high supply airflow is minimal. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High flow of supply air.	Potential pressurization of room relative to corridor 633. Potential release of any loose SNM to the corridor and entrainment in the ventilation system.	Same as above.	Same as above.	Same as above.	Same as above.	

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**Room 637, NDA laboratory (continued).**	E. Ventilation exhaust system (fans located in room 600).	Provides airflow for maintaining correct negative pressure control of room.	(1) Insufficient exhaust airflow.	Refer to item 4D(2)	Refer to item 4D(1)	Refer to item 4D(1)	Refer to item 4D(1)	Refer to item 4D(1)	There is normally no loose SNM in room 637. The potential for entrainment of SNM into the ventilation system as a result of insufficient or high exhaust airflow is minimal. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High exhaust airflow.	Refer to item 4D(1)	Refer to item 4D(1)	Refer to item 4D(1)	Refer to item 4D(1)	Refer to item 4D(1)	
		F. Ventilation exhaust air recycling system.	To recycle breathing-air quality exhaust air for use in the ventilation supply system.	Recycled exhaust air below breathing air quality standards for radionuclide content.	Potential inhalation of radioactive particulates by operators.	Three-stage HEPA-filtered exhaust air. CAM to detect airborne alpha contamination in recycled exhaust air. Dampers to divert recycled exhaust air to stack are controlled by the MICON™ system.	Procedure governing operator response to CAM alarm for NDA laboratory exhaust air recycling system.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
5	**Room 638 (including rooms 638A, 639, and 640)**	A. Storage rack for SNM storage containers (located in room 638A)	To maintain container separation for the purpose of criticality safety.	Loss of container separation.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an addtional contingency. Potential release of SNM from storage container(s). Potential entrainment of SNM in the ventilation system.	CAS to detect criticality and to activate criticality alarm horns. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm horn. Procedure governing operator response to CAM alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.4A.1.1, "Building Response During a Seismic Event."	A criticality could potentially result in serious consequences to workers. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Packaging/ unpackaging of shipping containers (rooms 638 and 639).	To safely package/unpackage containers as needed to support operations.	Failure to package/unpackage safely.	Potential release of SNM to the room. Potential entrainment of SNM in the ventilation system.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	Refer to item 1B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
5	**Room 638 (continued).**	C. Recanning of SNM storage containers (room 638).	To seal SNM storage container within additional container(s).	Failure to properly seal additional container(s).	Potential storage of improperly packaged container in room 638A or in the 2736-Z Building. Potential release of SNM in the event of a loss of containment provided by the inner container. Potential entrainment in the ventilation system.	CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator verification of container seal. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to item 1B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
6	**Room 642, IAEA surveillance activities.**	Refer to item 1.	--	--	--	--	--	--	--	Refer to item 1.
7	**Building ventilation system.**	A. Exhaust HEPA filters (located in room 600).	To filter exhaust ventilation air before atmospheric discharge (via the 296-Z-5 stack) in order to mitigate the release of SNM to the environment.	Loss of exhaust air filtration.	Potential release of SNM to the environment if a loss of containment event occurs concurrently.	Ventilation exhaust system, including HEPA filter housings, designed to survive DBE loads. HEPA filters have backup units on standby. Room 600 CAM and 296-Z-5 stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA filter DP gauges.	Procedure governing operator response to DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation supply system (fans located in room 602).	To provide airflow for maintaining correct negative pressure control of all areas of building (room 637 has dedicated supply fans; refer to items 4D and 4E).	(1) Insufficient supply airflow.	Potential excessive negative pressure within building relative to atmosphere.	Ventilation supply system has one operating fan and one on standby. Computer-controlled ventilation system is designed to disable fans upon sensing low flow condition. Loss of pressure alarm for supply fans. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded.	Procedure governing operator response to flow and pressure alarms. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.7F.4, "Building Depressurization–All Plutonium finishing Plant Operating Buildings."	The majority of SNM is sealed in storage containers or waste drums. Loose SNM is normally present only in glovebox 636. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
7	**Building ventilation system (continued).**	B. Ventilation supply system (continued).	To provide airflow for maintaining correct negative pressure control.	(2) High flow of supply air.	Potential pressurization of the building relative to atmosphere. Potential release of any loose SNM to the environment.	Loss of negative pressure alarm. Computer controlled ventilation system controls supply airflow. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 7B(1)	Refer to item 7B(1)	Refer to section 9.1.7C, "Excessive Building Pressurization, 2736-ZB Building."	Refer to item 7B(1). Building was designed to withstand a tornado [Giller (1990).] WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Ventilation exhaust system (located in room 600).	To provide airflow for maintaining correct negative pressure control of all areas of building (room 637 has dedicated exhaust fans; Refer to items 4D and 4E).	(1) Insufficient exhaust airflow.	Refer to item 7B(2)	Refer to item 7B(2)	Refer to item 7B(1)	Refer to item 7B(1)	Refer to item 7B(2)	Refer to item 7B(2) WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High exhaust airflow.	Refer to item 7B(1)	Computer-controlled ventilation system controls exhaust airflow. Pressure alarm activates if pressure is not within operating limits. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 7B(1)	Refer to item 7B(1)	Refer to section 9.1.7F.4, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	Refer to item 7B(1) WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
8	**Normal electrical power supply system.**	--	To provide electrical power for the building's electrical requirements.	Loss of electrical power.	Potential loss of ventilation system control which could potentially result in a release of SNM to the environment if a loss of containment occurs concurrently; potential inoperability of monitoring and alarm systems (e.g., CAS, CAMs).	Backup electrical power is provided by the 2721-Z Building and a UPS system. Sealed storage containers provide primary containment for the SNM.	Procedure governing operator response to loss of electrical power.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.8, "Loss of Ventilation."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-OO6 WHC-SD-CP-SDD-011

Table 9A.2.3
2736-Z Complex: 2736-ZB Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
9	**Instrument air system (room 602)**	--	To provide non-oily, clean, dry air for general use in instrument controls for the ventilation system.	Failure to provide air.	Potential loss of ventilation system control which could potentially result in a release of SNM to the environment if a loss of containment occurs concurrently.	Loss of instrument air alarm. Backup instrument air supplied by dry-air compressors located in room 602.	Procedure governing operator response to loss of instrument air alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.8, "Loss of Ventilation."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006
10	**Air sample vacuum system (ASV) (room 602)**	--	To provide the motive force (vacuum) necessary to operate the CAMs and samplers in the building, including the stack sampler and monitor.	Loss of vacuum.	Potential inoperability of CAMs and samplers. Potential failure to detect airborne contamination within the building and within the stack effluent.	One vacuum pump in operation and one on standby. ASV failure alarm system. Backup systems (e.g., portable CAMs) are available for use.	Procedure governing operator response to ASV failure alarm.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
11	**Wet-pipe sprinkler system.**	--	To contain water until it is necessary to be used to suppress a fire within the building.	Flooding of building with water.	Loss of a single contingency for criticality safety in those rooms containing SNM.	Containers are designed to resist moisture intrusion. Containers are restrained to stay within storage location.	Double-contingency principle precludes the potential for a criticality as the result of a single failure. Procedure governing operator response to discharge of water from sprinkler system.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.4A.2.11.A, "Accident Scenario-Criticality, Vaults."	WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
12	**Steam supply (provided from a PFP-dedicated diesel-fired boiler via a subheader in the 291-Z Building).**	--	To provide steam to heat the ventilation supply air.	Loss of steam.	Potential freezing of water lines that provide fire suppression and other water services within the building and in the 2736-Z Building.	Two coal-fired boilers on-line. Two coal-fired boilers on standby. One oil-fired boiler available for use should the normal supply be interrupted.	Procedure governing operator response to loss of steam.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.2.4

2736-ZC Building

The 2736-ZC Building provides an enclosed loading dock for the receipt of SNM, an area designated for the staging/storage of cargo restraint transporters, and a transfer corridor that connects to the 2736-ZB Building. A metal building encloses the loading dock and also a 4,000-lb-capacity, 360° jib crane with a chain hoist and a drum handler. In an emergency, a HEPA-filtered temporary greenhouse may be erected within the 2736-ZC Building to provide confinement for the opening of a material package.

The 2736-ZC Building has multiple barriers providing containment of hazardous material. The primary barrier is the SNM storage containers. The shipping containers used to hold the storage containers during transportation provide several barriers to release. The building structure provides an additional barrier.

Normal operations in the building expose workers to the common industrial hazards of mechanical pinchpoints, electrical shock, and dropped loads. Of these, only a dropped load can contribute to or initiate an accident that could result in significant hazards. Emergency operations (i.e., opening of a material package) could result in significant hazards.

The building has no active ventilation system.

Normal electrical power for the 2736-ZC Building is provided by the 2736-ZB Building. Backup electrical power is provided by the 2721-Z Building via the 2736-ZB Building.

Table 9A.2.4
2736-Z Complex: 2736-ZC Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Jib Crane**	Chain hoist/drum handler	Used to safely unload DOT 6M shipping containers from cargo-restraint transporters.	Failure to unload shipping container safely.	Potential for a shipping container to drop to the floor of the building. Potential for a release of SNM to the environment.	--	Packaging requirements for a minimum of two containment barriers. Procedure governing operator response to a .	This event is unlikely. The consequence is judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spill."	Currently there are a minimal number of shipments being received at the 2736-ZC Building (approximately 6 to 10/yr). The potential for a DOT 6M shipping container to be breached during unloading is minimal.
2	**HEPA filtered temporary greenhouse**	--	To provide confinement of SNM if it is necessary to open a container in the 2736-ZC Building.	Loss of confinement.	Potential for release of SNM to the building and to the environment if there is airborne contamination present.	Portable CAM to detect airborne alpha contamination and to activate local alarm should the alarm set point be exceeded.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to item 1.	
3	**DOT 6M shipping container.**	--	To provide containment of SNM.	Loss of containment.	Potential release of SNM to the building and to the environment.	--	Packaging requirement for a minimum of two containment barriers.	This event is anticipated. The consequences are judged to be low.	Refer to item 1.	Material shipped in DOT 6M containers is typically contained within four containment barriers in addition to that provided by the shipping container.

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.2.5

2736-ZD Building

The 2736-ZD Building currently stores three EBR II storage casks containing irradiated metallic fuel rods from the Los Alamos Molten Plutonium Reactor Experiment. The CPS for the building limits the storage to a total of seven casks and a total fissile mass limit of 4,000 g. The building is a concrete, cylindrical pipe that is 8 ft in diameter and 6 ft deep and has a 1-ft-thick concrete coverplate. It rests on top of the ground and is located west of the 241-Z Building and south of the 2736-ZC Building. The 2736-ZD Building is impervious to moisture, and all necessary shielding and containment is provided by the storage casks.

The 2736-ZD Building has two barriers designed to contain hazardous material. The primary barrier is the EBR II storage casks. The secondary barrier is the watertight concrete pipe that contains the storage casks.

The 2736-ZD Building has no support equipment (e.g., ventilation system components) and receives neither normal or backup electrical power. Surveillance of the building consists simply of walking near enough to observe any gross failure of the structure. Based on this information, there are no significant radiological or toxicological hazards associated with the operation of this building.

Appendix 9A.2.6

2721-Z Building

The function of the 2721-Z Building is to provide backup electrical power for the PFP facilities. The building does not contain any radiological material. The building is divided into two rooms designated as rooms 647 and 648. Room 647 contains a programmable controller that monitors and controls proper voltage levels for most of the operations at the PFP, a UPS system for the controller, and the switchgear necessary for transferring electrical loads to the diesel generators located in room 648. The only hazard associated with operations performed in room 647 is the common industrial hazard of electric shock.

Room 648 houses three 325-kW diesel generators that provide backup electrical power to the PFP facilities. The operation of the diesel generators has several associated common industrial type hazards. These hazards include mechanical pinchpoints, electrical shock, and potential exposure to diesel exhaust fumes. Since these hazards only have the potential to impact worker safety, they need no further evaluation. The failure of the diesel generators to provide electrical power to the PFP facilities in the event of the loss of normal electrical power would not result in significant radiological hazards within the 2721-Z Building. However, this failure could result in significant radiological hazards at other buildings within the PFP that contain SNM.

Exhaust ventilation for the building is provided by two through-the-wall exhaust fans. The fans normally operate only when cooling of the building is required. When the diesel generators are operating, motorized inlet and exhaust dampers open automatically to provide additional air for combustion and cooling.

Table 9A.2.6
2736-Z Complex: 2721-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Backup electrical power supply system.**	--	To provide electrical power to the PFP should the normal electrical power supply system fail.	Failure to provide power.	Potential loss of ventilation control within the various buildings of the PFP. Potential loss of monitoring/alarm/safety systems (e.g., CAMs, CAS, fire detection) within the PFP.	Some systems are equipped with UPS systems. CAS have backup battery-powered systems. 125 Vdc stationary battery system. Backup diesel generators are controlled and monitored by the MICON system.	Procedure governing operator response to loss of backup power. Procedure governing testing and inspection of diesel generators.	This event is extremely unlikely. The consequence is judged to be moderate.	Refer to section 9.1.8, "Loss of Ventilation."	

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.3

The 236-Z Building.

The 236-Z Building currently conducts only limited operations. The primary functions of the building are as follows: (1) to safely store residual radioactive materials in the process cell, process equipment, and in plutonium recovery gloveboxes, and (2) temporary storage of in-process material within plutonium recovery facilities (i.e., gloveboxes).

The 236-Z Building and its internal walls and equipment function as barriers to prevent an uncontrolled release of hazardous material. The primary barrier in the 236-Z Building is a process enclosure (e.g., glovebox 27), a process vessel within an enclosure, or a SNM storage or transportation container. The secondary barrier serves to enclose the area containing the primary barrier. An example is the internal building walls defining room 27, which contains glovebox 27. The external structure of the 236-Z Building provides an additional barrier.

The structure of the 236-Z Building in union with the building ventilation systems forms a confinement system designed to mitigate the release of hazardous material should a barrier failure occur. The building ventilation systems complete the confinement system by providing a controlled, continuous flow of air from the environment into the various building areas and process enclosures, through HEPA filters, and then back to the environment. The ventilation supply air is provided by supply fans located in the 234-5Z Building via a duct mounted on the roof of the 234-5Z Building. The flow of supply air within the building is from uncontaminated areas to potentially contaminated areas (zone 3), and then to normally contaminated areas (zone 4). The air pressure in both zone 3 and zone 4 is normally negative relative to the atmosphere to prevent the movement of airborne material out of the building. The ventilation exhaust systems, designated as E-3 and E-4 for zones 3 and 4, respectively, route the exhaust air to separate banks of HEPA filters located in room 26 of the 236-Z Building (exhaust air from the process cell passes through HEPA filters located in corridors 10 and 20 before reaching the E-4 system filters in room 26). The E-3 and E-4 systems provide single- and two-stage filtration, respectively. The ventilation system exhaust is discharged to the atmosphere via the 291-Z stack by the 291-Z exhaust fans.

The building is separated into 37 areas having individual room or corridor designations. The designations extend from corridor 10 to room 72. The majority of the areas in the building do not conduct operations having significant radiological or toxicological hazards associated with them. These areas and their function or description are listed below:

- Room 13--Cell maintenance area
- Room 15--Storage
- Room 16--Maintenance shop area
- Room 17--Office

- Room 18--Airlock
- Corridors 30 and 31--Access to water-filled viewing windows
- Corridor 33--Crane control and observation gallery
- Room 34--Electrical switchgear
- Room 36--Storage
- Room 37--Janitor
- Room 38--Restroom
- Room 44--Control room
- Room 45--Office
- Corridors 46 and 47--Access corridors
- Room 46--Office
- Room 70--Process cell airlock changeroom
- Room 71--Airlock access
- Room 72--Process cell airlock.

The process cell, designated as room 12, contains the majority of the process equipment (i.e., tanks and piping), while the access gloveboxes (located in corridors 11, 14, 21, and 25) and column gloveboxes (located in rooms 42, 50, and 60), contain tanks, piping, and valves associated with the process equipment. The plutonium recovery gloveboxes, used for temporary storage of radioactive materials, are located in rooms 41 and 43.

An NDA counting center is located in room 19. The room contains equipment used to analyze the radiological material content of waste drums. A glovebox located in room 27 is used to confine radioactive materials during operations involving the cutting of large sections of contaminated pipe or ductwork in preparation for disposal. An additional operation conducted in the glovebox is the cementation of small quantities of radioactive material. The room also contains storage shelves that are used to temporarily store containers holding contaminated pieces of equipment.

The mechanical equipment for the air sample vacuum system is located in room 35. This equipment is used to supply a vacuum to air monitoring (e.g., room CAMs) equipment within the 236-Z Building.

Equipment located in room 40 may be used to prepare acid solutions to be used for decontamination efforts. Currently, however, the room is not being used. Therefore, this activity will not be analyzed further.

Normal electrical power for the building is provided from a substation in the 291-Z Building. Backup electrical power is provided by the 2721-Z

Building via the 234-5Z Building.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Corridors 11, 12, 14, and 21; 1st and 2nd floor (east and west) access gloveboxes; rooms 42, 50, and 60; column gloveboxes.**	A. Glovebox enclosure	To provide confinement of SNM.	Loss of confinement.	Potential release of SNM from the glovebox to the corridor/room and potential entrainment in the ventilation system.	Access gloveboxes are seismically qualified. Gloveboxes maintained at negative pressure relative to the corridor/room. Glovebox DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to glovebox DP outside of operating limits. Procedure governing operator response to CAM alarm. CPSs limit the access gloveboxes to negligible dispersible material. CPSs limit the amount of SNM in the column gloveboxes.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Glovebox supply ventilation.	To provide airflow for maintaining correct negative pressure control of glovebox.	(1) Insufficient supply airflow.	Potential excessive negative pressure in glovebox. Potential loss of glovebox confinement.	Glovebox DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1A.	Refer to item 1A.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	Access and column gloveboxes draw air from the canyon, which draws air from the second and third floor corridors. Therefore, internal pressure of gloveboxes follows that of corridors unless leakage paths from the canyon to glovebox are obstructed. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High supply airflow.	Potential pressurization of glovebox relative to the atmosphere.	Supply air is provided via leakage from the canyon. Glovebox DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1A.	Refer to item 1A.	Refer to section 9.1.7B, "Excessive Pressurization of 236-Z Building."	Access and column gloveboxes draw air from the canyon that, in turn, draws air from the second and third floor corridors. Therefore, the gloveboxes will not be driven to a positive pressure relative to the corridor/room. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Access and column gloveboxes (continued).**	C. Glovebox E-4 exhaust ventilation.	To provide airflow for maintaining correct negative pressure control of glovebox.	(1) Insufficient exhaust airflow.	Potential pressurization of glovebox. Potential release of SNM from the glovebox to the corridor/room with potential entrainment in the ventilation system.	Exhaust system has three backup fans. Glovebox DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA- filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1A.	Refer to item 1A.	Refer to section 9.1.7B, "Excessive Pressurization of 236-Z Building.".	Gloveboxes will not be pressurized relative to corridor/room. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) High exhaust airflow.	Potential excessive negative pressure in glovebox. Potential loss of glovebox confinement and entrainment of SNM in the ventilation system.	Glovebox DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 1A.	Refer to item 1A.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings."	Refer to item 1B. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Glovebox exhaust HEPA filters.	To filter air as it is discharged from the glovebox in order to mitigate the release of SNM from the glovebox.	Loss of filtration.	Potential release of SNM from the glovebox and entrainment in the ventilation system.	Exhaust HEPA filter DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) if the alarm set point is exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to HEPA filter DP outside of operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		E. Process piping/tanks located within gloveboxes.	To provide containment of residual radioactive materials.	Loss of containment.	Potential release of SNM into the glovebox. Potential criticality in north end drain sections of first floor access gloveboxes. Potential release of SNM to the corridor and entrainment in the ventilation system.	Access gloveboxes north end sections and column gloveboxes equipped with criticality drains. CAS to detect criticality and to activate criticality alarm horns. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm horn. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.2.4A.6.3.2.A.a, "Accident Analysis-Calculations, 236-Z Criticality."	A criticality could potentially result in severe consequences to the worker. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Access and column gloveboxes (continued).**	F. Scraping radioactive material out of glovebox bays.	To safely remove residual radioactive material from glovebox.	Failure to safely remove material.	Potential release of radioactive material to building. Potential entrainment of material in the ventilation system. Potential release to the environment.	Scrapings placed in 1/2-l polyjars before removal from glovebox. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to material spill outside glovebox. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
2	**Room 12, process cell (canyon)**	Process cell and associated piping and columns.	To provide containment of residual radioactive materials.	Loss of containment.	Potential entrainment of SNM in the ventilation system. Potential release of SNM to the environment.	Process cell maintained at a negative pressure relative to corridors. Process cell floor designed to retain spills of SNM. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to a CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	The PRF is not authorized to operate. However, plutonium-bearing solutions and residues still exist in the process cell and associated piping and columns. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
3	**Room 41, MT-1, MT-3, MT-4, MT-5, MT-6, and MT-conveyor gloveboxes.** **Room 43, S&C dissolver charging, S&C sorting, S&C loading, and pulser gloveboxes.**	A. Glovebox enclosure.	To provide confinement of SNM.	Loss of confinement.	Potential release of SNM to room. Potential entrainment of SNM in the ventilation system. Potential release of SNM to the environment.	S&C dissolver charging glovebox seismically qualified. Gloveboxes maintained at negative pressure relative to the room. Glovebox DP gauges. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to glovebox DP outside operating limits. Procedure governing operator response to CAM alarm. CPSs limit the quantity of SNM in the gloveboxes. Quantity of SNM in gloveboxes MT-5 and MT-6 administratively controlled to less than CPS limits.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
3	**Rooms 41 and 43, gloveboxes (continued).**	B. Glovebox supply ventilation	To provide airflow for maintaining correct negative pressure control of glovebox.	Refer to item 1B.	Refer to item 3A.	Same as 1B, except supply air is provided by leakage from room containing glovebox.	Refer to item 3A.	This event is anticipated. The consequences are judged to be low.	Refer to item 1B.	Gloveboxes draw air from room through inlet HEPA filters. Therefore, internal pressure of gloveboxes follows that of room unless glovebox supply inlets are obstructed. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Glovebox E-4 exhaust ventilation.	Same as above.	Refer to item 1C.	Refer to item 3A.	Refer to item 1C.	Refer to item 3A.	This event is anticipated. The consequences are judged to be low.	Refer to item 1C.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Glovebox inlet/exhaust HEPA filters.	To filter air as it is discharged from the glovebox in order to mitigate the release of SNM from the glovebox.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		E. Storage and handling of SNM.	--	(1) Inadequate spacing of SNM.	Loss of a single contingency. Potential criticality if there is a loss of an additional contingency. Potential release of SNM to the room and entrainment in the ventilation system.	Gloveboxes MT-1, MT-5, and MT-6 have criticality drains. CAS to detect criticality and to activate criticality alarm horns. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm horn. Procedure governing operator response to CAM alarm. CPSs, which limit the mass and form of SNM contained within the gloveboxes, are posted on gloveboxes.	Inadequate spacing of SNM is an anticipated event. The consequences are judged to be low.	Refer to section 9.2.3, "Criticality", subsection 9.2.3.4.4, "Transport and Storage, Probability."	A criticality could potentially result in severe consequences to workers in proximity to the event, but a criticality as a result of inadequate spacing is not a credible event. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Dropped container.	Potential release of SNM into glovebox. Potential entrainment in the ventilation system.	Glovebox enclosure. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to CAM alarm. Procedure governing operator response to spill of SNM inside glovebox.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**Room 19, NDA package center**	Handling of Waste drums.	To safely handle waste drums as required to support NDA operations.	Failure to handle drums safely.	Potential breach of waste drum. Potential release of SNM to room and entrainment in the ventilation system.	Waste drums are designed to withstand a fall from 4 ft without a loss of containment. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing movement of SNM (waste drums) using drum barrel hand cart. Packaging requirement for double confinement. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.3, "Radioisotope-Bearing Powder Spills."	Since the waste drums are not lifted more than 4 ft high, the potential for a drum to be breached as a result of a handling accident is minimal. There is a potential for minor injury to the worker as a result of a dropped load. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
5	**Room 26 (E-3 and E-4 systems) corridors 10 and 20 (process cell), exhaust filtration.**	Exhaust HEPA filters.	To filter exhaust ventilation air before atmospheric discharge (via the 291-Z stack) in order to mitigate the release of SNM to the environment.	Loss of filtration.	Potential release of SNM to the environment.	Two-stage HEPA filtration. 291-Z stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.5B, "Filter Room 26, 236-Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
6	**Room 27, maintenance glovebox.**	A. Glovebox enclosure.	To provide confinement of SNM.	Refer to item 1A.	Refer to item 3A.	Glovebox maintained at negative DP relative to the room. CAMs to detect airborne alpha contamination and to activate alarm(s). HEPA-filtered exhaust system.	Refer to item 3A.	Refer to item 1A.	Refer to item 1A.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Glovebox supply ventilation.	To provide airflow for maintaining correct negative pressure control of glovebox.	Refer to item 1B.	Refer to item 3A.	Refer to item 3B.	Refer to item 3A.	Refer to item 1B.	Refer to item 1B.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Glovebox E-4 exhaust ventilation.	Same as above.	Refer to item 1C.	Refer to item 3A.	Refer to item 1C.	Refer to item 3A.	Refer to item 1C.	Refer to item 1C.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Glovebox inlet/exhaust HEPA filters	To filter any air discharged from the glovebox (reverse and normal flow).	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	Refer to item 1D.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
6	**Room 27, maintenance glovebox (continued).**	E. Cutting of pipe and ductwork.	To safely cut pipe/ductwork into sections small enough to be packaged for disposal.	Failure to safely perform cutting operation.	Potential breach of glovebox. Potential release of SNM from glovebox to room. Potential entrainment of SNM in the ventilation system and potential release to the environment.	Glovebox maintained at negative pressure relative to room. CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are moderate.	Refer to section 9.1.9, "Glovebox Glove Breach."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		F. Cementation of SNM.	To absorb free liquids and to cement solids together within a polyjar to allow for disposal.	Failure to cement properly.	Potential release of SNM from polyjar. Potential release of SNM to the glovebox. Potential release of SNM to the room and potential entrainment in the ventilation system.	Glovebox enclosure. Vented polyjars used for cementation. Cemented polyjars are stored within 55-gal waste drums. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Procedure governing operator inspection of cemented jar for free liquids. Procedure governing operator response to CAM alarm. Procedure governing allowable quantity of plutonium/jar.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
7	**Room 27, room storage of contaminated equipment in containers.**	A. Storage shelves	To maintain container separation for the purpose of criticality safety.	Loss of container separation.	Loss of a single contingency for criticality safety. Potential criticality if there is a loss of an additional contingency. Potential release of SNM into the room and entrainment in the ventilation system.	CAS to detect criticality and to activate criticality alarm horns. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	CPS limits the mass of SNM and the container dimensions. Double-contingency principle precludes the potential for a criticality as a result of a single failure. Procedure governing operator response to criticality alarm horn. Procedure governing operator response to CAM alarm.	This event is unlikely. The consequences are judged to be low.	Refer to section 9.2.4A.6.3.2.C.d, "Accident Analysis-Calculations, 236-Z–Room 27."	A criticality could potentially result in severe consequences to the worker. A criticality as a result of inadequate spacing of storage containers is not a credible event. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
8	**Building ventilation system.**	A. Ventilation supply air (provided by the 234-5Z Building)	To provide airflow for maintaining correct negative pressure control within building.	(1) Insufficient supply airflow.	Potential excessive negative pressure within building if the exhaust fans continue to operate.	Ventilation supply system has backup equipment on standby. Volume dampers control supply airflow based on signals received from DP sensor in supply duct. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation exhaust system to mitigate the release of SNM to the environment.	Procedure governing operator response to ventilation system upset. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium Finishing Plant Operating Buildings", subsection 9.1.7F.2, "236-Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow.	Potential pressurization of building relative to atmosphere. Potential release of any loose SNM to the environment.	Volume dampers control supply airflow based on signals received from DP sensor in supply duct. CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item above.	Refer to item above.	Refer to section 9.1.7B, "Excessive Pressurization of 236-Z Building."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation exhaust air (provided by the 291-Z Building)	Same as above.	(1) Insufficient exhaust airflow.	Same as 8A(2), if the supply fans continue to operate.	Same as 8A(2). Two exhaust fans are connected to backup power (1 of 2 operates on loss of normal power).	Refer to item 8A(1)	Refer to item 8A(1)	Refer to item 8A(2)	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive exhaust airflow.	Potential excessive negative pressure within building relative to atmosphere.	CAMs to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	Refer to item 8A(1)	Refer to item 8A(1)	Refer to item 8A(1)	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.3
236-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
9	**Normal electrical power supply system (provided by the 291-Z Building)**	--	To provide electrical power for the building's electrical requirements.	Loss of electrical power.	Potential loss of ventilation system control. Potential loss of negative pressure differential between building and atmosphere. Potential release of loose SNM to the environment.	Backup electrical power is provided by the 2721-Z Building via the 234-5Z Building.	Procedure governing operator response to loss of electrical power event.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.8, "Loss of Ventilation."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
10	**Air sample vacuum system (vacuum pumps located in room 35)**	--	Provides the motive force (vacuum) necessary to operate room CAMs.	Loss of vacuum.	Potential inoperability of room CAMs. Potential failure to detect airborne contamination within building.	Backup ASV system equipment (i.e., vacuum pump, electric motor). ASV failure alarm system.	Procedure governing operator response to ASV system failure alarm.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
11	**Steam supply (provided by a PFP dedicated diesel-fired boiler via a subheader in the 291-Z Building).**	--	Provides steam to reheat the ventilation supply air for the building.	Loss of steam.	Potential loss of ventilation supply air heating. Potential freezing of building water lines providing fire suppression.	--	Procedure governing operator response to loss of steam.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.4

The 241-Z Complex

The 241-Z Complex includes the 241-Z, 241-ZA, 241-ZB, and 241-ZG Buildings, 296-Z-3 stack, 241-Z-RB Retention Basins, and Tank 241-Z-361. The 241-Z Building and auxiliary buildings 241-ZA and 241-ZB are designed to collect, measure, stage, and treat aqueous liquids collected from the process facilities of the PFP. The treated liquid waste is pumped through double-encased lines to the collection tank in the 244-TX receiving facility.

The 241-Z Building is enclosed in a corrugated metal structure that houses the ventilation exhaust HEPA filter enclosures and a bridge crane used to lift the pit coverblocks. The building and its internal structures and equipment function as barriers to contain hazardous materials. The primary barrier in the 241-Z Building is a process enclosure or a process vessel (e.g., tank TK-D5). The secondary barrier serves to enclose the area containing the primary barrier. For the 241-Z Building, an example is the concrete sump cell (and associated coverblock) which contains tank TK-D5. The building structure also functions as a barrier.

The 241-Z Building structure and the ventilation system work together to provide a confinement system designed to mitigate the release of hazardous material should a barrier fail. The building ventilation system completes the confinement system by providing a controlled, continuous flow of air from the environment into the Building 241-ZA tank sampling glovebox and concrete sump cells, through HEPA filters, and then back to the environment. Supply air is provided to the glovebox and sump cells by in-leakage of outside air. The ventilation system does not have supply fans, therefore the motive power for airflow is provided entirely by the exhaust fans. Exhaust ventilation from each tank headspace, the sampling glovebox, and the TK-D9 caustic supply tank first passes through a demister and then joins the exhaust airflow from the sump cells. The exhaust air is then heated to remove any moisture and is passed through two stages of HEPA filtration before being exhausted to the 296-Z-3 stack.

The 241-Z Building is divided into five below-grade, concrete sump cells with coverblocks, with each cell containing a single stainless steel tank (except for one cell that has a primary tank and an additional smaller tank that receives overflow from all four of the operating primary tanks). The primary tanks are designated as tanks TK-D4 through TK-D8 (tank TK-D6 is a confirmed leaker and is no longer in service), and the smaller tank is designated as the TK-D7 overflow tank. Tank TK-D5 is used to treat the aqueous liquids, while the other tanks are used to collect, measure, and stage the liquids for treatment. The 241-ZA Building contains a glovebox that contains equipment used for sampling and testing the liquid waste. The building also contains an annunciator panel housing alarm indicators associated with tank liquid levels, cell sumps, and the transfer line. The 241-ZB Building is comprised of tank TK-D9 (a caustic storage tank that is inactive and scheduled for removal) and a spill barrier. The caustic stored in tank TK-D9 was used to adjust the pH of liquids in tank TK-D5. The 241-ZG Building is a changeroom for personnel and contains no significant radiological or toxicological hazards. The 241-Z-RB Retention Basin and 241-Z-361 Settling Tank are inactive and scheduled for stabilization.

Normal electrical power is provided by the 291-Z Building. Backup power is provided by the 2721-Z Building via the 234-5Z Building. However, no backup power is provided for the building exhaust fans.

Each of the cells has a leak detection system and has the capability to pump out any liquids that may leak from the tank.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.4
241-Z Complex.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**The 241-Z Building, liquid waste collection/ treatment system.**	A. Liquid waste collection system storage tanks.	To provide containment of radioactive and dangerous liquid wastes.	Loss of containment.	Release of liquid waste to the cell(s). Potential release of SNM to the environment. Potential release of hazardous materials to the environment.	Tank Weight Factor (level) alarm(s) in the 241-ZA and 236-Z Buildings. Cell sump probes to detect accumulation of liquid and activate alarm. Cells maintained at negative pressure relative to atmosphere. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment. Pumping equipment to remove liquid from cells. 291-Z-3 stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded.	Procedure governing operator response to high/low-level alarm and sump alarm. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Treatment and temporary storage of liquid wastes.	To safely store and treat waste so that it may be transferred to the tank farms.	Failure to store/treat liquid waste safely.	Potential criticality. Potential release of SNM to the cells. Potential release of SNM to the environment.	CAS to detect criticality and to activate criticality alarm horn. Tanks contained in concrete cells that are maintained at negative pressure relative to atmosphere. Tanks equipped with agitators. 291-Z-3 stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of SNM to the environment.	CPS limits the mass and concentration of plutonium in the tanks. Procedure governing sampling of tank contents. Procedure governing operator response to criticality alarm horn. Procedure governing operator response to CAM alarm.	This event is extremely unlikely. The consequences are judged to be moderate.	Refer to section 9.2.3, "Criticality", subsection 9.2.3.1.3.1, "Operation of 241-Z Tanks."	A criticality could potentially result in serious consequences to the worker. However, this building is not normally occupied. WHC-SD-CP-SDD-003 WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-008 WHC-SD-CP-SDD-011
		C. Transfer of treated waste to 244-TX.	To safely transfer treated liquid waste from the 241-Z Building to the 244-TX facility.	Failure to transfer waste safely.	Potential release of treated liquid waste to the environment.	Double-encased transfer line. Transfer line leak detection elements. Transfer line high temperature alarm.	Procedure governing operator response to leak . Procedure governing operator response to high temperature alarm.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	

Table 9A.4
241-Z Complex.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
2	**The 241-Z Building, ventilation system (the building does not have a supply system)**	A. Ventilation exhaust system.	To provide airflow for maintaining negative DP between vault (building) and metal enclosure.	(1) Insufficient exhaust airflow.	Potential loss of negative pressure differential between building and metal enclosure. Potential release of SNM to the environment.	Exhaust fan has a backup unit. Pressure solenoid monitors exhaust pressure and activates alarm in the 234-5Z Building upon loss of negative pressure. Tanks contained within covered, below grade cells. Ventilation system designed to shut down on loss of power.	Procedure governing operator response to loss of negative pressure alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7E, "Excessive Building Pressurization, 241-Z Building."	Since the building has no supply ventilation system, pressurization of the building cannot occur simply through failure of the exhaust system. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive exhaust airflow.	Potential HEPA filter damage. Potential release of SNM to the environment.	HEPA filter DP gauges. 291-Z-3 stack CAM to detect airborne contamination and to activate alarm(s) should the alarm set point be exceeded.	Procedure governing operator response to HEPA filter DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. Ventilation exhaust HEPA filters.	To filter exhaust ventilation air before atmospheric discharge in order to mitigate the release of SNM to the environment.	Loss of exhaust air filtration.	Potential release of SNM to the environment.	HEPA filter DP gauges. Backup HEPA filters. 291-Z-3 stack CAM to detect airborne contamination and to activate alarm(s) should the alarm set point be exceeded.	Procedure governing operator response to HEPA filter DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
3	**The 241-Z Building, bridge crane.**	Handling of cell coverblocks.	To safely handle cell coverblocks as necessary to support operations.	Failure to handle coverblock safely.	Potential impact between coverblock and waste tank. Potential breach of waste tank and release of SNM to cell and entrainment of SNM in the ventilation system. Potential release of SNM to the environment.	Tanks contained within concrete cells that are maintained at negative pressure relative to metal enclosure. Pumping equipment to remove liquid from cell. 291-Z-3 stack CAM to detect airborne contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to leakage of contents from tank. CPS limits the mass and concentration of Pu in the tanks.	This event is unlikely. The consequences are judged to be moderate.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
4	**The 241-ZA Building, sampling glovebox (GB-2-241-ZA)**	A. Glovebox enclosure.	To provide confinement of SNM.	Loss of confinement.	Potential release of SNM to the building. Potential release of SNM to the environment.	Glovebox maintained at negative pressure relative to building. Glovebox to room DP gauge. CAM to detect airborne contamination and to activate alarm should the alarm set point be exceeded.	Procedure governing operation of building exhaust fans. Procedure governing operator response to CAM alarm. Glovebox limited to 15 g of plutonium.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.4
241-Z Complex.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**Sampling glovebox (continued).**	B. Ventilation exhaust system (connected to 241-Z system)	To provide airflow for maintaining negative pressure differential between glovebox and building.	Insufficient exhaust airflow.	Potential loss of negative pressure differential between glovebox and building. Potential release of SNM to building and to the environment.	Exhaust fan has backup unit (both fans in operation when coverblock(s) are removed). Glovebox exhaust HEPA filter DP gauge. Glovebox to room DP gauge. CAM to detect airborne contamination and to activate alarm should the alarm set point be exceeded.	Procedure governing operation of building exhaust fans. Procedure governing operator response to DP outside of operating limits. Glovebox limited to 15 g of plutonium.	Refer to item 2A.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	The liquid samples taken in the glovebox are not readily dispersible. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Ventilation exhaust HEPA filters.	To filter exhaust ventilation air before atmospheric discharge in order to mitigate the release of SNM to the environment.	Refer to item 2B.	Refer to item 2B.	Same as item 2B, except cell information is not applicable.	Refer to item 2B.	Refer to item 2B.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		D. Sampling of tank contents.	(1) To safely obtain a sample of the contents of a tank.	Failure to safely obtain a sample.	Potential release of SNM to the environment.	Glovebox enclosure. Glovebox maintained at negative pressure relative to building. Double-encased sample lines. CAM to detect airborne contamination and to activate alarm should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation exhaust system.	Procedure governing operator response to spill of liquid within glovebox.	This is an anticipated event. The consequences are judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
			(2) To obtain a representative sample of the tank contents before a tank to tank transfer or a transfer from tank TK-D5 to the 244-TX facility.	Failure to obtain a representative sample.	Potential transfer of noncompliant waste to the 244-TX facility.	Tank TK-D5 is equipped with an agitator.	Procedure governing tank agitation before sampling. Procedure governing recirculation of sampling lines before sampling.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	
5	**Steam supply (provided by a PFP dedicated diesel-fired boiler via the 291-Z Building).**	--	To provide steam for: (1) the jet tranfer of liquid wastes and (2) for space heating.	Loss of steam.	Potential inoperability of jet transfer system. Potential loss of building heat.	--	Procedure governing operator response to loss of steam.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	

[a]Event category and hazard identifier
[b]The consequence, as given here, assumes none of the preventive/mitigative features are in place.
[c]The risk, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.5

The 232-Z Building.

The only operations being conducted in the 232-Z Building are those involved in preparing it for D&D. The equipment in the building is not used and has undergone bulk plutonium removal. In addition, sections of the ventilation exhaust system have been isolated to allow ducting contaminated with plutonium residues to be removed. The building is separated into six major rooms as follows: (1) process room, (2) electrical room, (3) chemical mix room, (4) airlock, (5) changeroom,
(6) storage room.

The 232-Z Building and its internal walls and equipment function as barriers to contain hazardous materials. The primary barrier in the 232-Z Building is a process enclosure such as the incinerator glovebox. The secondary barrier serves to enclose the area containing the primary barrier. An example is the internal walls that form the process room containing the incinerator glovebox. The 232-Z Building also functions as a barrier.

The 232-Z Building structure operates with the ventilation system to form a confinement system designed to mitigate the release of hazardous material should a barrier failure occur. The building ventilation system completes the confinement system by providing a controlled, continuous flow of air from the environment into the various building areas and process enclosures, through HEPA filters, and then back to the environment. A temporary, independent ventilation system for the building has been installed and is operating (the motive power for airflow through the building is provided by the two exhaust fans). Ventilation supply air is provided to the rooms (zone 3) via infiltration throughout the deactivated supply system, while air is supplied to the glovebox and incinerator (zone 4) via leakage from the rooms through inlet HEPA filters. Therefore, the flow of supply air within the building is from potentially contaminated areas (zone 3) to normally contaminated areas (zone 4). The air pressure in both zone 3 and zone 4 is normally negative relative to the atmosphere to prevent the movement of airborne material out of the building. Exhaust ventilation air from zone 3 passes through in-floor HEPA filters before being discharged to two exhaust ducts below the building floor. Zone 4 exhaust air is exhausted through an installed HEPA filter, routed to a filter box containing HEPA filters, and then discharged to the exhaust ducts. Exhaust air is discharged from the exhaust ducts through two-stage testable HEPA filtration and then to the environment via the 291-Z-14 stack.

The only room in the building that is a radiation area containing sources of radiation is the process room that contains the gloveboxes, hoods, and incinerator previously used for the process of combustible waste incineration. Since there are no significant radiological or toxicological hazards in the other rooms, only the process room will be analyzed further for hazards.

Normal electrical power for the ventilation system (e.g., exhaust fans, monitoring equipment) is provided to the building from the 2736-ZB Building, while power for lighting is provided from the 291-Z Building. Backup electrical power is provided by the 2721-Z Building via the 291-Z Building.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature. If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.5
232-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**232-Z Building, Ventilation system.**	A. Ventilation supply system.	To provide airflow for maintaining correct negative DP of the building and gloveboxes.	(1) Insufficient supply airflow.	Potential excessive negative DP.	Process Area DP indicator controller. Manual volume damper. 291-Z-14 stack monitoring system to detect airborne alpha contamination, to activate alarm(s) should the alarm set point be exceeded, and to close exhaust damper and shut off exhaust fan. Two-stage HEPA-filtered ventilation system to mitigate the release of contamination to the environment.	Procedure governing operator response to exhaust fan failure. Procedure governing operator response to DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed, but due to similarity of ventilation systems may refer to section 9.1.7F, "Building Depressurization--All Plutonium finishing Plant Operating Buildings", subsection 9.1.7F.5, "241-Z Building."	Since the equipment in the building has undergone bulk removal of plutonium, it is unlikely that there is a significant amount of loose contamination. In addition, there is minimal potential to depressurize the building due to the low flow rate of the exhaust fans. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow.	Potential loss of negative DP relative to atmosphere. Potential release of loose contamination to the atmosphere.	Process area DP indicator controller. Manual volume damper.	Procedure governing operator response to DP outside operating limits.	This event is not credible.	--	Since there are no supply fans for the building ventilation, it is not possible to pressurize the building relative to atmosphere. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. E-3 and E-4 ventilation exhaust system.	To provide airflow for maintaining correct negative DP control of building areas.	(1) Insufficient exhaust airflow.	Refer to item 1A(2)	Ventilation system designed to automatically switch to backup exhaust fan in the event of fan failure. Fan failure indicating light. Process area DP indicator controller. Manual volume damper.	Procedure governing operator response to exhaust fan failure. Procedure governing operator response to DP outside operating limits.	Refer to item 1A(1)	Refer to section 9.1.7E, "Excessive Building Pressurization, 241-Z Building."	Refer to item 1A(2) WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive exhaust airflow.	Refer to item 1A(1)	Refer to item 1A(1)	Refer to item 1A(1)	Refer to item 1A(1)	Refer to item 1A(1)	Refer to item 1A(1) WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

Table 9A.5
232-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	The 232-Z Building, ventilation system (continued).	C. Ventilation exhaust HEPA filters.	To filter exhaust ventilation air before atmospheric discharge in order to mitigate the release of SNM to the environment.	Loss of exhaust air filtration.	Potential release of SNM to the environment.	HEPA filter DP gauges. Backup HEPA filters. 291-Z-14 stack CAM to detect airborne alpha contamination, to activate alarm(s) should the alarm set point be exceeded, and to close exhaust dampers and shut off exhaust fans.	Procedure governing operator response to HEPA filter DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	Since the equipment in the building has undergone bulk plutonium removal, it is unlikely that there is a significant amount of loose contamination. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
2	**The 232-Z Building, normal electrical power supply system (provided by the 291-Z and 2736-Z Buildings).**	--	To provide electrical power for the building's electrical requirements (e.g., lighting ventilation system).	Loss of electrical power.	Potential loss of ventilation system control. Potential loss of negative DP between the building and the atmosphere. Potential release of SNM to the environment.	Backup power is provided by the 2721-Z Building via the 291-Z Building.	Procedure governing operator response to loss of normal electrical power.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.8, "Loss of Ventilation."	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
3	**The 232-Z Building, air sample vacuum (ASV); provided by equipment located in room 501 of the 291-Z Building.**	--	Provides the motive force (vacuum) necessary to operate room CAMs.	Loss of vacuum.	Potential inoperability of CAMs. Potential failure to detect airborne contamination within the building.	Backup systems (e.g., portable CAMs) are available. CAM failure alarm.	Procedure governing operator response to CAM failure alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-011

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.6

243-Z Low-Level Waste Treatment Facility: 243-Z and 243-ZA Buildings.

The function of the 243-Z LLWTF is to collect and treat potentially radioactive or chemically contaminated water from the process facilities of the PFP. The treated water is routed to the sewer system for disposal at the Treated Effluent Disposal Facility (TEDF).

The facility is comprised of the 243-ZA and 243-Z Buildings. The buildings and their internal walls and equipment function as barriers to contain hazardous materials. The primary barrier is a process enclosure or a container (e.g., a 55-gal drum) designed to hold hazardous material. The secondary barrier encloses an area containing a primary barrier. An example is the internal building walls that define room 405, which contains 55-gal drums holding hazardous material. The building structures also function as barrier.

The 243-Z Building structure combined with the building ventilation system forms a confinement system designed to mitigate the release of hazardous material should a barrier fail. The ventilation system completes the confinement system by providing a controlled, continuous flow of air from the environment into the building, through HEPA filters, and then back to the environment. Supply air to the 243-Z Building is provided by a single manual on/off supply fan. Exhaust ventilation air is provided by a single exhaust fan that maintains the building at a negative pressure relative to the atmosphere to prevent the movement of airborne material out of the building. Ventilation exhaust air is transferred through an open-faced hood, passed through a prefilter and a single-stage HEPA filter bank, and then is discharged to the atmosphere via the 296-Z-15 stack.

The 243-ZA Building contains a sump tank, a surge tank, and associated pumps. The 243-Z Building is separated into five rooms designated as rooms 401 through 405. Room 401 is an airlock providing access to room 402, which is a changeroom for personnel. Neither of these rooms contains significant radiological or toxicological hazards and therefore will not be analyzed further. Room 405 is the process room, and it contains the particulate prefilters, adsorption media treatment trains (each consisting of fifteen 55-gal drum process canisters with adsorption media), samplers, and the associated valving, piping, and instrumentation necessary to treat the potentially contaminated water. Room 403 is used for washing new 55-gal filter media canisters (activated carbon and bone char media) before placement in a media train. Since there are no significant radiological or toxicological hazards in this room, it will not be analyzed further. Room 404 contains the open-faced drum turning hood used for draining liquids from saturated 55-gal process canisters before disposal.

Normal electrical power to the 243-Z Building is provided by the 291-Z Building. Backup power is provided for the 243-ZA Building sump pumps by the 2721-Z Building via the 291-Z Building.

Table 9A.6
243-Z LLWTF

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**The 243-Z Building, room 404, drum turning hood.**	Treatment of saturated process canisters.	To properly drain liquids from process canisters to allow for disposal of canisters.	Failure to properly drain process canisters.	Potential release of radioactively and/or chemically hazardous material to the room. Potential entrainment of hazardous material in the ventilation system. Potential release of hazardous material to the environment.	Hood enclosure maintained at negative pressure relative to atmosphere. Building sump to contain liquid spills. Single-stage HEPA-filtered ventilation system to mitigate the release of hazardous material to the environment.	Procedure governing operator response to liquid spill within hood enclosure. Procedure governing performance of canister changeout.	This event is anticpated. The consequence is judged to be low.	Refer to section 9.1.1, "Radioisotope-Bearing Liquid Spills."	A spill of liquid from a process canister would involve minimal hazardous material. WHC-SD-CP-SDD-005
2	**The 243-Z Building, room 405, low-level liquid waste treatment system.**	Adsorption media train.	To provide containment of radioactive/toxic liquid wastes during treatment process.	Loss of containment.	Refer to item 1.	Leak detection system. Double containment system for liquid waste. Single-stage HEPA-filtered ventilation system to mitigate the release of hazardous material to the environment.	Procedure governing operator response to leak detection alarm.	Refer to item 1.	Refer to item 1.	A spill of liquid from the treatment train would involve minimal hazardous material. WHC-SD-CP-SDD-005
3	**The 243-ZA Building, low-level liquid waste treatment system.**	Sump and surge tanks.	To provide containment of liquid waste until it can be treated in the 243-Z Building.	Refer to item 2.	Potential release of hazardous material to the building. Potential release of hazardous material to the environment.	Double containment system for liquid waste.	Refer to item 2.	Refer to item 1.	Refer to item 1.	
4	**The 243-Z Building, ventilation system.**	A. Ventilation supply system.	To provide airflow for maintaining negative DP between the building and atmosphere.	(1) Insufficient supply airflow.	Potential excessive negative DP in building relative to atmosphere.	Flow switch designed to disable system upon sensing no flow and to activate a local alarm.	Procedure governing operator response to loss of ventilation alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed. Similarity of the ventilation system to the 241-Z Building allows reference to section 9.1.7F, "Building Depressurization--All Plutonium finishing Plant Operating Buildings", subsection 9.1.7F.5, "241-Z Building."	The simplicity and low flow rate of the system precludes any means to significantly depressurize the building. WHC-SD-CP-SDD-005

Table 9A.6
243-Z LLWTF

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**The 243-Z Building, ventilation system (continued).**	A. Ventilation supply system (continued).	To provide airflow for maintaining negative DP between the building and atmosphere.	(2) Excessive supply airflow.	Potential loss of negative DP relative to atmosphere. Potential release of contaminants to the environment if there is a concurrent loss of containment.	Supply fan is a simple manual on/off unit having low flow rate capacity.	--	Refer to item 4A(1)	Not specifically analyzed. Similarity of the ventilation system to the 241-Z Building allows reference to section 9.1.7E, "Excessive Building Pressurization, 241-Z Building."	The simplicity and low flow rate of the system precludes any means to significantly pressurize the building. WHC-SD-CP-SDD-005
		B. Ventilation exhaust system.	Refer to item above.	(1) Insufficient exhaust airflow.	Refer to item 4A(2)	Refer to item 4A(1)	Refer to item 4A(1)	Refer to item 4A(1)	Refer to item 4A(2)	Refer to item 4A(2) WHC-SD-CP-SDD-005
				(2) Excessive exhaust airflow.	Refer to item 4A(1)	Exhaust fan has low flow rate capacity.	--	Refer to item 4A(1)	Refer to item 4A(1)	Refer to item 4A(1) WHC-SD-CP-SDD-005
		C.Ventilation exhaust HEPA filters.	To filter exhaust ventilation air before atmospheric discharge in order to mitigate the release of hazardous materials to the environment.	Loss of exhaust air filtration.	Potential release of hazardous materials to the environment.	HEPA filter DP gauges.	Procedure governing operator response to HEPA filter DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005
5	**Normal electrical power supply system (provided from the 291-Z Building).**	--	To provide power to meet all of the building electrical requirements.	Failure to provide power.	Potential loss of ventilation system control. Potential loss of negative DP of the building relative to atmospheric pressure.	Backup electrical power is provided by the 2721-Z Building.	Procedure governing operator response to loss of power.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.7

291-Z Building and 291-Z Stack.

The 291-Z Building and 219-Z stack are primarily used to provide ventilation exhaust for the 234-5Z, 242-Z, 236-Z, and 291-Z Buildings. The building, which is normally unoccupied, is divided into 11 rooms having assigned designations of rooms 500 through 510. Room 500 houses two 1,000 kVa transformers and the electrical switchgear used to provide normal electrical power to the 232-Z, 236-Z, 241-Z (-ZA, -ZB), 243-Z, and 291-Z Buildings. Room 501 contains the ASV system equipment for the 234-5Z, 291-Z, 2736-Z, 2736-ZA, and 232-Z Buildings and the 296-Z-5 and 296-Z-6 stacks. Rooms 502 and 509 house the exhaust fans, including the steam-turbine driven backup exhausters. Rooms 503 and 510 house the exhaust plenums which are combined in a common plenum (room 508) that discharges to the 291-Z stack. The two rooms housing the exhaust fans are connected by two cross passageways (rooms 504 and 506). Room 505 contains the inlet plenum, and room 507 contains air supply units that provide conditioned air for the 291-Z Building.

The 291-Z Building and 291-Z stack contain no significant radiological or toxicological hazards. Operations conducted within the building expose workers to the common industrial hazards of electrical shock and mechanical pinchpoints. If the equipment in the building fails to provide exhaust ventilation for other buildings within the PFP, there is a potential for significant hazards to result within those buildings. The same is true if the equipment in room 500 fails to provide electrical power, instrument/process air, or vacuum (air sample vacuum) to the buildings it serves.

Table 9A.7
291-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**Rooms 502 and 509, ventilation exhaust system.**	E-3 and E-4 exhaust system fans for the 234-5Z, 236-Z, and 242-Z Buildings.	To provide exhaust air flow for the 234-5Z, 236-Z, and 242-Z Buildings to maintain correct negative pressure control.	Loss of exhaust air flow.	Potential loss of relative negative DPs between zones 1, 3, and 4 and relative to the atmosphere. Potential pressurization of buildings relative to atmosphere. Potential release of SNM to the environment.	Redundant supply fans. Backup electrical power provided by the 2721-Z Building via the 234-5Z Building. Two exhaust fans are provided with backup power (1 of 2 operates on loss of normal power). Computer controlled ventilation system designed to disable supply fans upon sensing exhaust plenum pressure increase.	Procedure governing operator response to ventilation system upsets.	This event is anticipated. The consequence is judged to be low.	Refer to section 9.1.8, "Loss of Ventilation."	Loss of exhaust ventilation may result in significant hazards in the buildings served by 291-Z. See Appendices A.1, A.3, and A.8 for the hazard analysis of a loss of exhaust ventilation as it pertains to these buildings. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
2	**Room 500, normal electrical power supply system.**	--	To provide electrical power to the 232-Z, 236-Z, 241-Z (-ZA, -ZB), 243-Z, and 291-Z Buildings.	Failure to provide power.	Potential inoperability of systems and equipment that are electrically powered (e.g., ventilation system, CAMs).	Backup electrical power is provided by the 2721-Z Building.	Procedure governing operator response to loss of power.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	Loss of electrical power would have minimal impact on the 291-Z Building, but may result in significant hazards in buildings served by 291-Z. See Appendices A.3, A.4, A.5, and A.6 for the hazard analysis of a loss of normal power for these buildings. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
3	**Room 501, process/ instrument air supply system.**	--	To supply non-oily, clean, dry air for use in instrument controls for the ventilation system and for process systems in the 234-5Z, 291-Z, 242-Z, 2736-ZA, 241-Z, 241-ZA, and 236-Z Buildings.	Failure to provide air.	Potential loss of ventilation control for the facilities served by the 291-Z Building system.	Second compressor starts automatically if pressure drops below 65 lb/in^2 (gauge). Diesel-powered backup compressor located outside of 291-Z.	Procedure governing operator response to loss of process/ instrument air.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.7
291-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE FEATURES		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered	Administrative	Relative probability/consequence discussion[c]	Representative analysis location[d]	
4	**Rooms 501, air sample vacuum system (ASV).**	--	Provides the motive force (vacuum) necessary to operate room CAMs in the 234-5Z, 291-Z, 2736-Z, 2736-ZA, and 232-Z Buildings and to operate the 296-Z-5, 296-Z-6, and 296-Z-14 effluent stack samplers and monitors.	Loss of vacuum.	Potential inoperability of room CAMs and stack samplers/ monitors. Potential failure to detect airborne contamination within room(s) and/or within stack effluents.	ASV failure alarm system. Single-stage HEPA-filtered inlet air to vacuum pumps.	Procedure governing operator response to ASV system failure alarm.	This event is unlikely. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
5	**Rooms 502 and 509, steam-turbine-driven ventilation exhaust fans.** (deactivated)	--	--	--	--	--	--	--	--	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011 Steam driven exhaust fans have been deactivated. Backup power has been provided to two of the electric exhaust fans to ensure the facility stays under negative pressure should normal power supply fail.

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

Appendix 9A.8

242-Z Building.

There are no current operations conducted in the 242-Z Building. The building houses equipment once used for PRF waste treatment and americium extraction. The building is separated into three sections; a tank room, an operations room, and an annex (provided for outside entry into the building). The building has not been used since an accident that released contaminated material from a glovebox in the operations room. Subsequent to the accident, nonessential services were disconnected and contaminated surfaces were treated with a strippable coating. Entry to the building is nonroutine and strictly controlled.

The building and its internal walls and equipment function as barriers to contain hazardous materials. The primary barrier is a process enclosure such as a glovebox, or a process vessel within an enclosure. The secondary barrier serves to enclose the area containing the primary barrier. An example is the internal building walls defining the process room which houses gloveboxes. The building structure also functions as a barrier.

The 242-Z Building structure in conjunction with the ventilation systems forms a confinement system designed to mitigate the release of hazardous material should a barrier fail. The ventilation systems complete the confinement system by providing a controlled, continuous flow of air from the environment into the various building areas, through HEPA filters, and then back to the environment. Supply air is provided to the building rooms (zone 3) through the 234-5Z Building supply plenum, while air is supplied to the gloveboxes and process cells (zone 4) via leakage from the room through HEPA filters installed near the floor. Zones 3 and 4 are normally maintained at negative pressures relative to the atmosphere to prevent the movement of airborne material out of the building. Exhaust ventilation air from zone 3 passes through single-stage testable HEPA filters before reaching the 234-5Z Building E-3 HEPA filters (also single-stage). Zone 4 exhaust air is filtered by a single-stage testable HEPA filter in room 308 of the 234-5Z Building, and then is filtered through the two-stage, testable E-4 filters in 234-5Z. Both streams then exhaust to the 234-5Z Building plenum and the 291-Z-1 stack.

All electrical power to the building has been disconnected.

The following Hazard Evaluation table identifies stack CAMs as a preventive/mitigative feature for several postulated failure events. The CAMs perform a passive function, which is to detect airborne radioactive material and to activate alarms should the alarm set-point on the CAM be exceeded. They do not provide an active function which would actuate equipment or systems to prevent or mitigate an accident. In most cases the CAMs do not serve to reduce the consequences associated with a release of airborne radioactive material because most accidents involve a sudden release of material over a short period of time. Therefore, by the time the stack CAM detects the release there would be insufficient time to mitigate the event. In addition, the CAM's location in the ventilation discharge stack precludes any preventive/mitigative action since the release would have already occurred. Potentially chronic releases from process operations, or due to equipment failures (e.g., failed HEPA filters), tend to be small in nature.

If these releases are sufficient to actuate the CAM alarm, operator action is generally adequate to limit the release so there is no significant consequence. It should be noted that accidents evaluated in the Chapter 9.0 analyses did not rely on the CAMs to serve a preventive/mitigative function.

Table 9A.8
242-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE CONTROLS		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered features	Administrative features	Relative probability/consequence discussion[c]	Representative analysis location[d]	
1	**The 242-Z Building, ventilation system.**	A. Ventilation supply system.	To provide airflow for maintaining correct negative DP of building and gloveboxes.	(1) Insufficient supply airflow.	Potential excessive negative DP.	Contaminated surfaces are covered with a strippable coating. Backup ventilation supply fans. Flow alarms. Modulating dampers to two exhaust fans open on high vacuum detection in the filter plenum.	Procedure governing operator response to flow alarm.	This event is anticipated. The consequences are judged to be low.	Refer to section 9.1.7F, "Building Depressurization--All Plutonium finishing Plant Operating Buildings", subsection 9.1.7F.1, "234-5Z Building."	Since all contaminated surfaces were coated, it is unlikely that there is a significant amount of loose contamination within the building. WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
				(2) Excessive supply airflow.	Potential loss of negative DP relative to atmosphere. Potential release of loose contamination to the atmosphere.	Contaminated surfaces covered with a strippable coating. Backup ventilation supply fans. Flow alarms. 291-Z-1 stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of contamination to the environment.	Procedure governing operator response to flow alarm. Procedure governing operator response to CAM alarm.	Same as 1A(1)	Refer to section 9.1.7A, "Excessive Building Pressurization--234-5Z."	Refer to item 1A(1). WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		B. E-3 and E-4 ventilation exhaust system.	To provide airflow for maintaining correct negative pressure control of building and gloveboxes.	(1) Insufficient exhaust airflow.	Refer to item 1A(2)	Contaminated surfaces covered with a strippable coating. Four of seven exhaust fans are normally in use, with the other fans available as backups. Flow alarms. 291-Z-1 stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded. Two-stage HEPA-filtered ventilation system to mitigate the release of contamination to the environment.	Refer to item 1A(2)	Refer to item 1A(1)	Refer to item 1A(2)	Refer to item 1A(1). WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-011

Table 9A.8
242-Z Building.

SYSTEM IDENTIFICATION				FAILURE CHARACTERIZATION		PREVENTIVE/MITIGATIVE CONTROLS		QUALITATIVE HAZARD SCREENING		REMARKS
Item[a]	System/ equipment	Subsystem/ activity	Function	Failure mode	Failure consequence[b]	Engineered features	Administrative features	Relative probability/consequence discussion[c]	Representative analysis location[d]	
	ventilation system (continued).	B. E-3 and E-4 ventilation exhaust system (continued).	To provide airflow for maintaining correct negative pressure control of building and gloveboxes.	(2) Excessive exhaust airflow.	Refer to item 1A(1)	Contaminated surfaces are covered with a strippable coating. Automatic modulating dampers on two of the exhaust fans control pressure in zone 3. Flow alarms.	Refer to item 1A(1)	Refer to item 1A(1)	Refer to item 1A(1)	Refer to item 1A(1) WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011
		C. Ventilation exhaust HEPA filters (located in the 234-5Z Building; refer to Appendix 9A.1)	To filter exhaust ventilation air before atmospheric discharge in order to mitigate the release of SNM to the environment.	Loss of exhaust air filtration.	Potential release of SNM to the environment.	HEPA filter DP gauges. Backup HEPA filters. 291-Z-1 stack CAM to detect airborne alpha contamination and to activate alarm(s) should the alarm set point be exceeded.	Procedure governing operator response to HEPA filter DP outside operating limits. Procedure governing operator response to CAM alarm.	This event is anticipated. The consequences are judged to be low.	Not specifically analyzed.	WHC-SD-CP-SDD-005 WHC-SD-CP-SDD-006 WHC-SD-CP-SDD-011

[a]Hazard identifier.
[b]The consequence, as given here, assumes none of the active preventive/mitigative features are in place.
[c]The probability/consequence, as given here, assumes that the preventive/mitigative features are operative.
[d]Gives the section number in the chapter where additional accident analysis is performed.

APPENDIX 9B

RELEASE FRACTIONS FOR PLUTONIUM POWDERS

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APPENDIX 9B

RELEASE FRACTIONS FOR PLUTONIUM POWDERS

The release fraction for Pu powders dispersed from the seismically unqualified glovebox depends on the forces acting on the powder. The Pu powder is contained in either sealed or open containers that are free to move around the glovebox, or are fixed in place by pedestals. The release fraction is a function of whether the glovebox topples or not, whether the powder leaves the container, and if so, the force on the powder outside of the container. It should be recognized that many gloveboxes are in the category of "unqualified". Most of the containers in these gloveboxes are open.

Gloveboxes are rigid rectangular enclosures of all welded 3/16" in. or thicker stainless steel construction, except for windows and gloveports. Gloveboxes have either small diamond shaped panels with the majority of the face area being steel, as depicted in Figure 9B-1, or large plastic panels as shown in Figure 9B-2. The panels are held in place by numerous bolted studs that are spaced every 2 in. Analysis of seismic loads on glovebox plastic panels in the *Glovebox and Filter Box Plastic Panel Seismic Evaluation*, WHC-SD-CP-SA-010 (Ocoma 1990a), determined the panels do not break or come out of the glovebox frames. Tests in which hydrogen explosions were intentionally set off in similar gloveboxes with large panels, as reported in "Fire and Explosion Test of Plutonium Gloveboxes" (Rhude 1962), resulted in gloves that were blown out but showed no damage to the panels. The *PFP Safety Systems and Components Seismic Evaluation*, DAR-RHO-0017, Rev. 1, p. 9A-124, (Ocoma 1990b), analyzed the accelerations of powder pans caused by seismic forces to see if the pans would be propelled out of the glovebox. The powder pans weigh 13 lb when loaded. They were accelerated to 20.6 ft/sec before impact. The plastic glovebox panels withstood impact within margin. Therefore, containers will not be propelled out of the glovebox.

The plutonium powder is contained in a variety of containers. There are poly-jars with screw top lids, slip-lid cans, (a "tin" can with a lid that stays on via friction), sealed food-pack cans, and open plastic "beakers." The strength of some of these containers has been tested. The sealed cans and slip-lid cans are constructed of 0.009 in.-thick steel sheets coated with a thin film of tin. Testing of the sealed cans in *The Effectiveness of Corrective Actions Taken to Prevent Events Involving Tin Cans and Plutonium*, RHO-HS-SA-SAP (Szempruch 1984), showed that they can withstand internal pressures up to 100 lbf/in^2. In another test entitled *One-Pound Slip-Lid Tin Drop Evaluation*, SD-CP-TRP-027 (Reichmuth 1988), slip-lid cans were loaded with between 400 and 600 g of damp sand or basalt cuttings, and were dropped from heights of 2 to 5 m onto a concrete floor. Neither the cans that had lids sealed with tape, nor those that were not taped, had any loss of material. The lids were slightly displaced on the untaped cans. None of the cans lost integrity.

In order for powder to be released to the room, the glovebox and open containers must topple, the closed containers must be opened, the glovebox must loose integrity before, or as it impacts the floor, and there must be a mechanism to push the suspended powder out.

The first accident analysis assumption is that all of the unqualified gloveboxes completely toppled. While this may be true for some, there are many gloveboxes for which the failure mode is much less severe, some lean to one side because of failure of the leveling bolts that are typically 2 or 3 in. long, and some "walk" away from their normal position. The failure mode depends on the size of the glovebox, the attachment to other gloveboxes (e.g., MT-4, MT-5 and MT-6 are attached to a conveyor glovebox), and attachment from above (ventilation piping, and electrical conduit).

Seismic analyses of the PFP gloveboxes (Ocoma 1990a, 1990b) determined that glovebox toppling caused by inadequate anchoring was the predominant failure. No cases of glovebox wall collapse or breakage was identified. Toppling of a glovebox can occur if the center of gravity is displaced horizontally beyond the width of its support. The glovebox would topple as a rigid structural unit (i.e., rectangular enclosure). The second assumption is that the glovebox looses its confinement function after it topples. This may be envisioned to occur as a result of a disconnection of the glovebox from ventilation ducts or the breakage of glovebox windows. No credit is given to the fact that glovebox exhaust filters, although not testable, are integral to the glovebox construction and disconnection from the ducting would most probably be downstream of these filters. Likewise the glovebox windows are either sheet plastic, laminated safety glass, or wire glass. All these materials are likely to substantially provide their confinement function even after the glovebox topples, however, it is not practical to perform analysis to provide a defensible quantitative fraction.

The third assumption is that all of the powder suspended is forced out of the glovebox. Gloveboxes that do not disconnect from the exhaust duct would remain under negative pressure if the ventilation system continued to function. Very few gloveboxes have energy sources within them that would force suspended powder out of them.

Determining the release fraction for a variety of closed-versus-open containers requires an understanding of the time and type of impact that can exist during a seismic event. The powder in open containers will initially be acted on by both horizontal and vertical seismic forces. If the container topples before significant glovebox movement, the release fraction is extremely small because the distance the powder travels is about the height of the can. After toppling, the powder remains on the working surface to the leading corner as the glovebox topples. The force on the particles is much less than that experienced during a free-fall because the powder is not free. The release fraction is much less that of a 1-m spill.

If the powder remains in the open container and the open container remains on the glovebox floor, without significant sliding as a result of an engineered restraint, the container's position, with regards to other surfaces and equipment, or combination of forces and friction, will either spill out on the way down or the container will fall to the leading face of the glovebox. If the powder spills out on the way down, the release fraction is again less than a 1 m spill because the working surface starts at 1 m above the floor. It is also realized that the powder may fall from a height of a little more than 1 m, depending on how the glovebox fails. It is assumed here that failure resulting in a topple starts with the buckling of the legs. For this analysis a 1-m spill value will be used. If the container falls to the floor

of the glovebox, the powder is forced out because of impact forces on the container and the resulting forces on the powder. A similar situation was studied in the experiments and reported in the *Simulated Seismic Event Release Fraction Data - Progress Report April 1986-1987*, RFP-4101, (Langer 1987). The powder in two of Langer's experiments was constrained in a similar fashion. The experimental setup is similar to the accident assumption of a container falling to the floor. The mass of the container is about the same as (or at most double) that used in Langer and the height is approximately 1/4 of Langer's study. It is assumed that the release fraction is a function of potential energy or a function of mass times height. Therefore, the release fraction is 1/2 that found by Langer, or 10^{-5} based on Test No. 2.

Another case for open containers occurs when the container slides to the back of the glovebox as it topples, and remains there until impact. The height is again 1/4 of that used by Langer and the mass is at most doubled. The factor of 1/4 will be ignored to account for any energy impacted to the container by the glovebox. The release fraction is therefore 4×10^{-5}.

The last case occurs where the powder free-falls to the leading face. It is assumed that on impact the equipment mounting bolts fail, a glovebox window breaks, or loose equipment (such as wrenches) become airborne and impact the powder on the floor. Again, the height is 1/4 of that used in Langer and the weights range from equal to that of Langer, to around 10 times more than his calculation. For this case, Langer's data for powder on the floor will be tripled (taken from the product of 10 times 1/4) to find the release fraction for the large equipment pieces. The result is a respirable release fraction that ranges from 10^{-2}% (1/4 of 3.3×10^{-2}% of Case 5) to 10^{-1}% (three times the 3.3×10^{-2}% of Case 5), or 10^{-4} to 10^{-3}.

It is important to note that in the last three cases Langer's data was used, as it appears in his report, because the conditions postulated are almost identical to those of the test. Closed containers falling with the glovebox will not open per the experiments by Reichmuth. There is no release in these cases.

If equipment falls onto a sealed can, a slip-lid can or a poly-jar with a screw on lid, it may be possible that they would break open. It is assumed that if a large piece of equipment falls on any of the sealed containers they will fail. Slip-lid cans holding 1 to 1.5 lb of sand did not fail after a drop from 14 ft; therefore, equipment falling from 6 ft, the approximate top of the average glovebox, would have to weigh more than 2 to 3 lb to cause damage to the slip-lid cans. This assumes that failure is directly related to potential energy and that the materials of construction are the same.

Studies discussed in Szempruch (1984) show sealed cans deformed significantly at pressures less than 50 lbf/in^2 and lose integrity at internal pressures slightly below 100 lbf/in^2. Cans deformed by impact from external forces would be expected to loose integrity at lower internal pressures. Data for pressurized releases from *Aerosols Generated by Releases of Pressurized Powders and Solutions in Static Air*, NUREG/CR-3093 (Sutter 1983), pg. B.1, for 350 g sources (the source load is at least that and larger; up to 2,500 g), and the Ballinger (1987) version of the document could be used to determine the maximum release fraction if the rupture pressure is known. Typical bulk PuO_2 or PuF_4 powder density is approximately 2 g/cm^2. The theoretical density

is approximately 11.5 g/cm^2. As a result, there is much air entrapped in the powder. Assuming a 0.625-L can containing 1,250 g of plutonium oxide, the actual volume of the Pu oxide is 108 cm^3, leaving 517 cm^3 of air. Comparisons to fuel-fabrication pellet-manufacturing practices makes it obvious that compression of the powder in a full can takes tons of force. Such forces will not occur if the glovebox topples. If the cans are partially full, the pressure to compress a can is much less, because there is air available to compress. For conservatism the release fraction from pressurized release based on 25 lbf/in^2 (gauge) will be used. The value for the release is 0.076% for 350 g sources and 0.127% for 100 g sources at 25 lbf/in^2 (gauge) as determined by *New Data for Aerosols Generated by Releases of Pressurized Powders and Solutions in Static Air*, NUREG/CR-4779 (Ballinger et al. 1987), Table 9A-6 . A value of 0.1% or 1 x 10^{-3} will be used in the analysis to account for uncertainties. Because the actual quantities are typically greater than 350 g, a realistic value could be 0.05% or less.

The following must be noted when considering use of this release fraction. First, the container will likely split open because of the impact. Depending on the pressure at the time of the split, the release could be much less. Second, a significant force must be applied to pressurize the can to 25 lbf/in^2. If the surface of the top of the can were 7 in^2 (3-in.-dia can), the force would have to be approximately 175 lb to cause the necessary change in volume, assuming that there is no mechanical strength in the can walls. Most of the seismically unqualified gloveboxes are in laboratories that contain almost no large pieces of equipment capable of generating 175 lb of force caused by a fall from approximately 6 ft (average height). While large pieces of equipment do exist in the other gloveboxes, only a very small fraction of the containers are envisioned to be directly and squarely impacted such that any significant compression is possible. The rest will release no plutonium (See earlier discussion on sealed containers falling with the glovebox). It is therefore believed that use of a release fraction of 0.1% for all sealed containers is overly conservative.

It is assumed that the slip-lid can and poly-jar fail at a pressure much less than 25 lbf/in^2. The plastic poly-jars crack fairly easily upon impact. Dented walls of a slip-lid can near the lid easily vent the can. The release fraction is much less than 0.1%.

The results of the above are summarized in Table 9B-1. It is noted from the summary, that the only case where the release fraction is larger than that used in the safety assessment occurs where large pieces of equipment impact powder on the floor, or impact the closed containers and fail them. There is no mechanism within the glovebox that could completely transport the suspended powder outwards and the small fraction of the total powder contained in gloveboxes, in sealed containers, will limit the release fraction of the material into the room to below that used in the safety assessment, except possibly for a few isolated very low probability cases.

The total release is judged to be appropriately calculated if the entire inventory in all of the unqualified gloveboxes is multiplied by 1.5 x 10^{-4}. By comparison to the envisioned range, the release is found to increase by 30% if 95% of the powder is assumed to be released with a release fraction of 1.5 x 10^{-4} and 5% released at the larger value of 10^{-3} based on free powder and sealed containers. The 5% is considered to be a very conservative estimate of

"direct hit" impacts onto free powder and sealed containers. The total release decreases by a factor of approximately 2 over that assumed in the safety assessment (which used a release fraction of 1.5×10^{-4}), if 95% is released using 4×10^{-5} (a more realistic case) and the remaining 5 % is released using 10^{-3}. Thus the range of the "real" release fraction would be considered as 7.5×10^{-5} to 2×10^{-4}. This range is calculated assuming the entire inventory is dispersible powder. Much of the inventory typically in the facility is damp-process residues, sludges, and liquid laboratory samples. Considering these form differences reinforces the appropriateness of the selected release fraction of 1.5×10^{-4}.

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Table 9B-1. Summary of release fractions.

Condition	Release fraction
1-Value used in the safety assessment (WHC 1994).	1.5×10^{-4}
2-Powder falls out of container before significant glovebox motion.	Much less than a 1 m spill $<4 \times 10^{-5}$
3-Powder falls out of the open container as the glovebox falls. Open container remains in place.	4×10^{-5}
4-Powder remains in container, container slides off surface and strikes leading face.	10^{-5}
5-Powder remains in container, container slides to back of the glovebox and then strikes surface on impact.	4×10^{-5}
6-Equipment impacts powder on floor.	10^{-4} to 10^{-3}
7-Slip-lid and sealed cans falling with the glovebox.	0.0
8-Equipment impact directly onto closed, sealed containers.	0.0 to 1×10^{-3}
9-Impact directly onto closed poly-jars and slip-lid cans.	0.0 to $<1 \times 10^{-3}$

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Figure 9B-1. Glovebox with Diamond Shaped Panels.

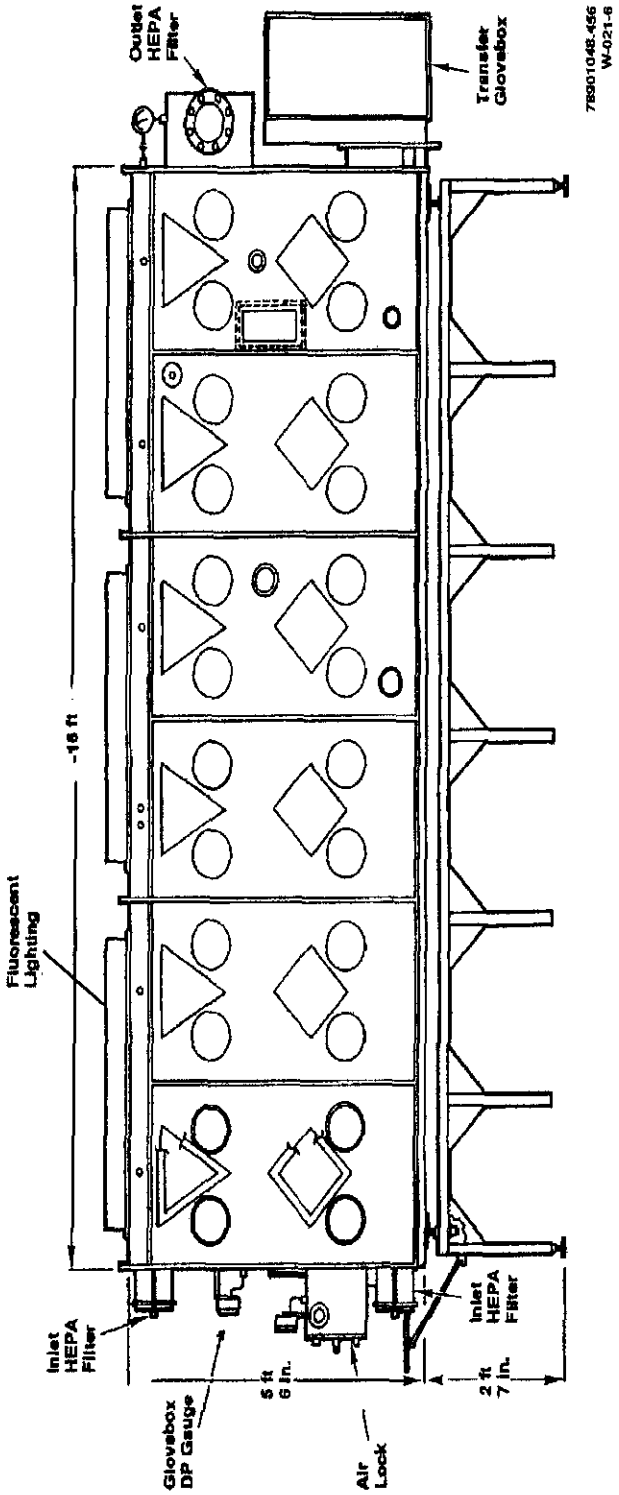
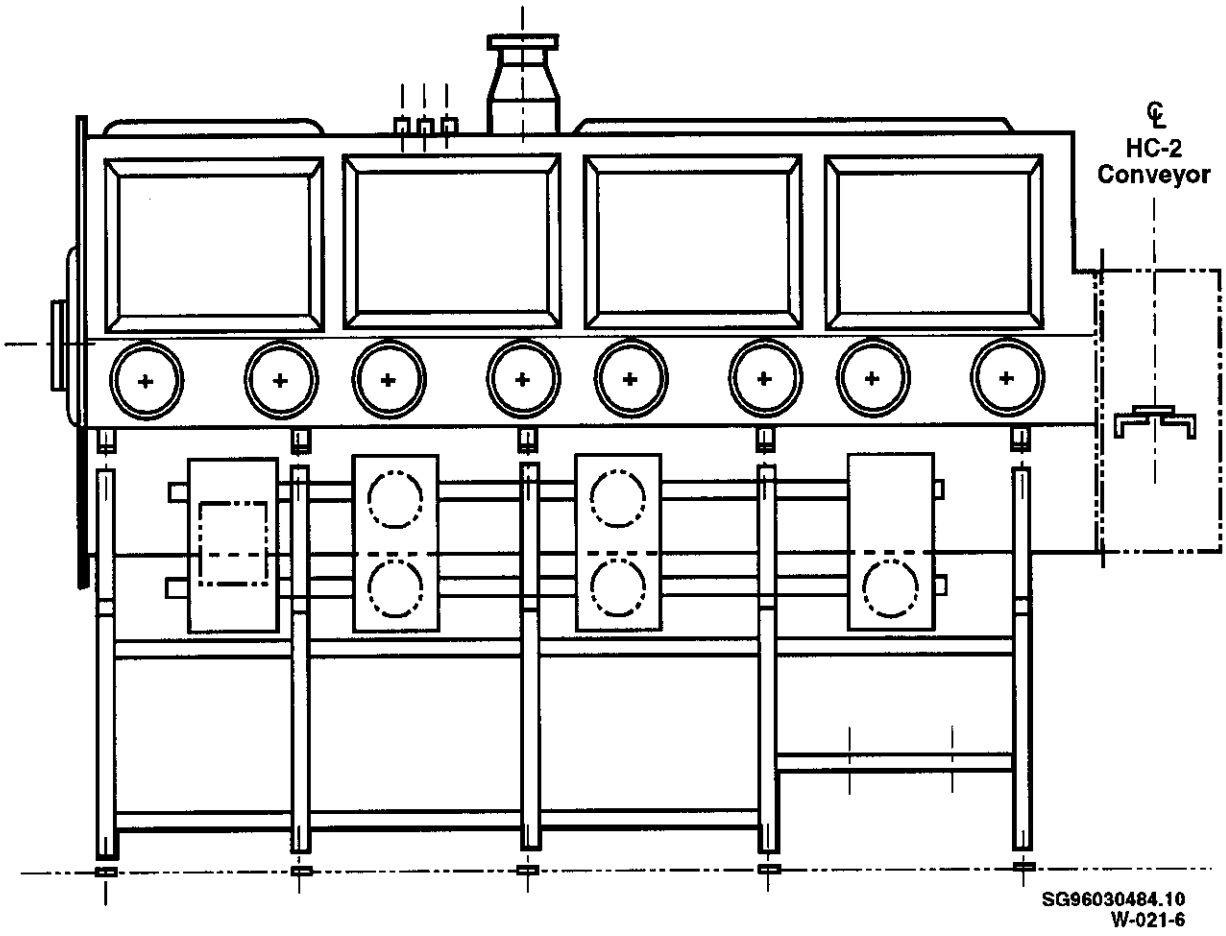


Figure 9B-2. Glovebox with Large Panels.



APPENDIX 9C

MODEL FOR DETERMINING RELEASES FROM FACILITIES

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APPENDIX 9C

MODEL FOR DETERMINING RELEASES FROM FACILITIES

Section 9.2.4.6.4, "Summary of Release Into Facility," presents the number of grams of respirable plutonium (i.e., with a particle size 10 μm or less) released into facilities as the result of a seismic event. The following sections present a model for estimating the number of grams released from the facilities to the environment.

9C.1 Accident Analysis-Calculations, Release Out of Facility, Particle Characteristics. Discussion in Section 9.2.2A.3.1 shows that only a small fraction of plutonium powders is considered respirable.

Based on the more conservative figure for particle density of 7 g/cm^3, spherical particles greater than 4 μm are not respirable. The dose models require particle size in AED. The AED is defined, in aerosol physics, as the diameter of a hypothetical particle of unit density (water) having the same settling velocity as the given particle.

The AED particle is assumed to be spherical, but the actual particles are not. The AEC (1968), p. 203 states that "the effect of shape upon fall velocities is, on the average, to reduce the velocity by about two-thirds from that of a smooth sphere." It is assumed that this means the velocity for an actual particle equals two-thirds times the velocity of a spherical particle.

Since, per AEC (1968), p 202

$$v_s = \frac{2r^2 g\,\rho}{9\mu}, \text{ for spherical particles}$$

$$v_s = \frac{2\ (2)}{3}\ \frac{r^2 g\,\rho}{9\mu} = \frac{4}{27}\ \frac{r^2 g\,\rho}{\mu}, \text{ for nonspherical particles}$$

$$v_s = \frac{2r^2 g}{9\mu}, \text{ for unit density spherical particles}$$

equating these to find AED

$$\frac{4r^2 g\,\rho}{27\ \mu} = \frac{2r_{AED}^2 g}{9\mu}$$

or,

$$= \frac{2r^2\,\rho}{3} = r_{AED}^2$$

so:

$$r^2 = \frac{r_{AED}^2\ (3/2)}{\rho} \text{ and } = \frac{r_{AED}\ (\sqrt{3/2})}{\sqrt{\rho}}$$

substituting:

$$r = r_{AED} \frac{\sqrt{3/2}}{\sqrt{7}} = r_{AED}\ 0.463$$

A 10-μm AED particle is therefore equivalent to a 4.6-μm particle of density 7 g/cm^3. The value of 5 μm will be used in this analysis so that 4.3% of the $PuFO_2$ powder is respirable.

9C.2 Accident Analysis-Calculations, Release out of Facility, Airflow Patterns. Air can enter the building through open doors or the building joint. There are at least three doors on each of all four sides of 234-5Z. The building joint is a 2-in.-wide gap between the 234-Z and 235-Z Buildings (hence the name 234-5Z). The following calculations assume that the doors opening to the outside at the first level of 234-5Z are left fully open after the seismic event. The ambient wind then blows through the building and transports aerosolized plutonium particles to the environment. The flow in the building is based on flow down corridors 5 and 6 (Figure 9-3) conservatively assuming that the numerous airlock doors remain blocked open after the seismic event. All of the airborne plutonium from the seismic accident analyses in 9.2.4 is available for transport out of the building. This is a significant conservatism since it ignores deposition over the tortuous pathways that the aerosols must travel to reach the corridors. Section 9.2.4.8.1, "Dose Calculations", will use the equations and information presented here in the calculation of dose but will use a more realistic assumption of door open-area.

For the building "breathing" case, it is assumed that a 5-mi/h wind blows on the east or west side, through the first floor, and out of the opposite side. The door dimensions are assumed to be 3 ft by 7 ft. The flow is

$$\frac{5\ \text{mi}}{\text{h}} \left(\frac{5{,}280\ \text{ft}}{\text{mi}}\right) \frac{\text{h}}{60\ \text{min}}\ (3)\ (3\ \text{ft by}\ 7\ \text{ft}) = 27{,}720\ \frac{\text{ft}^3}{\text{min}}$$

The cloud of suspended powders is mainly in the center of the building. The *Safety and Risk Assessment Technical Information to Support PFP Restart*, WHC-SD-SQA-TI-013, Rev. 2 (Marusich 1988, p Add-33) provides an equation for settling rate

$$\lambda = \frac{(\text{vel})\ A}{V}$$

where:

$\lambda = s^{-1}$

vel = Settling velocity, ft/min

A = Surface area along path, ft^2

V = Volume of path, ft^3.

Marusich (1988, p Add-34) shows how this is used

$$\frac{dM_b}{dt} = - M_{out} - M_{dep}$$

where:

M_b = Mass of powder dispersed in the building at any time

M_{out} = Mass flow rate out of the building

= Concentration of powder in the building at any time multiplied by the flow rate out of the building

$$= M_b \frac{q}{V}$$

q = Flow rate out of the building, ft^3/min

V = Volume of building

M_{dep} = Mass rate deposited

$= \lambda M_b$.

$$\frac{dM_b}{dt} = - \left[\frac{q}{V} + \lambda M_b\right]$$

The solution is

$$M_b = M_{bo} \exp\left[\left(- \frac{q}{V} - \lambda\right) t\right]$$

where:

M_{bo} = Quantity present at t = 0

t = Time, min.

To solve the equation:

q = 27,720 ft^3/min

A = [16(22 ft)] x (22+22+26+26+21+21)

where:

The first bracketed term in the equation for A is the length from column 7 to column 23 and the second bracketed term is the width from column A to column G.

$$A = 48{,}576 \text{ ft}^2$$

Since the ceiling is 9 ft high,

$$V = A(9) = 437{,}184 \text{ ft}^3$$

Substituting into the equation:

$$M_b = M_{bo} \exp\left(- \frac{27{,}720}{437{,}148} - \frac{\text{vel } (48{,}576)}{437{,}148} \, t\right)$$

$$= M_{bo} \exp\left[-(0.063 + 0.111 \text{ vel})t\right]$$

The quantity that gets out of the facility is

$$\frac{q}{V} M_b = \frac{q}{V} M_{bo} \exp\left[-(0.063 + 0.111 \text{ vel})t\right]$$

$$= 0.063 M_{bo} \exp\left[-(0.063 + 0.111 \text{ vel})t\right]$$

Now the suspended powders must be put into size bias so that "vel" can be obtained. Brown (1950), p 74 gives the deposition velocity in laminar flow as

$$v = \frac{(\rho_s - \rho_l) \, g \, D^2}{18\mu}$$

where, per Brown (1950), p 68:

$$v = \text{ft/s}$$

$$\rho_s = \text{Particle density} = \frac{4 \text{ g}}{\text{cm}^3} \frac{\text{lb}}{454 \text{ g}} \frac{30.5^3 \text{ cm}^3}{\text{ft}^3} = 25 \frac{\text{lb}}{\text{ft}^3}$$

For conservatism bulk density is being used rather than actual density of 11 g/cm^3.

ρ_l = Density of air = 0.068 lb/ft^3

$g = 32.2 \text{ ft/s}^2$

$$D = \text{Particle diameter} = d \text{ (microns)} \left(10^{-6} \frac{\text{m}}{\mu\text{m}}\right)\left(\frac{3.28 \text{ ft}}{\text{m}}\right)$$

$$\mu = \text{Viscosity} = 0.018 \text{ centipoise} \left(6.7 \times 10^{-4} \frac{\text{lb}}{\text{ft-s-centipoise}}\right)$$

For 1-μm particles

$$v = \frac{250(32.2)\ (d^2)(3.28\text{x}10^{-6})^2}{18(0.018)\ (6.7\text{X}10^{-4})} = 0.0004(d^2)\left(\frac{ft}{s}\right) = 0.024(d^2)\ \frac{ft}{min}$$

The respirable particles will be grouped as follows:

Particle size (μm)	Deposition velocity (ft/min)
1	0.024
2	0.096
3	0.215
5	0.598
10	2.39
20	9.57
50	59.8

Particle size (μm)	Fraction (of total weight)	Deposition velocity (ft/min)
0 - 2	0.005	0.024 (1 μm)
2 - 3	0.009	0.15 (2.5 μm)
3 - 5	0.029	0.38 (4 μm)

Note: The weight fractions are based on the data in Table 9-10.

The total released over time is given by

$$M_{TOT} = 0.063\ M_{bo} \int_o^t \exp\ [-(0.063 + 0.111\ vel)t]$$

This equation is of the form

$$M_{TOT}\ A \int_o^t \exp\ (-bt)\,dt$$

$$= \frac{A}{-b} \exp\ (-bt)\ \Big|_o^t$$

$$= \frac{A}{-b}\ [\exp\ (-b[t]) - 1]$$

Values for b range from 0.039 for 1-μm particles to 0.68 for 20-μm particles. Values of exp [-b(120)] range from 0.009 for 1-μm particles to 0 for 20 μm particles. For long times in the plume (i.e., hours) the value in the brackets is one and therefore:

$$M_{TOT} = \frac{A}{-b} = \frac{0.038\ M_{bo}}{0.038 + 0.111(vel)}$$

where M_{TOT} is the total release out of the facility assuming no evacuation.

To find the fraction of particles in each size group, assume that the respirable particles have sizes as on the previous page.

Particle size (μm)	Percentage	Percentage of total respirable for each size
0 - 2	0.5	12
2 - 3	0.9	21
3 - 5	2.9	67
	4.3 percent of total weight is respirable	

To solve for M_{TOT}, using the equation above and the fact from Section 9.2.4.7.2 that there are 1.87 g respirable

Particle size (μm)	Deposition velocity	Percent of respirable or nonrespirable	"M_{bo} Mass in each size "bin"*		M_{TOT}
0 - 2	0.024	12	0.22	0.22	
2 - 3	0.15	21	0.39	0.31	1.28 g
3 - 5	0.38	67	1.25	0.75	respirable

*Mass = "mass of respirable or nonrespirable" times percent.

9C.3 Accident Analysis-Calculations, Release Out of Facility, Sensitivity to Wind Speed. The flow rate through the building is proportional to the wind velocity. If the wind were 15 mi/h and not 5 mi/h, the flow rate through the building would be three times the 5-mi/h value, or 83,160 ft^3/min. If the wind were 2.2 mi/h, the flow rate through the doors would be 12,197 ft^3/min, or approximately 44% of the 5-mi/h value. Changing the flow through the building changes the 0.063 value derived from dividing flow rate by the volume. In the 15-mi/h wind scenario, 0.063 is changed to 0.190 and for the 2.2-mi/h wind 0.063 is 0.028. The fraction of each particle group is now determined using

$$\frac{M_{TOT}}{M_{bo}} = \frac{0.063}{0.063 + 0.111\ (vel)} \text{ or } \frac{0.190}{0.190 + 0.111\ (vel)}$$

$$\text{or } \frac{0.028}{0.028 + 0.111\ (vel)}$$

for 5 mi/h, 15 mi/h, or 2.2 mi/h, respectively.

Particle size (μm)	Deposition velocity	M_{TOT}/M_{bo}		
		2.2 mi/h	15 mi/h	5 mi/h
0 - 2	0.02	0.91	0.99	0.96
2 - 3	0.15	0.63	0.92	0.79
3 - 5	0.38	0.40	0.82	0.60

If the release into the building is 1.87 g and the quantity in each group is as given in the table above, then the release out is

Wind (mi/h)	Respirable mass (g)
5.0	1.28
15.0	1.61
2.2	0.95

REFERENCES

AEC, 1968, *Meteorology and Atomic Energy 1968*, July 1968, U.S. Atomic Energy Commission, Washington, D.C.

Brown, 1950, *Unit Operations*, John Wiley & Sons, Inc., New York, New York.

Marusich, R. M., 1988, *Safety and Risk Assessment Technical Information to Support PFP Restart*, WHC-SD-SQA-TI-013, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

APPENDIX 9D

PLUTONIUM FINISHING PLANT
PRODUCTION VERTICAL DENITRATION CALCINER
HAZARD EVALUATION

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PFP Production Vertical Denitration Calciner HAZOP

1.0 PRODUCTION VERTICAL DENITRATION CALCINER HAZOP

This appendix describes the methodology, organization, and results of the Plutonium Finishing Plant (PFP) Vertical Denitration Calciner (VDC) Hazards and Operability analysis (HAZOP).

1.1 METHODOLOGY

This section of the appendix presents the methodology used to identify and characterize hazards of the PFP VDC.

1.1.1 Hazard Identification Methodology

A Hazards and Operability Study (HAZOP) was chosen as the primary method of Hazard Identification/Hazard Evaluation for the PFP VDC. A HAZOP is a systematic approach used to identify and evaluate safety hazards in a process or operation and to identify operability problems which, although not hazardous, could compromise the ability to achieve design productivity. The HAZOP accomplishes this by evaluating the process or operation at specific points called "study nodes." These nodes can be process sections, operating steps, or support systems and are generally chosen in an order that follows the process or operation flow.

At each node potentially hazardous process deviations are identified using guide words. A general set of guide words is shown in Table 9D-1. By combining the guide words with specific process parameters, deviations from the intended process operation can be specified. For example, the guide word "low" combined with the process parameter "level" at the Feed Receipt Tank node results in the deviation "low level" for the Feed Receipt Tank. The use of guide words ensures that all relevant potential causes and consequences of deviations of process parameters are identified.

Although this technique captures a wide variety of conditions, initiators relating to Natural Phenomena and External Events were evaluated specifically and added to the end of the completed HAZOP table as nodes numbered 1000.x.x. Worker safety issues are addressed in this HAZOP as a general part of the information contained under the "Immediate Consequences" column as it relates to the "Possible Causes/Hazardous Event" column entry. However, most industrial safety concerns are not specifically identified in this HAZOP even though it is recognized that hazards such as cuts, abrasions, pinches, slips, trips, falls, and other similar things are associated with the calcining process. An energy source checklist, Table 9D-2, is included to provide a general indication of the presence of industrial hazards. Industrial hazards unique to the calcining process such as high temperatures, exposure to caustics and acids, and bottles of high pressure air are noted explicitly in the HAZOP. The completed HAZOP is contained in Table 9D-4.

1.1.2 HAZOP Data Description

The HAZOP, Table 9D-4, is made up of 13 columns. The following provides a description of each column.

Column 1 - "Bin ID" - An alpha-numeric identifier for designating the event category that the event of that row is assigned. This allows sorting the information into groups of events with similar characteristics.

Column 2 - "ID" - A unique alpha-numeric identifier that permits identification of the node from which the information contained in the HAZOP was derived. It is most useful when data is sorted in non-node order. This designation is comprised of a number in decimal/alphabetic form. The number preceding the decimal indicates the primary node being addressed. The primary nodes are described in Section 1.2 and follow a general "front-to-back" process flow path through the calciner glovebox.

Column 3 - "Node Description" - Specifies the area of the calciner being evaluated.

Column 4 - "Design Function" - Describes the function of the node and was used to assist the HAZOP team in evaluating the system.

Column 5 - "Parameter/Guide Word" - Specifies the HAZOP parameter and guide word being applied to the specific node. The combination of the process parameter and guide word is not normally done in a HAZOP table, but was done to reduce the amount of space taken up by this information.

Column 6 - "Possible Causes/Hazardous Event" - Contains a description of the event and lists the potential cause or causes of the hazardous event or failure.

Column 7 - "Material at Risk" - Describes the type and quantity of hazardous material that may be involved in the Hazardous event.

Column 8 - "Immediate Consequences" - Lists the potential consequences of the Hazardous Event.

Column 9 - "Engineered Safety Features" - Lists the plant's available hardware features that mitigate or prevent the event being evaluated.

Column 10 - "Administrative Safety Features" - Lists the plant's available administrative controls such as procedures, training, practices, etc., that could mitigate or prevent the event.

Column 11 - "Cons Cat" - Contains an estimate of the result of the event, assuming that no controls, engineered or administrative, are present. However, naturally occurring phenomena that limit the consequence of an event are assumed to take place (rules of the universe). The Consequence Ranking column is a "first cut," qualitative, consensus estimate of the safety severity of the consequences. An alphanumeric system is used to designate the severity.

Column 12 - "Freq Cat" - A "first cut," qualitative, consensus estimate of the frequency of the consequences assuming that no engineered or administrative

safety features are present. An alphanumeric system is used to designate the frequency.

Column 13 - "Remarks" - Contains information that the team judges requires documentation. This can include (but is not limited to) assumptions about facility operation or recommendations for changes in the planned design or operation.

1.1.3. HAZOP Scope

This HAZOP evaluates the HC-230C-2 glovebox and associated support systems present in room 230C and the solution transfer line from the Load-in/Load-out (LI/LO) glovebox, HC-227S. The LI/LO operation in glovebox HC-227S is not included since they are the same operations as previously performed and are essentially unchanged by the operations of the VDC except for an additional transfer line to glovebox HC-230C-2. Also not included are the processes that occur after the Pu oxide leaves glovebox HC-230C-2 since these processes are identical to the ones performed for the reactive material (thermal) stabilization operations. These are processes such as sampling, thermogravimetric analysis (loss-on-ignition) testing, packaging, movement between gloveboxes and buildings, and temporary as well as permanent storage.

Although this HAZOP was conducted in a manner that allowed consideration of the widest ranging possible causes of undesirable events that could result from operation of the VDC, two constraints were applied to maintain consistency with the existing PFP FSAR. The first is no consideration of random concurrent failures of E-3 or E-4 ventilation system high-efficiency particulate air (HEPA) filters. The existing FSAR analyses take credit for the presence of filters unless the event under consideration can be shown to adversely affect the filters. It is stated that the HEPA filters are Safety Class except for the seismic case. The second constraint is no consideration of random concurrent failures of the ventilation system fans and ductwork. Again, the existing FSAR analyses take credit for the operation of these fans unless the event being considered can be shown to adversely affect the fans and ductwork.

The HAZOP was performed by the following individuals:

Brett Hall - Fluor Daniel Northwest
Milton V. Shultz - Fluor Daniel Northwest

With assistance from the following personnel from the project and Plutonium Finishing Plant:

Greg Funston
Jerry Durnil

1.2 HAZOP ORGANIZATION

The general flow of the HAZOP is according to glovebox HC-230C-2 process flow of the Pu nitrate being converted into Pu oxide for long term storage.

There were 25 study nodes defined for the HC-230C-2 VDC glovebox. Figure 9D-1 shows the nodes on a schematic of the VDC glovebox. The nodes are:

HAZOP Node 1- VDC Feed Receipt Tank (includes transfer line and encasement from glovebox HC-227S)

HAZOP Node 2- VDC Feed Pump Tank

HAZOP Node 3- VDC Flush Tank

HAZOP Node 4- VDC Feed Pump P-230-A

HAZOP Node 5- VDC Injector Nozzle

HAZOP Node 6- VDC Vessel

HAZOP Node 7- VDC Offgas Line between calciner vessel and scrubber

HAZOP Node 8- VDC Offgas Scrubber

HAZOP Node 9- VDC Scrubber Phase Separator Tank

HAZOP Node 10- Glovebox HC-230C-2 spent scrub solution Receiver Tank

HAZOP Node 11- Glovebox HC-230C-2 spent scrub solution drain line from MOV 230-P to Tank D8

HAZOP Node 12- Glovebox HC-230C-2 Vacuum Trap

HAZOP Node 13- Glovebox HC-230C-2 Vent Catch Tank

HAZOP Node 14- Transfer line between glovebox HC-230C-2 pump P-230-E and HC-227S Receiver Tank

HAZOP Node 15- VDC Filter pulsing supply air piping (downstream of EV solenoid valves)

HAZOP Node 16- VDC Pulse/atomizing air supply upstream of pulse air 3 way valve (EV-230-A)

HAZOP Node 17- Sodium Hydroxide Feed Supply line downstream of pump P-230-B (pump and sodium hydroxide supply drum outside glovebox HC-230C-2)

HAZOP Node 18- VDC Offgas Scrubber Chiller

HAZOP Node 19- Glovebox HC-230C-2 Chemical Addition Tank (external to glovebox - feeds Flush Tank)

HAZOP Node 20- PFP plant compressed process air system

HAZOP Node 21- Calciner bottled compressed air supply (supplies VDC filter pulsing system and injector nozzle atomizing air)

HAZOP Node 22- Glovebox HC-230C-2 physical structure

HAZOP Node 23- E-4 exhaust duct at outlet of glovebox HC-230C-2

HAZOP Node 24- VDC product collection jars and slip lid convenience cans including handling within glovebox and transfer to conveyor system

HAZOP Node 25- VDC vacuum sensing line between calciner and vacuum regulator valve VRV-230-1

1.3 HAZARD EVALUATION METHODOLOGY

The qualitative potential consequence and likelihood estimates for the identified events were generated by the HAZOP team using a modified Delphi approach based on the team members' experience and judgment. The criteria for the consequence and likelihood categories are as follows.

The Consequence Ranking is defined as follows.

S0 No effect outside the facility confinement systems and no safety concerns for the facility worker, the onsite worker, or members of the general public.

S1 Potential industrial injury, radiological dose consequences or chemical exposure to the facility worker; limited environmental discharge of hazardous material outside the facility

S1* Potential serious injury or acute fatality from industrial hazard, or radiological or chemical exposures to the facility worker; limited environmental discharge of hazardous material outside the facility

S2 Potential significant radiological dose consequences or chemical exposure to the maximum onsite worker outside the facility; environmental discharge of hazardous material within the Hanford site boundary

It should be noted that no events with significant offsite consequences were identified and therefore, no S3 rankings were assigned.

Frequency of the consequences, assuming there are no engineered or administrative safety features, are defined as follows.

F0 Events not expected to occur and categorized as beyond extremely unlikely. The frequency range is <1E-06/yr.

F1 Events not expected to occur within the lifetime of a typical facility and categorized as extremely unlikely. The frequency range is $1E\text{-}06/yr \leq f < 1E\text{-}04/yr$.

F2 Events which could occur during the lifetime of the facility and categorized as unlikely. The frequency range is $1E\text{-}04/yr \leq f < 1E\text{-}02/yr$.

F3 Events which are expected to occur one or more times during the lifetime of the facility and categorized as anticipated. The frequency range is $1E\text{-}02yr \leq f < 1/yr$.

All events were classified by Category and Type. The categories are: Internally Initiated accidents (process accidents), accidents initiated by Natural Phenomenon, and accidents initiated by causes external to the facility (External Events).

Each internally initiated event identified in the HAZOP was assigned an accident bin identifier related to the event phenomena such as release from glovebox, fire in glovebox, explosion, toxic chemical release, criticality, etc. Events assigned to a given bin challenge analogous barriers. Analogous barriers reflect the same design philosophy for prevention and mitigation of the same event type. Events resulting from external events and natural phenomena were assigned their own specific bins. This was done because external events and natural phenomena related events result in multiple barriers being challenged in the PFP facility. This grouping was also related to the organization of the existing PFP FSAR Chapter 9 analyses. Event bins were also given an Event Type designation in keeping with the designations used in the PFP FSAR Chapter 9 analysis. The designations are Accident (AC), Abnormal Operation (AB), and Not Applicable (NA). NA is a type of accident that is not currently addressed in the PFP FSAR. The accidents represented by this designation relate to process upsets that can affect mission success, are as low as reasonably achievable (ALARA) concern only, or are related to industrial accidents normally addressed by institutional programs such as industrial health and safety.

The results of the binning process are summarized in Table 9D-3. There are a number of reasons that a summary table is used. The first reason is that the process flow orientation of the evaluation process does not create any kind of grouping of information suitable for the selection of accidents requiring additional analysis. For example, similar releases of radioactive material can occur from different parts of the calciner and its glovebox. This results in a significant number of similar hazards that are widely separated within the HAZOP table. Another reason is that information in HAZOP tables consists of abbreviated notes capturing a dynamic and creative process; they can be somewhat cryptic and often not easily compared and grouped by reviewers who were not part of the process. This condition, present in all qualitative Hazards Evaluation techniques, is referred to as "inscrutability" (Guidelines for Hazard Evaluation Procedures).

1.3.1 Binning Approach

The hazardous events were categorized into 15 Bin IDs. The Bin IDs are:

A1 - Process Upset - no worker impacts
A2 - Process upset - worker ALARA concern
B - Release inside glovebox
C - Release from transfer line
D - Deflagration in glovebox (ignition of flammable gas in calciner)
E - Criticality
F - Fire in glovebox (ignition of combustible materials present in glovebox)
G - Industrial hazards - not resulting in severe worker injury
H - Radiological release from glovebox (due to internal events) excludes categories Ds and Fs
I - Release to vacuum system

J - Toxic chemical release inside facility
K - Severe worker injury - impacts by high velocity objects
L - Storage canister rupture
NPH - Natural Phenomena initiator: Seismic Event, Ash Fall, and High Wind
XTRN - Initiator external to the facility (facility wide loss of power, range fire, and aircraft crash)

Events that resulted in process upsets but posed no significant radiological or toxic chemical threat to the facility worker were assigned the NA Event Type designation. Events representing only industrial hazards were also assigned this designation. Events with the potential for only minor consequence to the facility worker were assigned the AB designation. Events with the potential for onsite consequence or severe worker impact were assigned the AC designation. Event Type NA was assigned to bins A1, A2, and G. Event Type AB was assigned to bins B and I. Event Type AC was assigned to bins C, D, E, F, H, J, K, L, NPH, and XTRN.

1.4 DISCUSSION OF HAZARDOUS EVENT BINNING RESULTS

The total number of events in each bin are as follows:

Bin	No. of Events	Bin	No. of Events	Bin	No. of Events
A1	19	E	32	J	9
A2	47	F	5	K	2
B	79	G	2	L	12
C	3	H	18	NPH	3
D	2	I	27	XTRN	3

1.4.1 Special Considerations for NPH and XTRN Events

There are three natural phenomena grouped under the bin NPH. These are Seismic Event, Ash Fall, and High Wind. These events are single entry items in the table. However, each of these phenomena can cause multiple consequences. Using a single entry in the table for each of these events reduces the size of the table but does not cause a loss of information. In the case of the High Wind and Ash Fall events, the PFP FSAR provides sufficient information to show that the effect of adding glovebox HC-230C-2 and the calciner system will not materially affect the consequences from these events. High Wind and Ash Fall effects are described in Chapter 3.0 of the PFP FSAR. Ash Fall represents a roof loading concern, abrasive concern for moving equipment, and an electrical concern because of the conductivity of the ash. High Wind represents a threat to the 234-5Z Building but not to an individual glovebox inside the building. Chapter 9.0 considers the effect of a wind-driven plank striking the 234-5Z Building and concludes that no significant consequences result. The seismic event is considered in detail in Chapter 9.0 of the PFP FSAR. The addition of glovebox HC-230C-2 should be evaluated to determine the effect of continuous dispersion mechanisms inherent in the calcining process as well as the additional radioactive and chemical material inventory present in the process on the overall release from the seismic event.

There are three phenomena grouped under the bin XTRN. These are Facility Wide Loss of Power, Range Fire, and Aircraft Crash. These events are also single entry items in the table and can cause multiple consequences. However, as indicated above, using a single entry in the table for each of these events reduces the size of the table but does not cause a loss of information. Facility wide loss of power, and Range Fire result in essentially the same effect, loss of power to 234-5Z (and, therefor, the VDC). Range fire causing a building fire is not considered because a wide area devoid of vegetation exists and is maintained around the facility (vegetation control specified in Chapter 3.0 of the FSAR). The addition of glovebox HC-230C-2 does not materially alter the consequence of facility loss of power because all aspects of the calcining process ceases on loss of power. The effects of loss of power on the HC-230C-2 glovebox caused by internal initiators is addressed specifically in the HAZOP. Chapter 9.0 of the PFP FSAR currently addresses Aircraft Crash and determined that the frequency of such an accident is less than 1E-6 per year when flight restrictions that prohibit helicopter operation in proximity to PFP are implemented. Therefore, no further consideration of the Aircraft Crash is required.

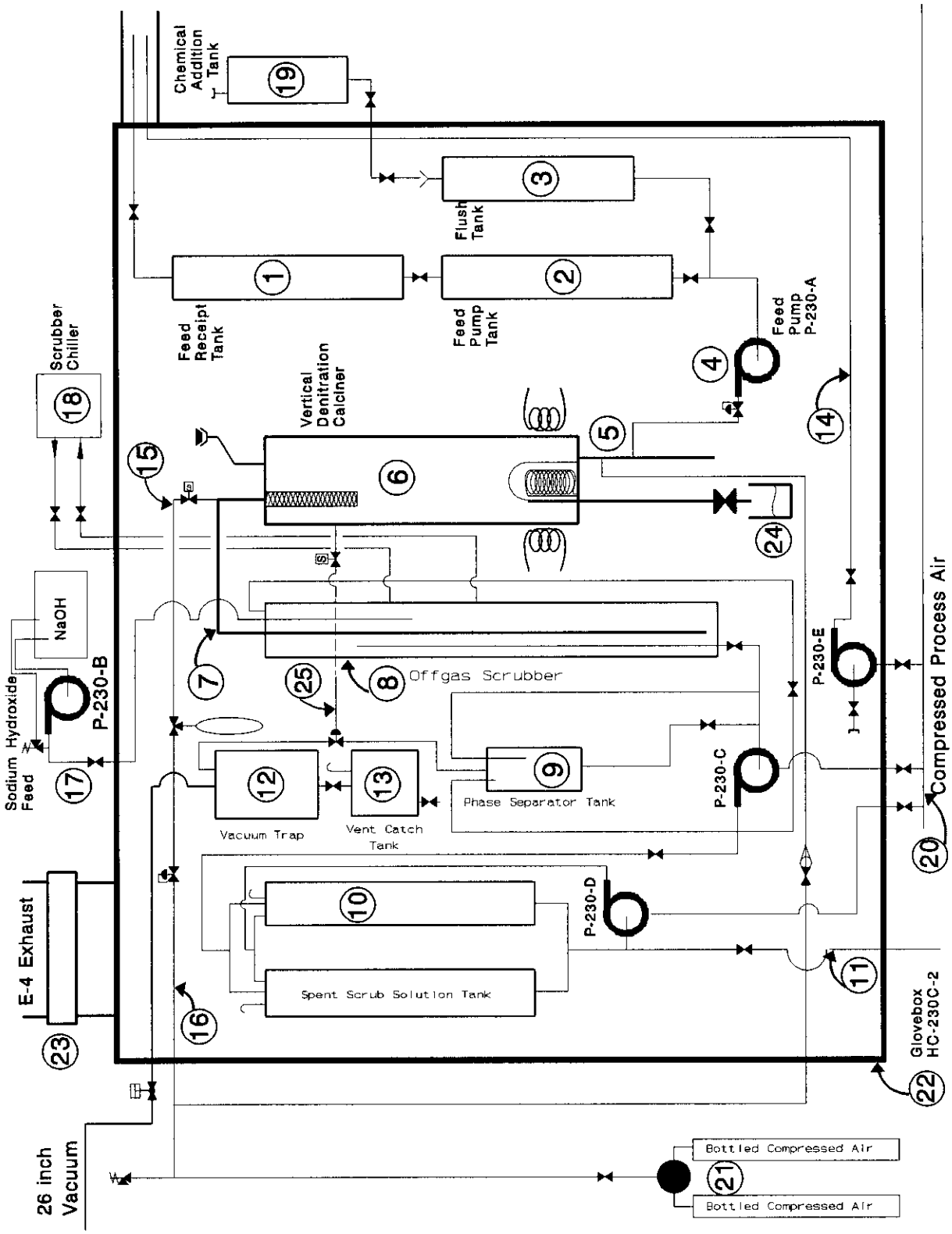
1.5 ENVIRONMENTAL PROTECTION

The facility features, such as a ventilation system with multiple stages of HEPA filtration that maintains a negative pressure relative to the atmosphere outside of the 234-5Z facility, protects the facility worker as well as serving to prevent and mitigate environmental releases of hazardous material. Under stagnant ventilation conditions the facility structure itself provides confinement of radioactive materials, limiting release to the environment. These features are listed in the HAZOP table (Table 9D-4) in the engineered and administrative safety features columns. These features are valid controls for environmental protection because in protecting the worker or public the environment is also protected. No release scenarios were identified where a release occurred that did not impact the worker but did impact the environment. In addition, there are generic programs of environmental monitoring which help discover unacceptable discharges.

1.6 REFERENCES USED DURING HAZOP

See last page of the HAZOP Table 9D-4.

Figure 9D-1. HAZOP Node Schematic



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Table 9D-1. HAZOP Guide Word/Deviation List

Process Variables[1]	Guide Words						
	No, Not, None	Less, Low, Short	More, High, Long	Part of	As well as, Also	Other than	Reverse
Flow	No flow	Low rate, Low total	High rate, high total	Missing ingredient	Misdirection, Impurities	Wrong material	Backflow
Pressure	No pressure	Low pressure	High Pressure				Vacuum
Temperature	Freezing	Low temperature	High temperature				Auto-refrigeration
Level	Empty	Low level	High level	Low interface	High interface		
Agitation	No mixing	Poor mixing	Excessive mixing	Mixing interruption	Foaming		Phase separation
Reaction	No reaction	Slow reaction	Runaway reaction	Partial reaction	Side reaction	Wrong reaction	Decomposition
Time procedure	Skipped or missing step	Too short, too little	Too long, too much	Action(s) skipped	Extra action(s), shortcuts	Wrong action	Out of order, Opposite
Speed	Stopped	Too slow	Too fast	Out of synch		Web or belt break	Backward
Special	Utility failure	External leak	External rupture	Tube leak	Tube rupture	Startup, shutdown, maintenance	

(1) Other variables include concentration, viscosity, pH, static, voltage, current, etc.

Table 9D-2. Energy Source Checklist (9 sheets)

(Extracted from "Job Safety Analysis", DOE 76-45/19, SSDC-19, 1979, U.S. Department of Energy, Washington D.C.)

Type of Hazard	Form of Hazard	Quantity
ELECTRICAL		
	Battery Banks	None
	Diesel Units	None
	High Lines	External to Facility
	Transformers	External to Facility
	Wiring	Present in large quantities
	Switchgear	Located in electrical room
	Underground Wiring	Outside evaluation scope
	Cable Runs	Present in Facility - quantity undefined
	Service Outlets and Fittings	Present in Facility - quantity undefined
	Pumps	None
	Motors	Present - quantity undefined
	Heaters	None
	Power Tools	Used during maintenance
	Small Equipment	Used during maintenance

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
NUCLEAR		
	Vaults	None for Calciner - Pu oxide stored in 2736-Z Vaults
	Temporary Storage Areas	None
	Receiving Areas	NA
	Shipping Areas	NA
	Casks	NA
	Burial Grounds	NA
	Storage Tanks	NA
	Canals and Basins	NA
	Reactor In-Tank Storage Areas	NA
	Dollies	Small carts used to transport Pu Oxide canisters and PR cans
	Trucks	Not permitted
	Hand Carry	Process allows hand carry of Pu oxide canisters inside glovebox
	Cranes	None
	Lifts	NA
	Shops	NA
	Hot Cells	The HC-230C-2 is a glovebox system
	Assembly Areas	Outside scope of Calciner
	Inspection Areas	Outside scope of Calciner
	Laboratories	NA
	Pilot Plants	NA
NUCLEAR (IN-REACTOR)		
	Reactors	NONE
	Critical Facilities	NONE
	Subcritical Facilities	NONE

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
KINETIC/LINEAR (IN PLANT)		
	Fork Lifts	Not allowed
	Carts	Used to transport Canisters of Pu Oxide and PR can assemblies
	Dollies	None
	Railroad	NA
	Surfaces	The HC-230C-2 glovebox is on ground level
	Obstructions (Collision With)	The facility has obstructions that can be collided with
	Shears	None
	Presses	None
	Crane Loads in Motion	None
	PV Blowdown	Pressurized air is used in the process in various locations
	Power Assisted Driving Tools	Used during maintenance
KINETIC/LINEAR (VEHICLE)		
	Cars	Outside the facility only
	Trucks	Outside the facility only
	Buses	Outside facility only

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
KINETIC/ROTATIONAL		
	Centrifuges	NA
	Motors	Undefined number of motors will be present
	Pumps	Pumps associated with this process are mostly located inside gloveboxes. The exception is the NaOH pump - pumps are either electrically or air driven
	Cooling Tower Fans	NA
	Cafeteria Equipment	NA
	Laundry Equipment	NA
	Gears	None
	Shop Equipment (Grinders, Saws, Brushes, etc.)	NA
	Floor Polishers	NA
PV-KD (PRESSURE, TENSION)		
	Boilers	NA
	Heated Surge Tanks	NA
	Autoclaves	NA
	Test Loops and Facilities	NA
	Gas Bottles	Pressurized gas bottles will be used to supply dry air to the calciner
	Pressure Vessels	The small accumulator for blowback air is a pressure vessel
	Coiled Springs	None
	Stressed Members	NA
	Gas Receivers	There are air receivers associated with the plant compressed air system

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
MGH (FALLS & DROPS)		
	Human Effort	Always present in some form
	Stairs	Stairs are present in the 227S glovebox area and may be present as portable units in room 230C
	Bucket and Ladder	None
	Trucks	None
	Elevators	NA
	Jacks	None
	Scaffolds and Ladders	None
	Crane Cabs	NA
	Pits	NA
	Excavations	NA
	Elevated Doors	None
	Canals	NA
	Vessels	NA
MGH (CRANES AND LIFTS)		
	Lifts	NA
	Cranes	NA
	Slings	NA
	Hoists	NA

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
FLAMMABLE MATERIALS		
	Packing Materials	NA
	Rags	May be present during cleanup activities inside and outside the HC-230C-2 glovebox
	Gasoline (Storage and in Vehicles)	NA
	Oil	Small quantities present to permit lubrication of moving parts
	Coolant Oil	NA
	Paint Solvent	NA
	Diesel Fuel	NA
	Buildings and Contents	The facility does contain combustible materials
	Trailers and Contents	NA
	Grease	Possibly present
	Hydrogen (Including Battery Banks)	Small quantities of hydrogen are generated in the process solution - adequate venting present
	Gases - Other	NA
	Spray Paint	NA
	Solvent Vats	NA
CORROSIVE		
	Acids	Nitric acid will be used for flushing and is present in a small tank outside the glovebox
	Caustics	Sodium hydroxide is used in the offgas scrubber - supplied from 55 gallon drum
	"Natural" Chemicals (Soil, Air, Water)	The glovebox is intended to exclude water
	Decon Solutions	Decon solutions could be used to clean up glovebox from time to time

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
RADIATION		
	Canals	NA
	Plug Storage	NA
	Storage Areas	NA
	Storage Buildings	NA
	Radioactive Sources	The Pu in the nitrate and oxide forms represents a source of ionizing radiation
	Waste and Scrap	The calcining process will generate waste
	Contamination	Pu oxide contamination will be present inside the HC-227S and HC-230C-2 gloveboxes
	Irradiated Experimental and Reactor Equipment	NA
	Electric Furnace	The calciner can be considered an electric furnace - operates at 1000 °C
	Blacklight (e.g., Magniflux)	NA
	Laser	None
	Medical X-Ray	NA
	Radiography Equipment and Sources	NA
	Welding	NA
	Electric Arc - Other (High Current Circuits)	NA
	Electron Beam	NA
	Equipment Noise	There is a possibility of noise from the equipment
	Ultrasonic Cleaners	NA
THERMAL RADIATION		
	Furnaces	The calciner can be considered an electric furnace - operates at 1000 °C
	Boilers	NA
	Steam Lines	NA
	Lab and Pilot Plant Equipment	NA
	Sun	NA

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
THERMAL (EXCEPT RADIANT)		
	Convection	The HC-230C-2 glovebox will experience convection heating
	Heavy Metal Weld Preheat	NA
	Exposed Steam Pipes	NA
	Electric Heaters	None outside the calciner
	Fire Boxes	NA
	Lead Melting Pot	NA
	Electrical Wiring and Equipment	There is electrical wiring and equipment but it does not represent a thermal source except during a fault
	Furnaces	The calciner can be considered an electric furnace - operates at 1000 °C
EXPLOSIVE PYROPHORIC		
	Caps	NA
	Primer Cord	NA
	Dynamite	NA
	Powder Metallurgy	None
	Dusts	Pu oxide dusts will be present in glovebox but are not combustible
	Hydrogen (Including Battery Banks and Water Decomposition)	There is a possibility that hydrogen may be generated in the Pu nitrate process liquid
	Gases - Other	NA
	Nitrates	Pu nitrate solution
	Electric Squibbs	NA
	Peroxides -Superoxides	None

Table 9D-2. Energy Source Checklist
(9 sheets)

Type of Hazard	Form of Hazard	Quantity
TOXIC/PATHOGENIC		
	Acetone	Only present if used for specialized cleaning
	Fluorides	NA
	Carbon Monoxide	NA
	Lead	NA
	Ammonia and Compounds	NA
	Asbestos	NA
	Trichloroethylene	NA
	Dusts and Particulates	NA
	Pesticides-Herbicides-Insecticides	NA
	Bacteria	NA
	Beryllium and Compounds	NA
	Chlorine and Compounds	NA
	Sandblast	NA
	Metal Plating	NA
	Asphyxiation-Drowning	NA

Table 9D-3. Summary of HAZOP results based on Event Bin Grouping
(5 sheets)

Bin ID[1]	Event Description	Event Type[2]	General Hazardous Event Considered	Cons Cat [3]
A1	Process upset - no worker impacts	NA	Failure to maintain Pu nitrate solution supply to calciner feed pump Misadjustment of calciner feed pump Scrubber chiller recirculation loop leaks Incorrect pressurized gas connected to calciner compressed air system Glovebox ventilation upsets - supply and exhaust Leaks in glovebox gloves or windows Failure of calciner compressed air or plant compressed air	S0
A2	Process upset - worker ALARA concern	NA	Inability to transfer Pu nitrate solution from HC-227S glovebox Failed valves or plugged Pu nitrate supply lines within glovebox HC-230C-2 Off gassing chemical reactions caused by accidental mixing of incompatible materials Use of low concentration nitric acid for calciner feed system flushes Plutonium polymerization/precipitation in glovebox tanks, without criticality Identified presence of separable organic phases in Pu nitrate calciner feed system Pu nitrate supply to calciner failures such as failed feed pump, loss of power, calciner nozzle plugging. Calciner failures such as calciner agitator motor failure, agitator shaft failure, loss of power, bearing failures, filter plugging, calciner powder drain plugging Scrubber failures such as failure to recirculate, solids accumulation, overflow of nitrate from calciner into scrubber, and other failures requiring downtime and operator exposure to correct	S1

Table 9D-3. Summary of HAZOP results based on Event Bin Grouping
(5 sheets)

Bin ID[1]	Event Description	Event Type[2]	General Hazardous Event Considered	Cons Cat [3]
B	Release inside glovebox	AB	Pu nitrate transfer line failures that remain inside encasement and drain to glovebox Mistransfers to gloveboxes other than HC-230C-2 Ruptures of feed receipt tank, feed pump tank Overflows of feed receipt tank, feed pump tank caused by overfill, double batching of flush solution, or backup from overflows into vent system Creation of vapors and aerosols from solution heating from addition of concentrated nitric acid or incompatible chemicals Accidental draining of Pu nitrate solution to glovebox floor Spray leaks of Pu nitrate solution due to piping and connection failures in calciner feed pump system Conditions and events that result in calciner overpressurization and release of nitric acid vapors, water vapor, NOx, and Pu oxide powder from pressure relief device such as excessive injection rate, plugged filters, vacuum failure, excess atomizing air flow or pressure, and similar causes Failure of calciner seals, welds, gaskets, collection bottle which result in release of Pu oxide to glovebox Ruptures of scrubber, phase separator, and spent solution tanks Spills of Pu oxide during removal of collection jar, filling of slip lid cans, or movement of cans on to conveyer	S1
C	Release from transfer line	AC	Failure of supply from HC-227S glovebox due to transfer line and encasement failure	S1*
D	Deflagration in glovebox	AC	Organics present in Pu nitrate injected into 1000C Pu oxide bed Explosion from injection of feed containing organics due to sampling or pretreatment errors Phase separation: presence of separable organics in feed stock due to failure in upstream sampling or pretreatment operations Butane explosion in calciner causes release of hot gases, steam, and very hot PU oxide to glovebox atmosphere	S1*

Table 9D-3. Summary of HAZOP results based on Event Bin Grouping (5 sheets)

Bin ID[1]	Event Description	Event Type[2]	General Hazardous Event Considered	Cons Cat [3]
E	Criticality	AC	Buildup of Pu oxide from spills and operating upsets Spills of Pu nitrate solution Buildup of Pu solids in tanks in glovebox HC-230C-2 due to precipitation reactions Overfilling calciner with Pu oxide or Pu nitrate solution Overflows of process solution into vacuum system Sampling and recirculation failures associated with the scrubber spent solution tanks Precipitation of Pu solids in HC-227S glovebox due to transfer of NaOH into tanks containing Pu nitrate Accumulation of too many containers of Pu oxide in the HC-230C-2 glovebox Floods in room 230 due to fire suppression system actuation	S1*
F	Fire in glovebox	AC	Incipient pump failure (high friction in piston area) Electric motor burnout due to deadhead conditions Electric motor spurious failure from wiring fault Low or no air flow results in hot injector pipe with flammable materials near pipe Control failure of heater power supply (full on) caused by controller failure, thermocouple failure,. software setpoint in error, human error Fire in room 230 due to ignition of combustibles in the room Loss of confinement due to overheating	S1*
G	Industrial hazards	NA	Inadequate time allowed for cooling prior to transferring Pu oxide to convenience can Failure to use high temperature gloves while removing product collection jar from calciner drop pipe	S1

Table 9D-3. Summary of HAZOP results based on Event Bin Grouping
(5 sheets)

Bin ID[1]	Event Description	Event Type[2]	General Hazardous Event Considered	Cons Cat [3]
H	Radiological release from glovebox	AC	Failures of compressed air supply regulators at high pressure air bottles coupled with system relief valve failure - results in possible line, accumulator, and calciner filter failures with resulting pressurized glovebox Releases from chemical supply tank due to open valves with venting from glovebox tank vent system Plant compressed air leaks or calciner compressed air leaks (catastrophic line failures and possibly air regulator failures) resulting in pressurized glovebox Flood in room 230 due to activation of room fire suppression system Glovebox ventilation system imbalances - both supply and exhaust failures causes pressurization of glovebox	S1*
I	Release to vacuum system	AB	Scrubber phase separator level control failures result in scrubber liquid being pulled into vacuum catch tank (scrubber solution may be contaminated with Pu oxide powder or solids) resulting in contamination of vacuum catch tank and vacuum system. Worker ALARA concern. Voiding of scrubber due to chiller failures allows nitric acid vapors and NOx to be drawn into vacuum system pH control failures permits nitric acid vapors and NOx to be released to vacuum system Failure of NaOh feed supply pump to supply NaOH (various mechanical or electrical failures) as continued operation of calciner neutralizes scrubber solution allows release of NOx to vacuum system and possible release out facility stack	S1
J	Toxic chemical release inside facility	AC	Breach of NaOH line outside glovebox results in potential spray leak and spill to room floor Failure of chiller refrigeration system allows release of refrigerant to room 230 atmosphere Chemical addition tank nitric acid leak to floor of room 230 Backflow from chemical flush tank to chemical addition tank permits release of Pu nitrate solution to room 230 (nitric acid and NOx concern for this category). Note: a funnel break has been added to preclude this mechanism.	S1*
K	Severe worker injury - Impacts by high velocity objects	AC	Failure of air bottles or supply valves due to mechanical impact or other manufacturing flaws Possible damage to confinement barriers because of mechanical impact with potential for radioactive material releases	S1*
L	Storage canister rupture	AC	Various process upsets and failures that result in inadequately stabilized Pu oxide result in material being canned and eventually experiencing can rupture in storage due to pressure buildup	S1*

Table 9D-3. Summary of HAZOP results based on Event Bin Grouping (5 sheets)

Bin ID[1]	Event Description	Event Type[2]	General Hazardous Event Considered	Cons Cat [3]
NPH	Natural phenomena	AC	Seismic event	S2
		AC	Ash fall	NA
		AC	High wind	S2
XTRN	External hazard	AC	Facility wide loss of power	S1
		AC	Range fire	S1
		AC	Aircraft crash	NA

1. Hazards binning ID key:

A1 - Process Upset - no worker impacts
A2 - Process upset - worker ALARA concern
B - Release inside glovebox
C - Release from transfer line
D - Deflagration in glovebox (ignition of flammable gas in calciner)
E - Criticality
F - Fire in glovebox (ignition of combustible materials present in glovebox)
G - Industrial hazards - not resulting in severe worker injury
H - Radiological release from glovebox (due to internal events) excludes categories D's and F's
I - Release to vacuum system
J - Toxic chemical release inside facility
K - Severe worker injury - impacts by high velocity objects
L - Storage canister rupture
NPH - Natural Phenomena initiator: Seismic event, Ash Fall, and High Wind
XTRN - Initiator external to the facility (facility wide loss of power, range fire, and aircraft crash)

2. Event Type key:

AC Event is to be treated as an ACCIDENT in the PFP FSAR
AB Event is to be treated as an ABNORMAL EVENT in the PFP FSAR
NA Event is not either an ACCIDENT or ABNORMAL EVENT

3. Consequence category is based on "no controls".
S0 - No significant consequence
S1 - Consequence to worker but does not result in acute fatality or serious injury
S1*- Event results in acute fatality or serious injury
S2 - Event results in onsite worker consequence

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Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A1	1.00	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Tank drained into feed pump tank without resupply (human error)	NA	Programmatic upset Delay in processing Pu nitrate solutions	None	Operator training and procedures	S0	F3	
B	1.01	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of supply from HC-227S glovebox due to transfer linE	10-40 L Pu nitrate at 450 g/L depending on whether RT or BT transfer is being made	Leak into encasement draining to either glovebox HC-230C-2 or 227-S resulting in : Splatter release to glovebox atmosphere Contamination of glovebox equipment and transfer line encasement	Transfer line encasement prevents release to zone 3 ventilation area Glovebox sump leak detectors and alarms Glovebox HC-230C-2 and HC-227S sump level alarms E-4 ventilation system maintains confinement E-4 ventilation system and HEPA filters mitigates release to atmosphere	Transfer procedures Operator visual surveillance of the feed receipt tank level (tank made out of glass) Operator alarm response procedures	S1	F3	S1/F3 for leak draining into glovebox
C	1.02.a	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of supply from HC-227S glovebox due to transfer line and encasement failure	10-40 L Pu nitrate solution at 450 g/L depending on whether RT or BT being used	Leak from encasement to duct level	E-3 ventilation system and HEPA filters mitigate release to atmosphere	Transfer procedures Operator visual surveillance of the feed receipt tank level (tank made out of glass) Operator alarm response procedures	S1*	F2	S1* /F2 for Pu nitrate release to duct level
E	1.02.b	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of supply from HC-227S glovebox due to transfer line or failure of vessel	NA	Potential criticality - from spill of solution to glovebox floor or by saturating calciner thermal insulation blanket	Glovebox sump leak detectors and alarms Glovebox criticality drains prevent accumulation of critical mass inside glovebox Glovebox HC-230C-2 and HC-227S sump level alarms	Transfer procedures Operator visual surveillance of the feed receipt tank level (tank made out of glass) Operator alarm response procedures	S1*	F1	S1*/F1 based on likelihood of criticality (criticality extremely unlikely given configuration of glovebox criticality drain - see CSER)

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	1.03.a	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of supply from HC-227S glovebox due to human error (misvalving, etc.)	10 L Pu nitrate at 450 g/L	Programmatic upset - dump to glovebox floor	Sump leak detector and alarm in glovebox HC-7 (for misroutes to HC-7) Glovebox criticality drains (for line leaks inside HC-227S, HC-230C-2, or misroutes into HC-7) Inlet and outlet HEPA filters on gloveboxes E-4 ventilation system and HEPA filters (maintains glovebox confinement and filters releases to the environment) E-3 ventilation and HEPA filters (if leak outside gloveboxes)	Operator surveillance of the feed receipt tank level	S1	F3	S1/F3 ranking assigned for release inside glovebox HC-227S, HC-7, or HC-230C-2
B	1.03.b	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of supply from HC-227S glovebox due to human error (misvalving, etc.)	10-40 L Pu nitrate at 450 g/L depending on whether RT or BT transfer is being made	Release of Pu nitrate from unanticipated location (not in room 227 or room 230), possibly glovebox HC-7 Deadhead transfer pump 227-P-B (in HC-227S) if no outlet valves are open; potential line failure due to overpressure Spray or splatter release inside glovebox	Sump leak detector and alarm in glovebox HC-7 (for misroutes to HC-7) Glovebox criticality drains (for line leaks inside HC-227S, HC-230C-2, or misroutes into HC-7) Inlet and outlet HEPA filters on gloveboxes E-4 ventilation system and HEPA filters (maintains glovebox confinement and filters releases to the environment)	Operator surveillance of the feed receipt tank level	S1	F3	
C	1.03.c	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of supply from HC-227S glovebox due to human error (misvalving, etc.)	10-40 L Pu nitrate solution at 450 g/L depending on whether RT or BT being used	Liquid leak into zone 3 areas if from unencased line or from line with failed encasement	E-3 ventilation and HEPA filters (if leak outside gloveboxes) Potential leak or mistransfer volume limited by batch transfer volume Transfer line encasement mitigates potential spray leak from primary line	Operator surveillance of the feed receipt tank level	S1*	F2	S1*/F2 for potential leak into zone 3
B	1.04	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Feed receipt tank rupture (spurious tank failures, failure at glass weld, seal failures, etc)	10 L Pu nitrate solution at 450 g/L	Splatter release of aerosols to glovebox atmosphere Contamination of glovebox equipment	Tank high level shutoff interlock Glovebox sump level alarm Glovebox criticality drain Glovebox structure, E-4 ventilation system and filters maintain confinement in event of spill	Operator surveillance of level in glass tank	S1	F3	S1 ranking for contamination of glovebox equipment and increased worker exposures criticality requires several tank failures and plugged criticality drain (criticality assumed to be extremely unlikely)

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	1.05	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Failure of transfer pump 227-P-B in HC-227S (due to loss of power or various equipment failures)	NA	Loss of Pu oxide production Programmatic upset	None	Operator surveillance of feed receipt tank level	S1	F3	S1 for operator exposure replacing pump
B	1.06	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Transfer line plugging with spray leak of liquid in glovebox	10-40 L Pu nitrate at 450 g/L depending on whether RT or BT transfer is being made	Deadhead transfer pump 227-P-B Programmatic upset Potential transfer line failure due to overpressure	Encasement pipe contains leak and directs leak to glovebox HC-230C-2 or HC-227S should primary transfer line leak due to overpressure Glovebox sump alarms (should leak occur) Glovebox inlet and outlet filters B-4 ventilation system and filters	Operator surveillance of feed receipt tank level	S1	F3	The potential for overpressurizing transfer line should be further assessed. failure of line conservatively assumed here.
B	1.07	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/low	Drain to Feed Pump Tank left open while filling the Feed Receipt Tank	10-40 L Pu nitrate at 450 g/L depending on whether RT or BT transfer is being made	Overflow of solution from Feed Pump Tank into Flush Tank via vent line Potential overflow into Vent Catch Tank and spill of solution to glovebox floor if multiple transfers from HC-227S are made or if transfer from HC-227S originates from batch tank instead of receipt tank Splatter aerosol release to glovebox atmosphere (if VCT overflows) and contamination of glovebox equipment	High level interlock in feed pump tank shuts DOV in supply line between feed receipt tank and the feed receipt tank Indicating light for high level in tank Inlet and outlet HEPA filters on glovebox B-4 ventilation system and HEPA filters Glovebox criticality drains Glovebox sump level alarm	Operator surveillance of feed pump tank (and other tanks that are glass)	S1	F2	
A2	1.08.a	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/ high	Operator fails to shut down transfer before tank reaches high level	10-40 L Pu nitrate at 450 g/L depending on whether RT or BT transfer is being made	Overflow into flush tank via vent Overflow to glovebox floor if transfer volume greater than capacity of flush tank, feed pump tank, and vent catch tank Transfer volume limited normally to RT volume (approx 12L)	Capacity of flush tank, feed pump tank and vent catch tank minimize potential for spill High level interlock in Feed Receipt Tank shuts diaphragm operated valve (DOV) on supply line on high level Indicating light for high level	Operator surveillance of feed receipt tank level	S1	F3	S1/F3 for operator exposure during glovebox cleanup
B	1.08.b	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/high	Feed receipt tank not emptied prior to transfer from HC-227S	10-40 L Pu nitrate at 450 g/L depending on whether RT or BT transfer is being made	Overflow into flush tank via vent Overflow to glovebox floor if transfer volume greater than capacity of flush tank, feed pump tank, and vent catch tank Transfer volume limited normally to RT volume (approx 12L)	Capacity of flush tank, feed pump tank and vent catch tank minimize potential for spill High level interlock in Feed Receipt Tank shuts diaphragm operated valve (DOV) on supply line on high level Indicating light for high level	Operator surveillance of feed receipt tank level	S1	F2	S1/F2 for overflow of vent catch tank to glovebox floor

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	1.09	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/other than	Phase separation: presence of separable organics in feed stock due to failure in upstream sampling or pretreatment operations	NA	Operations shut down, if organic noticed Programmatic upset	None	Operator surveillance of feed receipt tank level	S1	F2	S1 for increased operator exposures to take care of solids layer
D-XREF	1.10	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/other than	Phase separation: presence of separable organics in feed stock due to failure in upstream sampling or pretreatment operations	———	Possible deflagration/explosion due to injection of organics into calciner - see injector nozzle feed composition/other than (Node 5.34)					
A2	1.11.a	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/other than	Phase separation: plutonium polymerization/precipitation due to tank pH greater than 2 (nitric acid solution too dilute)	NA	Programmatic upset		Procedures governing mixing of materials in HC-227S Operator surveillance of feed receipt tank solids level Blending and sampling in the HC-227S glovebox	S1	F3	S1/F3 for programmatic upset requiring operator exposure to correct Incorrect pH could be caused by using nitric acid solution that's too dilute or flushing transfer line or tanks with water
E	1.11.b	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Level/other than	Phase separation: plutonium polymerization/precipitation due to tank pH greater than 2 (nitric acid solution too dilute)	NA	Potential criticality spec violation due to accumulation of solids in the tank Potential criticality if layer allowed to build up too deep	CAS (criticality alarm system)	Criticality prevention specifications Procedures governing mixing of materials in HC-227S Operator surveillance of feed receipt tank solids level Blending and sampling in the HC-227S glovebox	S1*	F1	S1*/F1 for criticality
A2	1.12	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Pressure/high	Off gassing chemical reaction that exceeds vent capacity (caused by accidental mixing of incompatible materials)	10 Pu nitrate at 450 g/L	Potential for rupture of tank and spill to glovebox floor NOx release to glovebox atmosphere	Glovebox outlet filters and B-4 ventilation system Glovebox sump level alarm	Solution makeup, sampling, and transfer setup procedures for the HC-227S glovebox Operator surveillance of feed receipt tank	S1	F3	
B	1.13	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Pressure/high	Feed receipt tank filled with blocked vent line (e.g., V-71 closed during filling)	20 L Pu nitrate solution at 450 g/L	Potential rupture of feed receipt tank, feed pump tank and flush tank Spill of Pu nitrate solution to glovebox floor Release of aerosols to glovebox atmosphere	Glovebox structure B-4 ventilation system and filters confine release to glovebox Glovebox sump level alarm Criticality drain	Operator training and procedures Operator monitoring of tank liquid level (tank is glass)	S1	F1	
NA	1.14	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Pressure/low	Not applicable	NA						

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	1.15	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Temperature/high	Heat of reaction due to addition of concentrated nitric acid to water from prior flush or water added to concentrated nitric acid during a flush	10 L Pu nitrate solution at 240 g/L	Potential boiling with steam generation and release of aerosols to vent system and glovebox atmosphere	Tanks made of pyrex glass which is resistant to temperature shock Glovebox and E-4 ventilation system maintain secondary confinement Vent prevents overpressurization	Procedures for the makeup and use of flush solutions Blending and sampling procedures in 227S	S1	F3	
B	1.16	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Temperature/high	Heat from organic-nitrate reaction (requires organic containing solution to be mixed with highly acidic HNO3 solution to be present with addition of concentrated nitric acid from next evolution)	NOx in 10 L Pu nitrate solution Pu in 10 L Pu nitrate solution	Production of NOx Possible increase in particulate releases from vent system Possible production of small quantities of flammable gasses	None	Operator surveillance of feed receipt tank to identify organic liquids Training and procedures	S1	F3	Not expected to result in large temperature increase or flammable gas concentration in glovebox Temperatures above 135°C are required for autocatalytic reaction
E	1.17	Feed Receipt Tank	Lag storage to support continuous calciner operation Safely contain Pu nitrate solution	Pu concentration/high	Sampling error Makeup error at source of Pu nitrate	NA	Potential criticality specification violation Programmatic upset	Criticality alarm system (CAS) Criticality drains for spills 6 inch tank geometrically unfavorable to criticality	Criticality prevention specifications Blending and sampling procedures in HC-227S	S1*	F1	Criticality highly unlikely given tank geometry
XREF	2.00	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/low	Tank not resupplied from feed receipt tank when required (miscellaneous causes related to feed receipt tank)	———	See nodes for feed receipt tank for Level/low (Nodes 1.03-1.06)					
B-XREF	2.01	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/low	Tank leak or rupture	———	See node for feed receipt tank for Level/low (Node 1.04)					
A2	2.02	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/low	Blocked line or inability to open valve between feed receipt tank and feed pump tank	NA	Potential pump damage Programmatic upset ALARA concern	None	None	S1	F3	Do positive displacement pumps cavitate on loss of supply
A2	2.03	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/low	Human error by not refilling tank when required	NA	Programmatic upset	None	None	S1	F3	

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	2.04	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/high	Human error by overfilling from feed receipt tank (transfer at wrong time while tank has material present - 10 L tank supplying into partially full 10L tank)	20 L Pu nitrate solution at 450 g/L	Vent overflows to flush tank; flush tank overflows to vent catch tank, vent catch tank overflows onto glovebox floor if transfer volume sufficient	Glass tank permits visual surveillance of level Capacity of the flush and vent catch tanks minimizes the potential for spill to glovebox floor Glovebox and B-4 ventilation system maintain secondary confinement WF transducer interlocked to shut off supply valve to feed pump tank on tank high level Glovebox sump level alarm	Operator surveillance of feed pump tank level Procedures for filling and draining feed receipt tank and feed pump tank	S1	F3	S1 based on splatter release to glovebox atmosphere
XREF	2.05	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/other than	Phase separation--presence of separable organic layer	———	See phase separation for feed receipt tank (Nodes 1.09-1.11)					
B-XREF	2.06	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/other than	Phase separation--plutonium polymerization/precipitation due to incorrect pH range.	———	See phase separation for feed receipt tank (Node 1 11.b)					
XREF	2.07	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Pressure/high	See feed receipt tank Pressure/high (Nodes 1.12-1.13)	———						
B-XREF	2.08	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Temperature/high	See feed receipt tank Temperature/ high (Nodes 1.15-1.16)	———						
B-XREF	2.09	Feed Pump Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Pu concentration/high	See feed receipt tank Pu concentration/high (Node 1.17)	———						

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	3.00	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/low when initiating or performing flush	Failure to refill after previous flush cycle (closed valve, human error, blocked line)	NA	Programmatic upset ALARA concern if unable to flush when desired to prevent/mitigate calciner injector plugging	Glass tank allows visual surveillance of level	Operator surveillance of flush tank	S1	F3	
B	3.01	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/low when initiating or performing flush	Tank rupture	4 L Nitric acid	Nitric acid spill to floor of glovebox	Flush tank capacity is 4 Liters limiting spill size Glovebox sump size and criticality drain configuration ensure small leaks are contained in glovebox Glovebox sump level alarm	Operator surveillance of flush tank	S1	F3	
B	3.02	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/low when initiating or performing flush	Quick disconnect valve inadvertently opened	4 L Nitric acid	Nitric acid spill to floor of glovebox	Flush tank capacity is 4 Liters limiting spill size Glovebox sump size and criticality drain configuration ensure small leaks are contained in glovebox Glovebox sump level alarm	Operating procedures and training Potential visual detection of leak	S1	F3	
NA	3.03	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/low during pumping of nitrate solution	Not a fault if flush tank refill not intended and pump supply valve closed	NA				NA	NA	
B	3.04	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/high	Double batching from chemical addition tank (operator error)	6-16 L Nitric acid	Overflow to vent catch tank Potential spill to glovebox	Vent system and vent catch tank capacity limit potential for spill to glovebox floor Glovebox and E-4 ventilation system maintain secondary confinement Glovebox sump level alarm	Operator training and procedures Operator surveillance during transfer	S1	F3	

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	3.05	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/high	Valves (v2 & v4) left open allowing liquid to backup up from feed pump tank into flush tank	1 L Nitric acid	Overflow to vent catch tank and potential spill to glovebox	Vent system and vent catch tank capacity limit potential for spill to glovebox floor Glovebox and E-4 ventilation system maintain secondary confinement Glovebox sump level alarm	Operator training and procedures	S1	F1	
B	3.06	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/high		Small quantity nitric acid	Potential minor heatup due to heat of neutralization if large pH difference exists between flush tank and feed pump tank with vapor release to vent system and glovebox atmosphere	E-4 ventilation system for worker	Operator training and procedures	S1	F2	
B	3.07	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Level/high	Overflow of feed pump tank or the feed receipt tank into flush tank via feed pump tank vent	21 L Pu nitrate solution at 450 g/l if BT involved	Overflow to vent catch tank and potential spill to glovebox	Vent system and vent catch tank capacity limit potential for spill to glovebox floor Weight factor and interlock minimize potential for overflow of feed pump tank Glovebox sump level alarm	Operator training and procedures	S1	F2	
B	3.08	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Composition/other than	Chemicals other than nitric acid (2M) inadvertently added to chemical addition tank	Small quantity of vapors released to vent system	Heating and pressurization in the flush tank resulting in possible release of vapors into the tank vent system	None	Operator training and procedures	S1	F3	Potential for adverse chemical reactions - should be further assessed
A2	3.09.a	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	pH/high (above pH of 2)	Human error - filling tank with dilute nitric acid or water	NA	Programmatic impact	None	Operator training and procedures	S1	F3	

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
E	3.09.b	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	pH/high (above pH of 2)	Human error - filling tank with dilute nitric acid or water	NA	Potential polymerization of Pu in transfer lines or vessels with possible criticality concerns or line plugging	None	Operator training and procedures	S1*	F2	S1* /F2 for criticality
B	3.10.a	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Pressure/high	Blocked vent line to vent catch tank or V-71 valve closed with addition of reactive chemical from chemical addition tank to heel in flush tank Assumes valve V-5 closed after filling tank	20 L Pu nitrate solution at 450 g/l	Rupture of flush tank, feed pump tank and feed receipt tank with spill of Pu nitrate to glovebox floor and release of aerosols to glovebox atmosphere	Glovebox sump level alarm E-4 ventilation and filters Funnel break in line between chemical addition tank and flush tank	Operator training and procedures for makeup of flush solutions	S1	F3	S1/F3 for solids precipitation in equipment Verification of vent valve V-71 status necessary to prevent pressurization in feed receipt tank, feed pump tank and flush tank Funnel break was added that prevents accident even if V-71 is closed
E	3.10.b	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Pressure/high	Blocked vent line to vent catch tank or V-71 valve closed with addition of reactive chemical from chemical addition tank to heel in flush tank Assumes valve V-5 closed after filling tank	NA	Criticality specification violation	Glovebox criticality drain Criticality alarm system (CAS)	Operator training and procedures for makeup of flush solutions	S1*	F2	S1* for criticality
NA	3.11	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Temperature/low	Not a concern since freezing is not credible in this room	NA				NA	NA	
B	3.12	Flush Tank	Provide lag storage for nitric acid flush solution Provides flush solution for flushing calciner feed system Provide net positive suction head for feed pump (P-230-A) during flushing	Temperature/high	Incompatible chemical reaction caused by human error (addition of wrong chemical)	Small quantity of nitric acid	Boil solution, create vapors, and NOx	Open flush tank vent line prevents overpressurization and tank rupture E-4 ventilation system and filters ensures confinement and filtration of particulates E-4 ventilation system prevents release of NOx gasses to room	Operator training and procedures for makeup of flush solutions	S1	F3	This item links to incompatible chemical events

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	4.00	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Flow/no	Supply valve from feed pump tank (V-2) closed Feed pump tank empty Failed pump Loss of power Closed pump discharge valve (V-3) Pump shutdown from various interlocks	NA	Programmatic upset Pump/line damage Pu oxide powder packed down injector tube by calciner agitator Overheating of nozzle Potential boiling of Pu nitrate solution in material injection nozzle (corrodes and plugs nozzle)	None	Operator may notice feed pump tank level not decreasing (WF reading or visual) or product collection jar level not increasing	S1	F3	S1 ranking due to increased worker exposure to unclog nozzle, repair or replace equipment.
A2	4.01	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Flow/low	Improperly set pump stroke Partial nozzle plugging Pump wear	NA	Low oxide output from calciner Programmatic effect Boiling of solution in nozzle leading to increased nozzle corrosion, potential nozzle failure, leak from nozzle and reduced vacuum in calciner vessel	None	Operator may notice feed pump tank level not decreasing (WF reading or visual) or product collection jar level not increasing	S1	F3	Unnecessary worker exposure if nozzle needs to be replaced prematurely
L	4.02	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Flow/high	Improperly set pump stroke	4.5 kg/can Pu oxide powder	Inadequate atomization of Pu nitrate solution fed to calciner Inadequately stabilized Pu oxide powder due to low residence time in calciner; potential Overpressurization of site convenience cans during handling or in storage	E-3 vent system and filters if convenience can ruptures in Zone 3 area 2736Z vent system and filters if can rupture occurs in vaults	TGA testing of Pu oxide powder before packaging in site convenience can	S1*	F3	S1*/F3 for rupture I occupied zone 3 area
B	4.03	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Flow/high	Improperly set pump stroke	4 L/hr or Pu nitrate solution released to glovebox	Build up of liquid on calciner baseplate, boiling of Pu nitrate solution on baseplate, corrosion and failure of calciner baseplate Programmatic impact Potential spill of solution to glovebox floor Potential spray leak at failure point; elevated aerosol release to E-4 vent system	Glovebox outlet filter E-4 vent system maintains glovebox confinement E-4 filters mitigate potential release to atmosphere Vacuum system limits vapor release to glovebox	None	S1	F3	
B	4.04	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Flow/high	Improperly set pump stroke	Pu oxide contained in calciner	Offgas rates (pulses) in excess of vacuum line capacity; venting of Pu oxide through pressure relief valve to glovebox atmosphere	E-4 vent system and filters and glovebox structure maintain confinement vacuum system	None	S1	F3	
A1	4.05	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Flow/as well as	Pu nitrate mixed with flush solution due to valve V-4 left open (human error)	NA	No significant consequences		Operator training and procedures	S0	F3	

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
F	4.06	Feed Pump P-230-A	Supply Pu nitrate to calciner injector nozzle at required flow and pressure	Temperature/high	Incipient pump failure (high friction in piston area) Electric motor burnout due to deadhead conditions Electric motor spurious failure from wiring fault	Total inventory of Pu in glovebox	Pump failure Programmatic impact Possible fire in glovebox from overheated electric motor Potential loss of glovebox confinement and spread of contamination to room 230	Glovebox high temperature annunciator and pump shutdown (fire condition) Glovebox dry fire suppression system E-3 ventilation system and HEPA filters limit release to atmosphere through exhaust stack	Operator training and procedures for responding to fire in glovebox	S1*	F3	Postulated fire is small due to glovebox design and limited combustible loading; glovebox is metal with fire resistant windows
B	5.00	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Nozzle plugging caused by scale buildup, cake formation, etc. Deadheaded feed pump Potential injector and line heatup with pressurization of transfer line	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Programmatic impact--reduced production Potential injector and line heatup with pressurization of transfer line and liquid slug releases into calciner causing calciner pressurization and Pu oxide releases through pressure relief cap	Nozzle equipped with cleanout rod	Operator monitoring of feed tank level	S1	F3	S1 for operator exposure during equipment repair, replacement
B	5.01	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Line leak/break between pump and injector	4 L/hr Pu nitrate injection rate	Release to glovebox floor; potential spray release Splatter or spray release of aerosols to glovebox atmosphere Elevated radioactive release through E-4 ventilation system	Glovebox outlet HEPA filter mitigates potential release to the environment E-4 ventilation system and HEPA filters mitigate potential release to environment Sump alarm	Visual detection	S1	F3	
B	5.02	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Pump discharge valve not open during pumping (human error)	4 L/hr Pu nitrate injection rate	Programmatic impact; potential transfer line rupture due to high pressure Release of aerosols to glovebox atmosphere through failed line of pump or valve seals	Glovebox outlet HEPA filter mitigates potential release to the environment E-4 ventilation system and HEPA filters mitigate potential release to environment Sump alarm	None	S1	F3	
A2	5.03	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Feed line plugging caused by solids accumulation (e.g., Pu precipitates or polymers if pH too high)	NA	Programmatic impact; increased campaign duration	None	Visual monitoring of feed pump tank level	S1	F3	S1 for ALARA concerns during recovery
A2	5.04	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Pump failure due to equipment failure or electrical supply failure	NA	Programmatic impact; increased campaign duration	None	Visual monitoring of feed pump tank level	S1	F3	S1 for ALARA concerns during recovery
A1	5.05	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Pump stroke set low	NA	Programmatic impact	None	Visual monitoring of feed pump tank level Operator training and procedures	S0	F3	
A1	5.06	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Feed pump tank empty during pumping	NA	Programmatic impact	Level indication (WFT-230-1)	Visual monitoring of feed pump tank level Operator training and procedures	S0	F3	

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A1	5.07	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Feed pump supply valve shut due to human error	NA	Programmatic impact	None	Visual monitoring of feed pump tank level Operator training and procedures	S0	F3	
A2	5.08	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump (P-230-A) stroke set too high	NA	Cake formation in calciner vessel causing potential nozzle plugging or seizure of agitator Programmatic impact; increased mission time Increased operator exposures to unplug calciner or to replace equipment	None	Operator surveillance of feed pump tank level Collection jar observed to not be filling Operator training and procedures	S1	F3	
L	5.09	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump (P-230-A) stroke set too high	4.5 kg/can Pu oxide powder	Inadequate Pu oxide residence time in calciner leading to potential convenience can ruptures in storage vault (due to overpressurization from hydrogen production)	None	Pu oxide tested by TGA prior to canning Operator training and procedures	S1*	F3	
E	5.10.a	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump (P-230-A) stroke set too high	NA	Formation of large Pu oxide particles leading to plugging of product discharge tube, possible Pu mass violation in calciner vessel due to product buildup, inadequately stabilized Pu oxide	CAS (Criticality Alarm System)	Mass balances performed to monitor calciner vessel bed mass TGA testing prior to canning in glovebox HC-21A	S1*	F1	S1*, F1 for criticality (criticality extremely unlikely given configuration of calciner - see CSER)
L	5.10.b	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump (P-230-A) stroke set too high	4.5 kg/can Pu oxide powder	Formation of large Pu oxide particles leading to plugging of product discharge tube, possible Pu mass violation in calciner vessel due to product buildup, inadequately stabilized Pu oxide	B-3 ventilation system and HEPA filters mitigate Pu oxide release through ruptured cans to Zone 3 areas	TGA testing prior to canning in glovebox HC-21A	S1*	F3	S1, F3 for production of inadequately stabilized Pu oxide leading to can rupture in Zone 3 area
B	5.11	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump (P-230-A) stroke set too high	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Pressurization of calciner vessel due to vapor releases in excess of vacuum capacity Pu oxide powder release to glovebox atmosphere through pressure relief cap release of nitric acid vapor and NOx to glovebox atmosphere	Calciner vessel pressure transmitter and computer display Glovebox and B-4 ventilation system confine powder release Glovebox outlet and B-4 filters mitigate potential release to the environment Relief cap designed to maintain confinement up to 1.3 psi	Operator monitoring of calciner vessel vacuum	S1	F3	
A2	5.12	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump (P-230-A) stroke set too high	NA	Liquid pooling at baseplate causing premature failure of vessel due to accelerated corrosion resulting in programmatic impact	None	Operator monitoring of feed tank level and product receiver level	S1	F3	S1 based on ALARA for operator exposure for calciner repair

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	5.13	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Nozzle plugging	NA	Programmatic impact; shutdown of calciner	Flow switch 230-1 interlocked to shut off liquid feed pump P-230-A on low flow Flow indicating controller 230-1 provides indication of flow rate	Operator monitoring of critical parameters Operator training and procedures	S1	F3	S1 for operator ALARA concerns from repair activities
A2	5.14.a	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Air supply bottles empty	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc. also see liquid flow/high node for injector	Flow switch 230-1 Flow indicating controller 230-1 Geometrically favorable calciner design for preventing criticality Pressure switch 230-1 opens on loss of pressure and shuts down supply pump E-3 ventilation system and HEPA filters mitigate Pu oxide released from ruptured convenience cans in storage	Operator monitoring of critical parameters Operator training and procedures	S1	F3	S1 for operator ALARA concerns from repair activities
B-XREF	5.14.b	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Air supply bottles empty	———	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc	Flow switch 230-1 Flow indicating controller 230-1 Geometrically favorable calciner design for preventing criticality Pressure switch 230-1 opens on loss of pressure and shuts down supply pump	Operator monitoring of critical parameters Operator training and procedures	S1*	F1	S1* for criticality. (criticality extremely unlikely given configuration of calciner - see CSER)
L	5.14.c	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Air supply bottles empty	4.5 kg/can Pu oxide powder	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 Flow indicating controller 230-1 Pressure switch 230-1 opens on loss of pressure and shuts down supply pump E-3 ventilation system and HEPA filters mitigate Pu oxide released from ruptured convenience cans in storage	Operator monitoring of critical parameters Operator training and procedures	S1*	F3	S1*/F3 for canister ruptures in Zone 3 areas

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	5.15.a	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Regulator valve failure	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 Pressure switch 230-1 opens on loss of pressure and shuts down supply pump Calciner geometry makes possibility of criticality extremely unlikely	Operator monitoring of critical parameters Operator training and procedures	S1*	F1	S1* for criticality - see CSER regarding potential for criticalities I calciner
A2	5.15.b	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Regulator valve failure	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 Pressure switch 230-1 opens on loss of pressure and shuts down supply pump	Operator monitoring of critical parameters Operator training and procedures	S1	F3	S1 for operator ALARA concerns from repair activities
E	5.16.a	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Valve EV-230-K closed	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 Pressure switch 230-1 opens on loss of pressure and shuts down supply pump E-3 ventilation system and HEPA filters	Operator monitoring of critical parameters Operator training and procedures	S1*	F1	S1* for criticality concerns
A2	5.16.b	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Valve EV-230-K closed	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 Pressure switch 230-1 opens on loss of pressure and shuts down supply pump E-3 ventilation system and HEPA filters	Operator monitoring of critical parameters Operator training and procedures	S1	F3	S1 for operator ALARA concerns from repair activities
E	5.17.a	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Incorrectly set flow indicating controller FIC 230-1	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 (flow indication) Pressure switch 230-1 opens on loss of pressure and shuts down supply pump E-3 ventilation system and HEPA filters	Operator monitoring of critical parameters Operator training and procedures	S1*	F1	S1* for criticality concerns

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	5.17.b	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/no	Incorrectly set flow indicating controller FIC 230-1	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 (flow indication) Pressure switch 230-1 opens on loss of pressure and shuts down supply pump B-3 ventilation system and HEPA filters	Operator monitoring of critical parameters Operator training and procedures	S1	F3	S1 for operator ALARA concerns from repair activities
A2	5.18	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/low	Incorrectly set flow indicating controller fic 230-1 (human error)	NA	Inadequate atomization of Pu nitrate into calciner causing inadequate stabilization, cake formation, Pu accumulation, etc.	Flow switch 230-1 and interlock to feed pump P-230-A Flow indicating controller 230-1 (flow indication) Pressure switch 230-1 opens on loss of pressure and shuts down supply pump B-3 ventilation system and HEPA filters	Operator monitoring of critical parameters Operator training and procedures	S1	F3	S1 for operator ALARA concerns from repair activities
B	5.19	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/high	Failed open regulator on bottled air supply combined with air system PRV failure	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Potential rapid plugging of ceramic filters (quicker than pulse cleaning removes) with possible pressurization of calciner with eventual relief of pressure and powder dispersal in glovebox air flow may exceed capacity of vacuum system causing pressurization of calciner with eventual relief of pressure and powder dispersal in glovebox	FIC 230-1 indicates flow and limits maximum flow rate Calciner pressure indicator Calciner pressure relief PRV-230-? on Compressed air supply B-4 ventilation system and filters	Operator monitoring of key parameters	S1	F2	Air supply system relief valve setting may be important to safety of calciner -- too high a setting will permit unacceptably high pressures in calciner for the given operating temperature. What is basis for PRV setting?
B	5.20	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/high	Failed open regulator on bottled air supply combined with air system PRV failure	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	High air flow voids area around nozzle causing possible aerosolization of Pu nitrate without denitration resulting in deposition on ceramic filters	FIC 230-1 indicates flow and limits maximum flow rate Calciner pressure indicator Calciner pressure relief designed to maintain confinement up to 1.3 psig Calciner pressure relief prevents calciner from significantly overpressurizing PRV-230-? on compressed air supply Glovebox, B-4 ventilation system and filters provide confinement of release	Operator monitoring of key parameters	S1	F2	(Eventual results might be plugging of ceramic filters in such a way that air pulse will not clear them requiring complete disassembly of calciner, OR, pressurization of calciner and resulting pressure relief action that allows Pu nitrate mist into glovebox)

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
L	5.21	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/high	Failed open regulator on bottled air supply combined with air system PRV failure	4.5 kg/can Pu oxide powder	Inadequate stabilization of Pu oxide powder if powder bed voided (possible reduction of residence time due to actual injection point being above base plate)--leads to potential rupture of convenience can in storage vault Personnel exposure to Pu in Zone 3 areas	FIC 230-1 indicates flow and limits maximum flow rate Calciner pressure indicator Calciner pressure relief design PRV-230-? on compressed air supply Glovebox, E-3 ventilation system and filters provide confinement of release	Operator monitoring of key parameters TGA testing prior to canning	S1*	F3	
B	5.22	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/high	FIC 230-1 set too high (human error)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Potential rapid plugging of ceramic filters (buildup quicker than pulse cleaning removes) with possible pressurization of calciner and eventual relief of pressure and powder dispersal in glovebox Air flow exceeds capacity of vacuum system causing pressurization of calciner with eventual relief of pressure and powder dispersal in glovebox	FIC 230-1 indicates flow and limits maximum flow rate Calciner pressure indicator Calciner pressure relief Glovebox, E-4 ventilation system and filters maintain confinement	Operator monitoring of key parameters	S1	F3	setting of the flow controller high probably has a smaller effect than the pressure regulator failure
B	5.23	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/high	FIC 230-1 set too high (human error)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	High air flow voids area around nozzle causing possible aerosolization of Pu nitrate without denitration resulting in deposition on ceramic filters Plugged filters result in pressurized calciner and release of Pu, NOx and nitric acid vapor to glovebox atmosphere	FIC 230-1 indicates flow and limits maximum flow rate Calciner pressure indicator Calciner pressure relief Glovebox, E-4 ventilation system and filters	Operator monitoring of key parameters	S1	F3	
L	5.24	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air flow/high	FIC 230-1 set too high (human error)	4.5 kg/can Pu oxide powder	Inadequate stabilization of Pu oxide powder if powder bed voided (possible reduction of residence time due to actual injection point being above base plate)--leads to potential rupture of convenience can in storage vault	FIC 230-1 indicates flow and limits maximum flow rate Calciner pressure indicator Calciner pressure relief Glovebox, E-4 ventilation system and filters	Operator monitoring of key parameters	S1*	F3	S1* for potential worker exposure to Pu in Zone 3 areas
XREF	5.25	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid pressure/low	See nozzle liquid flow/low (Nodes 5.01-5.07)	———						
XREF	5.26	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Liquid Pressure/high	See liquid flow/low and liquid flow/high (Node 5.0 and Nodes 5.08-5.12)	———						

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[2]	Remarks
A2	5.27	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air pressure/low	See nozzle air flow/low (Node 5.18) Loss of supply or valve closed (controller 230-1 or EV 230-K or regulator valve on supply tanks closed)	NA	Flow of feed into compressed air line results in air line contamination Programmatic upset	Check valve V-52 Flow switch 230-1 interlocked to feed pump Pressure switch 230-1 interlocked to feed pump	Operator response to alarms	S1	F3	S1 based on ALARA concerns for recovery and cleanup
XREF	5.28	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Air Pressure/high	Redundant with air flow/high (Nodes 5.19-5.24)	———						
NA	5.29	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Temperature/low	Not relevant (no adverse affects - intended condition)	NA				NA	NA	
A2	5.30	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Temperature/high	Low or no air flow can result in possible boiling in the injector (with cake formation and plugging or nozzle failure due to accelerated corrosion)	NA	Programmatic impact if disassembly of nozzle required to clear plug Potential spray release of Pu nitrate inside glovebox Programmatic impact if disassembly of nozzle required to clear plug	Flow switch 230-1 interlock to shutdown pump (pump shutdown annunciated) Pressure switch 230-1 interlock to shutdown pump Manual clean out rod for nozzle Glovebox, E-4 ventilation system and HEPA filters maintain confinement in event of leak	Procedures for use of cleanout rod Operator training and procedures for response to process alarms	S1	F3	S1 for increased worker exposures in recovering from leak or to clear plug
F	5.31	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Temperature/high	Low or no air flow results in hot injector pipe with flammable materials near pipe	Total inventory of Pu in glovebox	Fire in glovebox with elevated release of soot, water vapor, and particulate to E-4 ventilation system and filters Potential glovebox loss of confinement with contamination spread to Zone 3	Flow switch 230-1 interlock to shutdown pump (pump shutdown annunciated) Pressure switch 230-1 interlock to shutdown pump Glovebox temperature detector, interlocked to pump shutdown, and alarm Glovebox dry fire protection system	House keeping requirements Limits on combustible loading Gloves required to be pulled out of glovebox when not required Operator training and procedures for response to glovebox high temperature indication (including actions to extinguish fire such as use of bayonet fire extinguisher)	S1*	F3	S1* based on release to Zone 3
B	5.32	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Temperature/high	Low or no liquid flow (possible boiling in injector with plugging)	NA	Programmatic impact if disassembly of nozzle required to clear plug or nozzle failure due to accelerated corrosion	Manual clean out rod for nozzle	Operator surveillance of feed tank and product collection bottle level changes	S1	F3	ALARA concerns for operator if extensive effort required to clear plug

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	5.33	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Temperature/high	Low or no liquid flow or low or no air flow resulting in nozzle plugging	4 L/hr Pu nitrate injection rate	Possibility of pipe pressurization and rupture with release of Pu nitrate aerosols to glovebox atmosphere	For loss of air there is flow switch 230-1 and pressure switch 230-1 No engineered features for loss of feed flow PRV on feed pump discharge The glovebox (provides confinement) E-4 Ventilation system and HEPA filters	Operator surveillance of feed tank and product collection bottle level changes Operator training and procedures for response to process alarms	S1	F3	This event would result in a possible pressure pulse of some magnitude, but not expected to challenge glovebox confinement integrity or ventilation system
D	5.34	Calciner Injector Nozzle	Atomize Pu nitrate with air and feed atomized Pu nitrate into calciner chamber in controlled manner	Feed composition/other than (other than Pu nitrate)	Organics present in Pu nitrate injected into 1000C Pu oxide bed	Pu oxide contained in calciner	Flammable gas generation and possible ignition inside calciner; potential failure of calciner Release of Pu oxide powder to glovebox atmosphere Potential pressurization of glovebox due to steam and hot particulates released from calciner vessel Potential glovebox damage due to pressurized release	Calciner pressure relief cap Sturdy glovebox design E-3 ventilation system and HEPA filters mitigates release to atmosphere HC-230C-2 glovebox atmosphere in communication with other RMC gloveboxes through conveyer glovebox	Administrative procedures for sampling in HC-227-S glovebox before Pu nitrate is transferred to feed receipt tank Pretreatment in HC-7C for solutions containing or suspected of containing organic material Operator surveillance of feed receipt tank and feed pump tank for separable layers	S1*	F2	Consequences related to type of organic and ignition energy release (needs calculation) S1* assumes significant release to room 230
A2	6.00	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/low	Failure to charge powder bed prior to start of processing	NA	Cake formation, cement formation, plugging of nozzle with large particles Programmatic upset	None	Operating procedures for startup of the calciner	S1	F3	S1 based on ALARA concerns in recovering from event
L	6.01	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/low	Overflow tube set too low	4.5 kg/can Pu oxide powder	Inadequate stabilization with potential for eventual rupture of convenience can in storage	None	TGA testing Procedures for operating calciner and operator training	S1*	F3	S1* based on operator exposure and injury from canister rupture during handling

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
E	6.02	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/low	High air flow with failed ceramic filter	NA	Deposition of Pu oxide in scrubber (and possibly the phase separator) precipitation of Pu hydroxides have potential for criticality if solids build up too deep	Clear glass tank allows visual detection of contamination Scrubber geometry favorable for preventing criticality	Visual observation of scrubber solution color by operator	S1*	F1	S1* for potential criticality (criticality extremely unlikely given configuration of calciner - see CSER)
B	6.03.b	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/low	Pressurization event causing release through relief cap	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide in glovebox	Calciner vacuum pressure monitor E-4 ventilation systems and filters The glovebox (provides confinement)	Operator surveillance of feed receipt tank to identify organic material	S1	F3	S1 based on operator exposure potential
B	6.03.a	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/low	Pressurization event causing release through relief cap (excessive Pu nitrate injection, loss of vacuum, etc.)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide in glovebox	Calciner vacuum pressure monitor E-4 ventilation systems and filters The glovebox (provides confinement)	Operator surveillance of feed receipt tank to identify organic material	S1*	F3	S1* based on operator exposure potential (assumes glovebox loss of confinement)
B	6.04.b	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Product overflow tube set too high (potential for plugging tube)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Ceramic filter plugging and potential calciner pressurization	Calciner pressure relief device prevents catastrophic overpressure Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Pu mass balances performed during processing Operator training	S1	F3	S1/F3 based on release to glovebox

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	6.04.a	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Product overflow tube set too high (potential for plugging tube)	NA	Potential criticality from packing calciner full	Criticality alarm system Calciner geometry unfavorable to criticality Calciner pressure relief device prevents catastrophic overpressure Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Pu mass balances performed during processing Operator training	S1*	F1	Top of notch in dome considered an acceptable level (criticality extremely unlikely given configuration of calciner - see CSER)
B	6.05.b	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Plugging of product overflow tube due to scale, cake formation, etc. (could be caused by high injection rate, lack of sufficient atomizing air)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Ceramic filter plugging and potential calciner pressurization with release of Pu oxides to glovebox	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Pu mass balances performed during processing Operator training	S1	F3	S1/F3 for release to glovebox
E	6.05.a	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Plugging of product overflow tube due to scale, cake formation, etc. (could be caused by high injection rate, lack of sufficient atomizing air)	NA	Potential criticality from packing calciner full	Criticality alarm system Calciner geometry unfavorable to criticality Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Pu mass balances performed during processing Operator training	S1*	F1	S1* for potential criticality (criticality extremely unlikely given configuration of calciner - see CSER)
B	6.06.b	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Loss of agitation allows buildup away from overflow	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Ceramic filter plugging and potential calciner pressurization	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Mass balances Operator training	S1	F3	S1/F3 for pressurized release to glovebox

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
E	6.06.a	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Loss of agitation allows buildup away from overflow	NA	Potential criticality from overloading calciner	Criticality alarm system Calciner geometry unfavorable to criticality Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Mass balances Operator training	S1*	F1	S1* for potential criticality (criticality extremely unlikely given configuration of calciner - see CSER)
B	6.07.b	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Initial overcharge of calciner bed (double batching)	Two times Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Ceramic filter plugging and potential calciner pressurization	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Mass balances Operator training	S1	F3	S1/F3 for pressurized release into glovebox
E	6.07.a	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Initial overcharge of calciner bed (double batching)	NA	Potential criticality	Criticality alarm system Calciner geometry unfavorable to criticality Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Operating procedures Mass balances Operator training	S1*	F1	S1* for criticality (criticality extremely unlikely given configuration of calciner - see CSER)
B	6.08	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Plugged ceramic filters	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1) B-4 ventilation system and HEPA filters provide confinement Glove box provides confinement	Operator training and procedures	S1	F3	S1 based on ALARA concerns for cleanup operations

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	6.09	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Pump stoke too large (large quantity of vapor generated)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1) E-4 ventilation system and HEPA filters provide confinement Glove box provides confinement	Operator training and procedures	S1	F3	S1 based on ALARA concerns for cleanup operations
D	6.10	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Explosion from injection of feed containing organics due to sampling or pretreatment errors	Pu oxide powder in calciner	Release of Pu oxide into glovebox due to pressure relief cap being displaced	E-4 ventilation system and HEPA filters Glove box provides confinement	Operator training and procedures Operator monitoring for separable layers in feed pump tank and feed receipt tank Sampling and pretreatment to remove organics in HC-227S and HC-7 respectively	S1*	F3	S1* based on potential to degrade glovebox confinement
B	6.11	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Filter pulse system failure allowing excess flow to filters	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1) E-4 ventilation system and HEPA filters Glove box provides confinement	Operator training and procedures	S1	F3	S1 based on ALARA concerns for cleanup operations
B	6.12	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Loss of or reduced vacuum due to: Loss of vacuum pump Vacuum line valved closed (AOBV-230-L shut) Vacuum regulator valve (VRV-230-1) fails closed or regulates low due to sensing line EV-230-G remaining shut following filter pulse or due to plugged sensing line	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1) E-4 ventilation system and HEPA filters Glove box provides confinement	Operator training and procedures	S1	F3	S1 based on ALARA concerns for cleanup operations

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	6.13	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Valve V-32 at scrubber closed prevents flow from calciner	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1) E-4 ventilation system and HEPA filters Glove box provides confinement	Operator training and procedures	S1	F3	S1 based on ALARA concerns for cleanup operations
B	6.14	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Vacuum regulator VRV 230-1 fails closed	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Release of Pu oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1) E-4 ventilation system Glove box provides confinement	Operator training and procedures	S1	F3	S1 based on ALARA concerns for cleanup operations
NA	6.15	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/low (excessive vacuum)	Failure of vacuum regulator VRV 230-1 (fails open)	NA	No significant consequence identified			NA	NA	
B	6.16	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/low (excessive vacuum)	Pressure relief cap left on during calciner cool down (human error)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Suck scrubber solution back into calciner vessel Pressurized release through relief cap due to flashing of scrubber solution Plug up the calciner with long term loss of production	E-4 ventilation system and glovebox maintain confinement Vent system filters minimize release through stack Inleakage through DPTs minimizes potential for suckbacks	Operator training and procedures	S1	F2	

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
F	6.17	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of heater power supply (full on) caused by controller failure, thermocouple failure, software setpoint in error, human error	Total inventory of Pu in glovebox	Structural failure of calciner (partially melts) with spill of hot Pu oxide to floor of glovebox Pressurization of glovebox due to heat released and flashed liquid, damage to glovebox and loss of confinement Pu oxide and NOx released to room	Glovebox temperature interlock (TSH 230-A) to heater elements Calciner temperature interlock (TSH 230-B) to heater elements Calciner temperature controller (TSH 230-A) E-3 ventilation system E-4 ventilation system Multiple temperature elements located throughout calciner heater system read out on recorders	Procedures for setting and monitoring calciner temperature	S1*	F2	S1* due to loss of glovebox confinement (burn hole through bottom of glovebox or overpressurize glovebox) Heater elements may short out and fail before melting of calciner occurs
F	6.18	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of heater power supply (full on) caused by controller failure, thermocouple failure,. software setpoint in error, human error	Total inventory of Pu in glovebox	Glovebox overheat and fire with potential for release of Pu particulates and aerosols to room 230	Glovebox temperature interlock (TSH 230-A) to heater elements Calciner temperature interlock (TSH 230-B) to heater elements Calciner temperature controller (TSH 230-A) Multiple temperature elements located throughout calciner heater system read out on recorders E-3 ventilation system E-4 ventilation system Glovebox dry fire suppression system	Procedures for setting and monitoring calciner temperature	S1*	F3	
B	6.19	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of heater power supply (full on) caused by controller failure, thermocouple failure,. software setpoint in error, human error	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Vaporization (boiling) of scrubber solution due to hotter gases from overheated calciner resulting in NOx, water vapor, and nitric acid vapor to vacuum system Pressurization of calciner vessel (assuming calciner doesn't fail) with release of Pu oxide, NOx, acid vapor to glovebox	Glovebox temperature interlock (TSH 230-A) Calciner temperature interlock (TSH 230-B) Calciner temperature controller (TSH 230-A) Multiple temperature elements located throughout calciner heater system read out on recorders	Procedures for setting and monitoring calciner temperature	S1	F3	Postulated elevated NOX release to stack

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	6.20	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of heater power supply (full on) caused by controller failure, thermocouple failure,. software setpoint in error, human error	Less than 5 kg Pu oxide powder	Possibility of failing collection jar with release of Pu oxide to glovebox	Glovebox temperature interlock (TSH 230-A) Calciner temperature interlock (TSH 230-B) Calciner temperature controller (TSH 230-A) Multiple temperature elements located throughout calciner heater system read out on recorders E-3 ventilation system E-4 ventilation system	Procedures for setting and monitoring calciner temperature	S1	F3	S1 based on ALARA concerns for cleanup
L	6.21	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Failure of heater controller Failure of heater elements Start processing cycle before calciner up to temperature (human error)	4.5 kg/can Pu oxide powder	Inadequate stabilization of Pu oxide (if temperature above boiling point but not close to 1000°C) Potential canister rupture in storage vault if inadequate stabilization not detected via TGA testing	Interlock between calciner temperature elements and feed pump P-230-A shuts off supply if calciner temperature too low E-3 ventilation system for mitigating releases inside storage vaults or other areas of PFP	TGA testing of Pu oxide powder before canning	S1*	F3	S1* for potential convenience can rupture in storage vault
E	6.22	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Failure of heater controller Failure of heater elements Start processing cycle before calciner up to temperature (human error)	NA	Bed buildup in calciner vessel	Interlock between calciner temperature elements and feed pump P-230-A shuts off supply if calciner temperature too low Calciner vessel geometry and volume minimize likelihood of criticality	Pu mass balances performed during processing to indicate mass accumulation in calciner vessel	S1*	F1	(criticality extremely unlikely given configuration of calciner - see CSER)
A2	6.23	Vertical Denitrator Calciner (VDC) Vessel		Temperature/low	Incorrect setting of heater controller (human error) Failure of heater controller Failure of heater elements Start processing cycle before calciner up to temperature (human error)	NA	Cake or cement formation in calciner vessel, nozzle plugging, and seizing of calciner agitator Programmatic upset	Interlock between calciner temperature elements and feed pump P-230-A shuts off supply if calciner temperature too low Indicating light on agitator motor	Operator surveillance of feed pump level and product collection jar level	S1	F3	S1 for operator exposure to cleanout calciner or replace equipment

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	6.24	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Failure of heater controller Failure of heater elements Start processing cycle before calciner up to temperature (human error)	NA	Flooding the calciner with liquid Pu nitrate solution (if calciner bed temperature not substantially above solution boiling point) Potential for Pu nitrate solution to be sucked into the scrubber vessel (if ceramic filters submerged) or for Pu nitrate aerosols to be sparged and sucked into scrubber vessel (if offgas line height too high to allow liquid flow) Overflow solution into vacuum sensing line Contamination of compressed air supply lines (if ceramic filters submerged) Potential unfiltered Pu oxide release to scrubber (if filters submerged and calciner heats up to temperature) Plugging of ceramic filters with Pu oxide or precipitates	Interlock between calciner temperature elements and feed pump P-230-A shuts off supply if calciner temperature too low	Operator observation of contaminants in scrubber vessel	S1	P3	Collection bottle full in as little as 7.5 minutes (bottle assumed to be one half liter) S1 for ALARA concerns unplugging calciner or replacing equipment

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
E	6.25	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Failure of heater controller Failure of heater elements Start processing cycle before calciner up to temperature (human error)	NA	Flooding the calciner with liquid Pu nitrate solution (if calciner bed temperature not substantially above solution boiling point) Potential for Pu nitrate solution to be sucked into the scrubber vessel (if ceramic filters submerged) or for Pu nitrate aerosols to be sparged and sucked into scrubber vessel (if offgas line height too high to allow liquid flow) Overflow solution into vacuum sensing line Contamination of compressed air supply lines (if ceramic filters submerged) Potential unfiltered Pu oxide release to scrubber (if filters submerged and calciner heats up to temperature) Plugging of ceramic filters with Pu oxide or precipitates Accumulation of moderated Pu mass in calciner poses criticality concern	Interlock between calciner temperature elements and feed pump P-230-A shuts off supply if calciner temperature too low	Operator observation of contaminants in scrubber vessel	S1*	F1	S1*/F1 for criticality in calciner vessel (criticality extremely unlikely given configuration of calciner - see CSER)
A2	6.26	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Agitation/no/low	Motor failure Shaft failure Loss of power Bearing failure Cement formation inside vessel due to inadequate atomization, low temperature, feed contaminants (see Node 6.25 above)	NA	Inadequate Pu oxide stabilization Plugging of feed nozzle Formation of cake or cement inside calciner vessel Programmatic upset; extended shutdown of process	Stall interlock shuts down feed pump P-230-A on loss of agitation	Operator training and procedures for response to alarms	S1	F3	S1 for ALARA concerns to repair calciner
NA	6.27	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Agitation/excessive	Motor failure Shaft failure Loss of power Bearing failure Cement formation inside vessel due to inadequate atomization, low temperature, feed contaminants (see Node 6.25 above)	NA				NA	NA	Not evaluated

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
XREF	6.28	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Time procedure/out of sequence	Feed injected into calciner before it has come up to temperature (See vertical Denitrator Calciner Temperature/low Nodes 6.21-6.22)	———						
B	6.29	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Confinement/low/no	Failure of calciner agitator seal	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Reduced vacuum in calciner headspace Increased air flow through vacuum system to scrubber Potential NOx, nitric acid vapor, and water vapor release to glovebox atmosphere (during filter pulsing)	Pressure gauge in calciner DP gauges across calciner ceramic filters Glovebox structure and E-4 vent system to maintain confinement in event of release from calciner	Operator monitoring of calciner pressure	S1	F3	
B	6.30	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Confinement/low/no	No collection jar connected and valve open	Pu oxide produced at 4 L/hr at 450 g/L	Increased air flow into calciner Reduction in calciner bed temperature Spill of hot Pu oxide powder to floor of glovebox	DP gauge across calciner ceramic filters Glovebox structure and E-4 ventilation system to maintain confinement of particulate release	Operator monitoring of calciner pressure, calciner filter DP	S1	F3	
B	6.31	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Confinement/low/no	Inadequate seal at collection jar connection Leaky flanges, bad welds	Pu oxide produced at 4 L/hr at 450 g/L	Increased air flow into calciner Potential spill of Pu oxide powder to glovebox	DP gauge across calciner ceramic filters Glovebox structure and E-4 ventilation system to maintain confinement of particulate release	Operator monitoring of calciner pressure, calciner filter DP	S1	F3	S1 based on operator ALARA concerns during cleanup

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
F-XREF	6.32	Vertical Denitrator Calciner (VDC) Vessel	Convert Pu nitrate into dry stable Pu oxide Confine offgasses and particulates generated in the denitrating process Contain Pu oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Confinement/low/no	Loss of confinement due to overheating	———	See temp/high deviation (Node 6.17)					
B	7.00	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/low	Filter plugging due to various causes	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	If all filters plugged, calciner pressurizes releasing Pu oxide, NOx, and acid vapors to glovebox atmosphere	Filter pulsing air system Filter delta pressure monitoring (DPT-230-2)	Operator training and procedures	S1	F3	
B	7.01	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/low	Inadequate vacuum due to vacuum system failure, closed valves, or incorrect vacuum regulation	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Potential calciner pressurization	Calciner delta pressure to atmosphere monitor (DPT-230-1) E-4 ventilation system and HEPA filters Glovebox structure provides confinement	Operator training and procedures	S1	F3	
A2	7.02	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/low	Pipe failure (leak - not catastrophic)	NA	Potential calciner pressurization Hot denitration gas leak into glovebox air	Glovebox structure and E-4 ventilation system maintain confinement		S1	F3	
I	7.03	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Relief cap off of calciner during processing due to human error	NOx produced in calciner at injection rate of 4 L/hr	Excessive bubbling in scrubber Inadequate scrubbing, elevated NOx release through stack Entrainment of liquid in vacuum system line	Differential pressure gauges across ceramic filters DP recorder (DP across filter and glovebox relative to calciner vessel) Software interlock shuts down feed pump on low calciner pressure Vacuum trap and vacuum trap high level alarm	Operator observes that cap is off Operator training and procedures Operator trained to shut down system on visual observation of orange color in scrubber	S1	F2	
A2	7.04	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Calciner vessel develops inleakage paths (at flanges, collection jar, seals, agitator bearing, etc.)	NA	Excessive bubbling in scrubber Inadequate scrubbing, elevated NOx release through stack Entrainment of liquid in vacuum system line	Differential pressure gauges across ceramic filters DP recorder (DP across filter and glovebox relative to calciner vessel) Software interlock shuts down feed pump on low calciner pressure Vacuum trap and vacuum trap high level alarm	Operator observes that cap is off Operator training and procedures Operator trained to shut down system on visual observation of orange color in scrubber	S1	F2	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
XREF	7.05	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Excessive air feed to feed nozzle	———	See injector air flow/high (Nodes 5.22-5.24)					
B-XREF	7.06	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Excessive liquid flowrate into calciner through feed nozzle (increased offgas causes calciner pressure rise which causes vacuum regulator valve to open up more)	———	See injector liquid flow/high (Node 5.11)					
B	7.07	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Broken offgas line (due to thermal stress, improper connection)	4 L/hr nitric acid converted into acid vapor	Excessive bubbling in scrubber (from air sucked into broken line) NOx, nitric acid vapor, steam release to glovebox atmosphere through calciner relief cap	Differential pressure gauges across ceramic filters (pressure will drop substantially DP recorder on calciner and across ceramic filters (DPT-250-1 and -2) B-4 ventilation system maintains negative pressure in glovebox	Operator training and procedures	S1	F2	
XREF	7.08	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Temperature/low	See calciner temp/low (Nodes 6.22-6.26)	———						
B-XREF	7.09	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Temperature/low	Broken pipe	———	See offgas line flow/high (Node 7.07)					
XREF	7.10	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Temperature/high	See calciner temp/high (Nodes 6.17-6.20)	———						
XREF	7.11	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/low (excessive vacuum)	See calciner pressure/low (Node 6.15)	———						
I-XREF	7.12	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/low (excessive vacuum)	Excessive vacuum due to low scrubber level	———	See scrubber Level/low (Node 7.01)					
XREF	7.13	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/high (inadequate vacuum or positive pressure)	See calciner Pressure/high (Nodes 6.08-6.14)	———						

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	7.14	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/high (inadequate vacuum or positive pressure)	Inadequate vacuum (vacuum system failure or regulator valve failures, valve V-32 closed)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	NOx, nitric acid vapor, steam release to glovebox atmosphere	Calciner pressure gauge (DPT-230-1) Software interlock to shut off feed pump P-230-A on low vacuum Delta pressure transduce (DPT-230-2) rs and recorder across ceramic filters	Operator monitoring of various pressure readings	S1	F3	
A2	7.15	Offgas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Composition/contamination particulate	Ceramic filter failure(s)	NA	Pu oxide contamination in scrubber vessel	None	Operator monitoring of scrubber (operator trained to shut down system on visual observation of "mud" in scrubber)	S1	F3	Increased worker exposure to recover from upset
B	8.00	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form sohible salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/low	Scrubber vessel failure Failure at glass welds Leaking flanges or gaskets	15 L scrubber solution	Release of caustic solution to glovebox floor Release of potentially contaminated caustic aerosol to glovebox atmosphere Reduced or increased vacuum at calciner depending on inleakage rate and liquid level Reduced scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Inadequate quenching of condensible vapors Release of NOx, nitric acid vapor, contaminated steam to glovebox atmosphere through leakage paths and calciner relief cap	B-4 ventilation system to maintain negative pressure in the glovebox should vapors and gases be released from system	Visual observation of scrubber level (glass tank)	S1	F3	There appears to be no good method for recovering from this event. The 227-S glovebox normally handles acids, not bases.

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	8.01	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/low	Failure of level control system on phase separator and scrubber drain open (valve V-31 and DOV 230-H open at same time)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) Flash liquid in phase separator tank Accelerated use of NaOH feed supply No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack (when NaOH feed supply exhausted) Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor (when NaOH feed supply exhausted)	Vacuum trap (limits potential for liquids from going into vacuum system) Vacuum trap high level interlock (LEH 230-2) shuts down caustic feed supply and vacuum Temperature element 230-5 and temperature recorder	Visual observation of scrubber level (glass tank) Visual observation of spent scrubber solution receiver tanks	S1	F2	S1 for contamination of vacuum system
I	8.02	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/low	Scrubber voided out (contents vaporized) due to insufficient cooling caused by loss of chiller	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor	Vacuum trap (limits potential for liquids from going into vacuum system) Temperature element 230-5 and temperature recorder	Visual observation of scrubber level (glass tank)	S1	F3	S1 for contamination of vacuum system
A1	8.03	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/high	Failure of pH monitoring (low pH indication) causes NaOH feed to be added when not required (transient condition continues as long as NaOH supply lasts)	NA	No significant safety effect, provided phase separator tank level controls and pump P-230-C remains running Excessive use of NaOH Spent scrub solution receiver tanks filled prematurely		Visual monitoring of liquid levels in phase separator and spend scrub solution receiver tanks	S0	F3	
I	8.04	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/high	Failure of phase separator tank high-high level indicator prevents pumpdown of phase separator tank	Small quantity of scrubber solution	Phase separator tank goes full, allowing overflow into vacuum system vacuum trap with eventual release of aerosols to vacuum system	Vacuum system shutdown interlock on level indication in vacuum trap Vacuum trap high level interlock shuts down caustic feed supply pump	Operator observation of scrubber, phase separator, and vacuum trap liquid levels Operator training and procedures	S1	F3	S1 for contamination of vacuum system

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	8.05	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/high	Failure of valve DOV-230-H or DOV-230-HB (FTOD) prevents transfer of phase separator tank contents to spent scrub solution receiver tanks when level high	Small quantity of scrubber solution	Phase separator tank goes full, allowing overflow into vacuum system vacuum trap with eventual release of aerosols to vacuum system	Vacuum system shutdown interlock on level indication in vacuum trap Vacuum trap high level interlock shuts down caustic feed supply pump	Operator observation of scrubber, phase separator, and vacuum trap liquid levels Operator training and procedures	S1	F3	
I	8.06	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/high	Pump P-230-C fails when needed to pump down separator tank due to various hardware failures or loss of air supply	Small quantity of scrubber solution	Phase separator tank goes full, allowing overflow into vacuum system vacuum trap with eventual release of aerosols to vacuum system	Vacuum system shutdown interlock on level indication in vacuum trap Vacuum trap high level interlock shuts down caustic feed supply pump	Operator observation of scrubber, phase separator, and vacuum trap liquid levels Operator training and procedures	S1	F3	
B	8.07	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	Level/high	Valve V-32 (between scrubber and phase separator) closed due to human error (valve V-32 located on overflow line between phase separator and scrubber)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Potential calciner pressurization with release of NOx, steam, and nitric acid vapor to glovebox atmosphere due to loss of vacuum flow	Overflow line elevation and capacity prevent high level Level indication and level controller in phase separator tank Delta pressure indication across ceramic filters (DPT-230-2) Absolute pressure indication (DPT-230-1) Off gas line pressure alarm switch DPS-230-A V-32 normally open Glovebox structure E-4 ventilation system and filters mitigate release to atmosphere through stack	Operator observation of scrubber tank level (glass tank) Operator training and procedures Operator observation of steam being released from calciner pressure relief	S1	F2	If pH incorrectly read downstream of pump as a result of valve failure, caustic solution could backflow into calciner
A2	8.08	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/high	Standpipe plugging	NA	Calciner pressurization with release of NOx, steam, and nitric acid vapor to glovebox atmosphere	Delta pressure indication across ceramic filters (DPT-230-2) Absolute pressure indication (DPT-230-1) Off gas line pressure alarm switch DPS-230-A Vacuum trap high level interlock (LSH 230-2) shuts down caustic feed supply and vacuum Glovebox structure E-4 ventilation system and filters	Operator observation of scrubber tank level and solution color (glass tank) Operator training and procedures Operator observation of steam being released from calciner pressure relief	S1	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
NA	8.09	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Temp/low	Chiller temperature set point set too low	NA	No significant effect identified			NA	NA	
I	8.10	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Temp/high	Loss of power to chiller results in voiding of scrubber from boil out Chiller failure (general failures of equipment) results in voiding of scrubber from boil out Chiller supply or return valve closed results in voiding of scrubber from boil out Loss of chiller fluid from supply or return line failure results in voiding of scrubber from boil out	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor	Vacuum trap limits amount of liquid that can move into vacuum system Vacuum trap high level interlock (LEH 230-2) shuts down caustic feed supply and vacuum Temperature element 230-5 and temperature recorder	Operator observation of calciner level (glass tank)	S1	F3	S1 for elevated NOx release and contamination of vacuum system
NA	8.11	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Pressure/low (excessive vacuum)	VRV-230-1 fails open Calciner develops leak which demands VRV-230-1 open	NA	No adverse effects identified			NA	NA	
B	8.12	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas streams by reacting to form soluble salts Cool offgas stream from calciner	Pressure/high (inadequate vacuum or positive pressure)	Vacuum regulating valve VRV-230-1 fails closed or partially closed V-32 (manual valve between scrubber and phase separator) closed with no vacuum path to calciner Path failure on vacuum side of scrubber	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Pressurization of calciner vessel Release of Pu oxide powder, water vapor, NOx, nitric acid vapor to glovebox atmosphere Creates "seal pot" out of scrubber	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 E-4 ventilation system and filters Glovebox confinement structure	Visual observation of steam release from calciner pressure relief cap or steam in product collection jar Operator training and procedures Operator periodic surveillance of the delta pressure gauges	S1	F3	

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	8.13	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	pH/low (less than 13)	pH sensor 230-1 in pump 230-C discharge line fails high as continued operation of calciner neutralizes scrubber solution or pH in phase separator not indicative of pH of solution in the scrubber	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	NOx scrubbing efficiency reduced (as well as removal of other materials in the calciner offgas) which results in NOx going to 26" vacuum system and creating acidic condition in seal water Possible release of NOx from vacuum system to facility stack	None	Operator observation of scrubber solution color - deep orange (glass tank)	S1	F3	
I	8.14	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	pH/low (less than 13)	Failure of NaOH feed supply pump to supply NaOH (various mechanical or electrical failures) as continued operation of calciner neutralizes scrubber solution	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Potential for NaOH feed piping rupture and spray of material inside or outside the glovebox NOx scrubbing efficiency reduced (as well as removal of other materials in the calciner offgas) which results in NOx going to 26" vacuum system and creating acidic condition in seal water Possible release of NOx from vacuum system to facility stack	E-3 ventilation system and filters E-4 ventilation system and filters	Operator observation of scrubber solution color - deep orange (glass tank)	S1*	F3	S1* based on NaOH particulates generated in room from spray leak
I8	8.15	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner	pH/low (less than 13)	Valves in supply line to scrubber closed (V-41 or V-42) as continued operation of calciner neutralizes scrubber solution	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	NOx scrubbing efficiency reduced (as well as removal of other materials in the calciner offgas) which results in NOx going to 26" vacuum system and creating acidic condition in seal water Possible release of NOx from vacuum system to facility stack	None	Operator observation of scrubber solution color - deep orange (glass tank)	S1	F3	pH reads out on computer.
I	8.16	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	pH/low (less than 13)	NaOH supply drum empty (human error)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	NOx scrubbing efficiency reduced (as well as removal of other materials in the calciner offgas) which results in NOx going to 26" vacuum system and creating acidic condition in seal water Possible release of NOx from vacuum system to facility stack	None	Operator observation of scrubber solution color - deep orange (glass tank)	S1	F3	
I	8.17	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	pH/low (less than 13)	Incorrect material supplied to NaOH feed pump (wrong drum) Examples: dilute NaOH solution, acid, water	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	NOx scrubbing efficiency reduced (as well as removal of other materials in the calciner offgas) which results in NOx going to 26" vacuum system and creating acidic condition in seal water Possible release of NOx from vacuum system to facility stack	None	Operator training and procedures	S1	F2	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A1	8.18	Scrubber	Condense and neutralize nitric acid vapors Remove NOx from calciner offgas stream by reacting to form soluble salts Cool offgas stream from calciner Protect process vacuum system from nitric acid vapors and heat	pH/high (10 M NaOH)	pH indicator failure (low indication)	NA	Excessive consumption of NaOH solution - programmatic impact Also see scrubber Level/high (Node 8.04)	None	Operator training and procedures	S0	F3	
B	9.00	Phase Separator Tank	Separate liquids from gasses in vacuum stream Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/low	Failure of the phase separator tank (various mechanical failures)	10 L scrubber solution	Leak spent scrubber solution to floor of glovebox (splatter release of slightly contaminated solution) Possible loss of vacuum to calciner and scrubber Loss of vacuum results in release of NOx, acid vapor, water vapor to glovebox atmosphere	DPS-230-A pressure switch and alarm on high pressure in the scrubber relative to calciner DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Pressure indicator PI-230-1 on phase separator tank inlet Sump level alarm	Operator observation of phase separator tank	S1	F3	
B	9.01	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/low	Vacuum failure (prevents material being drawn into separater) e.g., loss of vacuum system, vacuum regulator valve closed	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Calciner pressurization with release of NOx, steam, and nitric acid vapor to glovebox atmosphere	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Pressure indicator PI-230-1 on phase separator tank inlet	Operator observation of phase separator tank	S1	F3	
B	9.02	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/low	Valve V-32 closed preventing flow from scrubber to phase separator	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Calciner pressurization with release of NOx, steam, and nitric acid vapor to glovebox atmosphere	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Pressure indicator PI-230-1 on phase separator tank inlet	Operator observation of phase separator tank	S1	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	9.03	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/low	Failure of tank high level probe (spurious high indication) causes tank to be completely drained (pump out of tank to spent scrub solution receiver tanks) Failure causes discharge valves to remain continuously open so that system communicates with spent scrub solution receiver tank vents (unknown hydraulic characteristics)	NA	Cavitation of P-230-C and loss of recirculation to scrubber due to closed valve DOV 230-HA (tank fully drained) Possibly draw vacuum on spent scrub solution receiver tanks (they have open vents)	None	Operator observation of phase separator tank	S1	F3	
I	9.04	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/high	Failure of tank high-high level probe (high level not sensed) drain sequence not started	Small quantity of scrubber solution	Scrub solution pulled into vacuum trap Accelerated use of NaOH supply Possible movement of liquid into main vacuum system	Annunciator on vacuum trap level high (LEH-230-2) 26 inch vacuum system seal pot Interlock on vacuum trap level high-high shuts down caustic feed and after time delay shuts down process vacuum	Operator training and procedures Operator observation of phase separator tank	S1	F3	
I	9.05	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/high	Failure of pump (P-230-C)	Small quantity of scrubber solution	scrub solution pulled into vacuum trap Possible movement of liquid into main vacuum system	Annunciator on vacuum trap level high (LEH-230-2) 26 inch vacuum seal pots protect vacuum system components Interlock on vacuum trap level high-high shuts down caustic feed and after time delay shuts down process vacuum	Operator training and procedures Operator observation of phase separator tank	S1	F3	
I	9.06	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Level/high	Failure of supply (DOV-230-H) and discharge (DOV-230-HB) valves for pump (P-230-C)	Small quantity of scrubber solution	Scrub solution pulled into vacuum trap Possible movement of liquid into main vacuum system	Annunciator on vacuum trap level high (LEH-230-2) 26 inch vacuum system seal pots Interlock on vacuum trap level high-high shuts down caustic feed and after time delay shuts down process vacuum	Operator training and procedures Operator observation of phase separator tank	S1	F2	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
NA	9.07	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Pressure/low (vacuum excessive)	Vacuum regulator valve (VRV-230-1) fails or regulates incorrectly	NA	No significant consequences			NA	NA	
B	9.08	Phase Separator Tank	Separate liquid from gas that goes into vacuum system Facilitates removal of noncondensables from scrubber Transmit vacuum from 26" vacuum system to scrubber and calciner Provide for level control in the scrubber	Pressure/high (inadequate vacuum)	Vacuum regulator valve (VRV-230-1) fails closed or regulates incorrectly Vacuum system valves closed (AOBV 230-1)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Calciner pressurization with release of NOx, steam, nitric acid vapor, Pu nitrate aerosols and Pu oxide particles to glovebox atmosphere	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Pressure indicator PI-230-1 on phase separator tank inlet	Visual observation of steam release from calciner pressure relief cap or steam in product collection jar Operator training and procedures Operator periodic surveillance of the delta pressure gauges	S1	F3	
A2	10.00	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/high	Human error--spent solution flow not switched to second bank when first bank full Banks not drained prior to processing campaign Solution from 2nd bank of tanks inadvertently recirculated into bank 1	NA	Spent solution dumped to floor of glovebox through vent Programmatic impact	Weight factor instrumentation in one of two tanks in bank (tanks are hydraulically equal)--high level annunciation Glovebox sump level alarm	Operator surveillance of tank level Operator training and procedures	S1	F3	S1 for increased worker exposure in recovering from event If caustic has to be pumped back to HC-227S, potential acid/base reactions could occur or plutonium precipitation could occur if Pu nitrate solutions and caustic solution mixed
B	10.01	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/low	Ruptured tanks or tank seals	40 L spent scrub solution	Spill of solution to glovebox floor Programmatic impact Solution has to be pumped back to HC-227S	Glovebox sump level alarm	Operator surveillance of tank level Operator training and procedures	S1	F3	
A2	10.02	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/low	Solution recirculated to other bank (human error)	NA	Overflow tank in other bank Spill of solution to Glovebox floor Programmatic impact	Glovebox sump level alarm	Operator surveillance of tank level Operator training and procedures	S1	F3	
A2	10.03	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/low	Tap V-44 left open while recirculating	40 L spent scrub solution	Spill of solution to glovebox floor Programmatic impact Solution has to be pumped back to HC-227S	Glovebox sump level alarm	Operator surveillance of tank level Operator training and procedures	S1	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[2]	Remarks
A2	10.04	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/low	Transfer pipe failure	40 L spent scrub solution	Spill of solution to glovebox floor Programmatic impact Solution has to be pumped back to HC-227S	Glovebox sump level alarm	Operator surveillance of tank level Operator training and procedures	S1	F3	
A2	10.05	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/low	Evaporation of solution in tanks leaving solids layer (of $NaNO_3$, NaOH, etc.)	NA	Programmatic impact - necessity of cleaning tanks	None	Operator observation of tanks	S1	F3	S1 based on ALARA concerns for cleanup activities
E	10.06	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/low	Tank 1 drain open while filling or recirculating tank 1 (same scenario for tank 2)	NA	Material drained to tank D-8 that has not been sampled for pH or Pu content - potential for buildup of Pu solids with potential for criticality	3 way valve interlocks prevent draining the same tank that is being filled or recirculated Keyswitch in MOV-230-P cannot open without key from supervisor. Prevents transfer to Tank D-8	Operator training and procedures	S1*	F1	S1*/F1 for potential criticality in tank D-8
E	10.07	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Filter failure at calciner	NA	Buildup of Pu oxide sludge in tanks with possibility of criticality	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Criticality alarm system	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F1	S1* based on criticality event
E	10.08	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Filter failure at calciner	NA	Possible transfer of Pu material to tank D-8 with potential criticality specification violation	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Keyswitch in MOV-230-P cannot open without key from supervisor. Prevents transfer to Tank D-8	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F1	S1* for potential criticality in tank D-8
A2	10.09	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Filter failure at calciner	Less than 1.5 kg Pu oxide powder	Programmatic impact in having to remove and reprocess material	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Keyswitch in MOV-230-P cannot open without key from supervisor. Prevents transfer to Tank D-8	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1	F3	S1 for worker exposures during recovery

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	10.10	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Nitrate oversupply in calciner resulting in overflow of calciner into scrubber	NA	Buildup of Pu oxide sludge in tanks with possibility of criticality	Criticality alarm system Calciner geometry unfavorable to criticality Filter delta pressure monitoring (DPT 230-2) Calciner delta pressure to atmosphere (DPT 230-1)	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F1	S1* based on criticality event
B	10.11	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Nitrate oversupply in calciner resulting in overflow of calciner into scrubber	NA	Possible transfer of Pu material to tank D-8 with potential for criticality specification violation in tank D-8	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F1	S1*/F1 for potential criticality
A2	10.12	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Nitrate oversupply in calciner resulting in overflow of calciner into scrubber	10 L Pu nitrate solution at 450 g/L	Programmatic impact in having to remove and reprocess material	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1	F3	
B	10.13	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Pressure/high	Both vents on a "tank" blocked (a "tank" is comprised of two tanks connected by a common header on both inlet, drain, and recirculation)	40 L spent scrub solution	Possible failure of "tank" with spill to glovebox floor (assuming deadhead pressure of transfer pump P-230-C sufficient)	None	None	S1	F1	F1 based on two passive vents plugging from unknown processes
NA	10.14	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Pressure/high	Chemical reaction in "tank" from incompatible material mixing (a "tank" is comprised of two tanks connected by a common header on both inlet, drain, and recirculation)	NA	No significant chemical reactions identified			NA	NA	
A1	10.15	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Pressure/low (vacuum in "tank")	Both vents blocked and drain opened	NA	Inability to drain tanks - programmatic impact	Tank vents have no valves	None	S0	F1	

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
NA	10.16	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Pressure/low (vacuum in "tank")	Both vents blocked and significant cooling of solution occurs	NA	No significant impact	None	None	S0	F1	
A1	10.17	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Pressure/low	Both vents blocked and significant cooling of solution occurs	NA	No significant impact	Tank vents have no valves		S0	F1	
NA	10.18	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Temperature/high	Chemical reaction in "tank" from incompatible material mixing (a "tank" is comprised of two tanks connected by a common header on both inlet, drain, and recirc)	NA	No significant chemical reactions could be identified			NA	NA	
I	10.19	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	pH/low (<13)	pH controller failure at scrubber	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Inadequate scrubbing of calciner offgas allowing NOx and acid release to vacuum system		Recirculation and sampling for Pu content	S1	F3	
A1	10.20	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	pH/low (<13)	pH controller failure at scrubber	NA	No significant impact to spent scrub solution receiver tanks; however pH of tank D-8 could be significantly affected	Keyswitch for MOV-230-P valve to prevent inadvertent sending to D-8	None	S0	F3	Potential effect on tank D-8 unknown
NA	10.21	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	pH/high		NA	Design intent, no significant consequence			NA	NA	
E	10.22	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Composition/high Pu	Filter failure at calciner	NA	Buildup of Pu oxide sludge in tanks with possibility of criticality	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Criticality alarm system	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F1	S1* based on criticality event
E	10.23	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Composition/high Pu	Filter failure at calciner	NA	Possible transfer of Pu material to tank D-8 with potential for criticality due to buildup of Pu solids	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Keyswitch for MOV-230-P valve to prevent inadvertent sending to D-8	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
A2	10.24	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Composition/high Pu	Filter failure at calciner	Less than 1.5 kg Pu oxide powder	Programmatic impact in having to remove and reprocess material	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1	F5	
E	10.25	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Composition/high Pu	Nitrate oversupply in calciner resulting in overflow of calciner into scrubber	NA	Buildup of Pu oxide sludge in tanks with possibility of criticality	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Criticality alarm system	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F1	S1* based on criticality event
E	10.26	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Composition/high Pu	Nitrate oversupply in calciner resulting in overflow of calciner into scrubber	NA	Possible transfer of Pu material to tank D-8 with resulting criticality concern due to Pu solids buildup	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Keyswitch for MOV-230-P prevents inadvertent sending to D-8. Need key from supervisor to operate	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1*	F3	S1* based on criticality event
A2	10.27	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Composition/high Pu	Nitrate oversupply in calciner resulting in overflow of calciner into scrubber	10 L Pu nitrate solution at 450 g/L	Programmatic impact in having to remove and reprocess material	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1	Recirculation and sampling for Pu content Operator observation of solution color Operator observation of tanks (glass for visibility of solids layer) Operator training and procedures for response to process parameter indications	S1	F3	
A1	10.28	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Mixing/no/low	V-91 or V-92 closed, or MOV 230-M & N set to drain	NA	Programmatic impact	None	Operator training and procedures for setting up recirculation	S0	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
E	10.29	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Mixing/no/low	Recirculation pump failure Failure of process air to recirculation pump (P-230-D)	NA	Inaccurate Pu sample results, ultimately could result in excessive quantities of Pu to tank D-8 with potential for criticality from buildup of Pu solids	None	Operator training and procedures for setting up recirculation	S1*	F1	S1*/F1 for potential criticality in tank D-8
E	10.30	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Mixing/no/low	Failure to operate pump (human error)	NA	Inaccurate Pu sample results, ultimately could result in excessive quantities of Pu to tank D-8 with potential for criticality from buildup of Pu solids	Keyswitch for MOV-230-P prevents sending to D-8. Need key from supervisor to operate	Operator training and procedures for setting up recirculation	S1*	F1	S1*/F1 for potential criticality in tank D-8
B-XREF	10.31	Spent scrub solution receiver tank (tank in bank 1 representative of all four tanks)	Provide lag storage of spent scrub solution for blending and sampling prior to transferring solution to Tank D8 for disposal	Mixing/no/low	Recirculation piping failure	_____	See Level/low node for scrubber receipt tanks (Node 10.01)					
E	11.00	Spent Scrub Solution Drain Line from MOV 230-P to Tank D8	Transfer spent scrub solution to tank D8 to permit eventual transfer to tank farms	Composition/high Pu concentration	Calciner filter failure permits movement of Pu into scrubber and failure to detect visually or by sampling	NA	Potential for buildup of Pu in tank D8 and possible criticality concern	Keyswitch for MOV-230-P prevents sending to D-8. Need key from supervisor to operate	Procedure for sampling spent scrubber solution before being sent to tank D8 Operator observation of scrubber solution color in scrubber	S1*	F1	S1* based on criticality concern
I-XREF	12.00	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Level/high	See phase separator node for Level/ high (Nodes 8.04-8.06)	_____						
I	12.01	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Level/high	Level element failure (assumes entrained liquid will eventually accumulate to significant level)	Small quantity of scrubber solution	Liquid permitted to enter vacuum system with possible damage to the vacuum pumps resulting in programmatic impact Contamination of vacuum system with radioactive caustic solution	Two level indications on vacuum trap interlocked to isolate the calciner system from the plant vacuum system Seal pots in the plant vacuum system	Operator observation of level in vacuum trap (glass tank)	S1	F3	
B-XREF	12.02	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Pressure/high (lack of vacuum)	Failure of plant vacuum system valve AOBV-230-L closed	_____	Pressurization of scrubber and calciner - see calciner Pressure/ high (Node 6.12) & Temperature low (Node 6.25)					
B-XREF	12.03	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Pressure/high (lack of vacuum)	Vacuum trap drain valve V-72 left open	_____	Pressurization of scrubber and calciner - see calciner Pressure/ high (Node 6.12)					
NA	12.04	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Pressure/high (lack of vacuum)	Excessive inleakage from various points in the calciner system due to piping and vessel failures	NA	Addressed at various nodes specific to the rest of the system			NA	NA	
XREF	13.00	Vent Catch Tank	Provide a liquid catch volume for the Feed Receipt Tank vent, Feed Pump Tank vent, Flush Tank vent that can be recovered by use of valve V-74 Provide a drain volume for the Vacuum Trap with recovery by use of valve V-74	Level/high	Overflow of feed receipt tank, flush tank or feed pump tank	_____	See feed receipt tank, feed pump tank and flush tank nodes Level/ high (Nodes 1, 2, 3)					

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	13.01	Vent Catch Tank	Provide a liquid catch volume for the Feed Receipt Tank vent, Feed Pump Tank vent, Flush Tank vent that can be recovered by use of valve V-74 Provide a drain volume for the Vacuum Trap with recovery by use of valve V-74	Level/high	Vacuum trap drained to vent catch	2.5 L Pu nitrate solution at 450 g/L	Potential overflow vent catch tank (depending on vacuum trap quantity) Aerosol release to glovebox atmosphere of scrubber solution due to splatter	Level monitoring in vacuum trap limits quantity drained to vent catch tank	Visual observation of tank levels	S1	F3	
B	13.02	Vent Catch Tank	Provide a liquid catch volume for the Feed Receipt Tank vent, Feed Pump Tank vent, Flush Tank vent that can be recovered by use of valve V-74 Provide a drain volume for the Vacuum Trap with recovery by use of valve V-74	Pressure/high	Blocked overflow vent and gas generation or heat generation due to chemical reaction in feed receipt tank, feed pump tank, flush tank, or vent catch tank	20 L Pu nitrate solution at 450 g/L	Potential rupture of vent catch tank, flush tank, or feed receipt tank Spill of Pu nitrate solution to glovebox floor NOx release to glovebox atmosphere	Glovebox sump and level alarm Criticality drain Glovebox structure and E-4 ventilation system maintains confinement	Visual observation of gas bubbles in affected tank	S1	F1	
B	13.03	Vent Catch Tank	Provide a liquid catch volume for the Feed Receipt Tank vent, Feed Pump Tank vent, Flush Tank vent that can be recovered by use of valve V-74 Provide a drain volume for the Vacuum Trap with recovery by use of valve V-74	Pressure/high	Blocked overflow vent and waste transferred into feed receipt tank from HC-227S	20 L Pu nitrate solution at 450 g/L	Potential rupture of vent catch tank, flush tank, or feed receipt tank (if pump pressure potential high enough) Spill of Pu nitrate solution to glovebox floor	Glovebox sump and level alarm Criticality drain Glovebox structure and E-4 ventilation system maintains confinement	Visual observation of gas bubbles in affected tank	S1	F1	
B	13.04	Vent Catch Tank	Provide a liquid catch volume for the Feed Receipt Tank vent, Feed Pump Tank vent, Flush Tank vent that can be recovered by use of valve V-74 Provide a drain volume for the Vacuum Trap with recovery by use of valve V-74	Pressure/low (vacuum)	V-72 valve open (valve between vent catch tank and vacuum tank) and vent catch tank overflow vent plugged	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Reduced vacuum draw on scrubber and calciner; potential release from calciner due to overpressure Slight vacuum draw on feed receipt tank, feed pump tank, flush tank; no significant consequence	Tanks judged to survive full system vacuum Pressure indicator 230-3 on vacuum trap indicates inleakage or vacuum system failure If severe enough other pressure transducers in system would indicate inleakage	Operator training and procedures	S1	F3	S1/F3 for potential release through calciner pressure relief cap
A2	14.00	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Flow/low	Pump fails when required Valve V-81 downstream of pump closed when required	NA	Programmatic upset (repairs can't be made or out of spec solution can't be reprocessed)	None	Operator surveillance of source and receipt tanks	S1	F3	How do you recover should Pu content in scrub receiver tanks exceed 2 g/L? Solution is incompatible with acidic waste in glovebox HC-227S and probably shouldn't be sent there via pump P-230-E

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	14.01	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Flow/low	Pipe leak	20 L Pu nitrate solution at 450 g/L	Spray leak or liquid leak inside glovebox HC-230C-2, glovebox HC-227S, or inside transfer line encasement Elevated aerosol release to E-4 ventilation system	Glovebox sump level alarm Encasement pipe prevents aerosol release to Zone 3 areas Encasement drains back to gloveboxes Glovebox structure and E-4 ventilation system maintains confinement	Visual detection of leak	S1	F3	
C	14.02	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Flow/low	Pipe leak and encasement leak	10-40 L Pu nitrate solution at 450 g/L depending on whether RT or BT being used	Liquid release to Zone 3 areas (duct level, or room 230, or room 227	E-3 ventilation system mitigates release to environment Zone 3 CAMs	Major leak detected by monitoring source and receipt tank levels	S1*	F2	
NA	14.03	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Flow/high	Overspeed pump	NA	No significant consequences identified			NA	NA	
B	14.04	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Flow/high	Catastrophic pipe failure (downstream of pump) Leak inside glovebox HC-230C-2,	20 L Pu nitrate solution at 450 g/L	Aerosol release to glovebox atmosphere due to splatter	Glovebox structure and E-4 ventilation system maintains confinement Glovebox sump alarm	Visual detection of leak	S1	F2	
NA	14.05	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Pressure/low	Redondant to flow/low	NA				NA	NA	
A1	14.06	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Pressure/high	Deadheaded transfer pump due to closed valve V-81	NA	Pump overheating with potential for boiling liquid in pump (energy transfer to fluid) - pump cavitation	None	Operator observation of receipt tank - no level increase	S0	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
E	14.07.a	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Composition/other than Pu nitrate solution	Transfer of caustic material to HC-227S by pumping vent catch tank (via P-230-B) which contains scrubber solution	NA	Pu precipitation due to neutralization of Pu nitrate solution with potential for criticality	Criticality Alarm System	Procedures governing transfers back to HC-227S from HC-230C-2	S1*	F1	S1*/F1 based on criticality
B	14.07.b	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Composition/other than Pu nitrate solution	Transfer of caustic material to HC-227S by pumping vent catch tank (via P-230-B) which contains scrubber solution	20 L Pu nitrate solution at 450 g/L	Presence of caustic in glovebox HC-227S tanks that normally contain acid with potential of heating due to chemical reaction	Criticality alarm system	Procedures governing transfers back to HC-227S from HC-230C-2	S1	F2	S1/F2 based on ALARA concerns for splatter and heating in RT-3
E	14.08.a	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Composition/other than Pu nitrate solution	Transfer of spilled caustic solution from scrubber, phase separator, or spent scrub solution receipt tanks to HC-227S via pump P-230-E	NA	Pu precipitation due to neutralization of Pu nitrate solution with potential for solids accumulation and criticality	Criticality alarm system	Procedures governing transfers back to HC-227S from HC-230C-2	S1*	F1	S1*/F1 based on criticality
B	14.08.b	Transfer line between pump P-230-E and HC-227S receipt tank	Transfer solutions out of feed pump tank, feed receipt tank, flush tank, or vent tank back to HC-227S (tanks may need to be emptied to unplug or repair calciner or to rework solutions)	Composition/other than Pu nitrate solution	Transfer of spilled caustic solution from scrubber, phase separator, or spent scrub solution receipt tanks to HC-227S via pump P-230-E	Caustic in transfer	Presence of caustic in glovebox HC-227S tanks that normally contain acid with potential of heating due to chemical reaction	None	Procedures governing transfers back to HC-227S from HC-230C-2	S1	F2	S1/F2 based on ALARA concerns for splatter and heating in RT-3
B	15.00	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Pressure/low	Blowback air accumulator empty due to: - 3-way solenoid valve remains in the calciner feed position (does not cycle to the instrument air supply position to recharge blowback air accumulator) - Air supply bottles exhausted (either failure to replace exhausted bottles when required or failure of system pressure relief empties bottles) - High pressure bottle supply pressure regulator fails closed - Blowback air pressure regulator PRV-230-2 fails closed - Block valve from air bottles closed	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Calciner offgas filters plug with resulting calciner pressurization and release of Pu oxide, nitric acid vapor, or NOx to glovebox	Pressure indication on PRV-230-2 Pressure indication light on bottled air regulator DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Glovebox structure and B-4 ventilation system and filters Calciner pressure relief device prevents significant pressurization of calciner	Operator training and procedures	S1	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	15.01	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Pressure/low	Failure of single pulse solenoid closed (failure to open on demand)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Plugging of single calciner offgas filter with possibility of reduced offgas flow and pressurization of calciner	Glovebox structure and E-4 ventilation system and filters Calciner pressure relief device	Operator training and procedures	S1	F3	There is no way of directly detecting this failure
H	15.02	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Pressure/high	Combination failure of high pressure bottle regulator, failure of PRV-230-7 and failure of PRV-230-2 high	Pu oxide powder in calciner	Ceramic offgas filter (all of them) cracking and movement of Pu oxide into scrubber Possible calciner damage by exceeding vessel pressure capacity (airflow exceeds capacity of calciner pressure relief device) with subsequent dispersal of hot Pu oxide contained in the calciner to the glovebox atmosphere - continued release of oxide due to continued cycling of solenoid valves	Calciner pressure relief device Design of system with three outlet paths reduces likelihood of calciner pressurization	Operator detection of color change in scrubber solution Operator observation of bottle pressure regulator output pressure	S1*	F1	Assuming pulsing solenoid valves are capable of withstanding 2000 psig and operating correctly
H	15.03	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Pressure/high	Failure of high pressure bottle regulator, failure of PRV-230-7 and failure of PRV-230-2 high	3/8 inch Pu oxide powder on glovebox floor plus normal Pu oxide concentration in glovebox atmosphere	Very high pressure supplied to blowback accumulator with possibility of accumulator tank failure resulting in compromised glovebox integrity and contamination spread to room 230 Collateral damage to various components within the glovebox (possible destruction of glass tanks, injury to operator, puncture of lexan windows, loss of glovebox confinement) Possible penetration of glovebox by cylindrical missile (loss of confinement) Possible pressurization of glovebox with resulting release of Pu oxide into room atmosphere	Air supply relief valve PRV-230-7 PRV-230-2 blowback air regulator Pressure regulator on bottle air supply Continuous air monitors (CAM)	None	S1*	F?	F? assigned due to lack of information on pressure capability of blowback accumulator What is pressure set point of PRV-230-7?
B	15.04	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Pressure/high	Failure of PRV-230-2 high	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Higher than desired pressure supplied to blowback accumulator with possibility of damaging ceramic offgas filters allowing movement of Pu oxide into scrubber and causing potential pressurization of the calciner and release of Pu oxide, NOx, and acid vapor to glovebox atmosphere	Air supply relief valve PRV-230-7 prevents catastrophic overpressurization of calciner and glovebox Pressure regulator on bottled air supply	Operator detection of color change in scrubber solution	S1	F3	Assumed that this pressure not sufficient to cause calciner pressurization
NA	15.05	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Flow/low	Redundant with supply line pressure low	NA				NA	NA	
NA	15.06	Filter pulsing supply air piping (downstream EV solenoid valves)	Provide supply of air to prevent filter plugging	Flow/high	Redundant with supply line high pressure	NA				NA	NA	

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
H	16.00	Pulse/atomizing air supply upstream of pulse air 3 way valve (EV-230-A)	Contain and route air to pulse air and atomizing air systems	Flow/high	Catastrophic failure of line in glovebox (random failure, seismic event, mechanical impact)	3/8 inch Pu oxide powder on glovebox floor plus normal Pu oxide concentration in glovebox atmosphere	Pressurize glovebox by exceeding glovebox vent capacity with release of contamination to room 230	PRV-230-7 limits ultimate pressure and volumetric flow Continuous air monitor (CAM) in room	Operator observation of glove pressurization	S1*	F2	F2 based on estimated seismic frequency May not get enough airflow through pipe to significantly pressurize the glovebox
XREF	16.01	Pulse/atomizing air supply upstream of pulse air 3 way valve (EV-230-A)	Contain and route air to pulse air and atomizing air systems	All other deviations - see node for filter pulsing supply air piping (downstream EV solenoid valves)		---						
B	16.02	Pulse/atomizing air supply upstream of pulse air 3 way valve (EV-230-A)	Contain and route air to pulse air and atomizing air systems	Time procedure/air pulse timing wrong	incorrect programming of blowback solenoid timers (time between pulses very long)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Plugging of calciner offgas filters with possibility of calciner pressurization and release of Pu oxide, NOx, and acid vapor to glovebox atmosphere	DPS-230-A pressure switch and alarm on high pressure DPT-230-1 and DPT-230-2 delta pressure transducers across calciner filters and recorder 230-1 Glovebox structure and E-4 ventilation system and filters Calciner pressure relief device	Operator training and procedures	S1	F3	
A1-XREF	17.00	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	Flow/high (excessive or continuous)	See scrubber Level/high failure of pH controller (Node 8.03)	---						
A2	17.01	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	Flow/reverse	Pressurize scrubber causing gas to go up feed line	NA	No significant consequence	PRV-230-4 relief pressure is much higher than potential scrubber over pressure Check valve V-84 Calciner pressure relief device Positive displacement pump prevents backflow by inherent design		S1	F1	
J-XREF	17.02	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	Flow/low/no (inadequate to meet process requirements)	See scrubber pH/low (Node 8.14)	---						
J	17.03.a	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	Flow/low/no (inadequate to meet process requirements)	Breach of transfer line	55 gallons of NaOH at 8 M	Spill of caustic solution to room floor and potential spray leak	None	Operator training and procedures	S1*	F3	S1*/F3 for potential spray leak

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
J	17.03.b	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	Flow/low/no (inadequate to meet process requirements)	Breach of transfer line	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Backflow of offgasses from calciner and/or scrubber into room 230	None	Operator training and procedures	S1*	F3	S1* for operator exposure to Pu oxide
J	17.04	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	Pressure/high	V-41 or V-42 closed (the feed pump is a positive displacement pump)	55 gallons of NaOH at 8 M	Line rupture with possible spray leak into room 230 (NaOH aerosols)	PRV-230-4 prevents line rupture. Outflow is routed back into drum	Operator training and procedures	S1*	F3	Is this a pressure regulating valve or a pressure relief valve
I-XREF	17.05	Sodium Hydroxide Feed Supply line downstream of pump P-230-B	Supply NaOH feed to scrubber when scrubber pH drops to 13 thus ensuring adequate removal of acids and NOx from the calciner offgas Contain NaOH solution thereby preventing worker exposure	pH/low	Wrong drum used to supply feed pump (low concentration of NaOH)	———	See scrubber pH/low (Node 8.17)			S1	F3	
A1	18.00	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Leak in chiller recirculation loop outside glovebox (random failures)	NA	Spill of water to floor	None	Operator training and procedures	S0	F3	
A1	18.01	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Leak in chiller line in scrubber	NA	Addition of water to scrubber resulting in high level and reduced pH	Recirculation system has limited volume of liquid available for leakage into unintended areas Scrubber temperature monitoring Chiller temperature monitoring (TI-230-1 and TI -230.2)	None	S0	F3	
XREF	18.02	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Leak in chiller line in scrubber	———	See scrubber Temperature/high (Node 8.10) Loss of cooling to scrubber resulting in decreased removal of water vapor and acid vapor allowing vapors to enter plant vacuum system					
A2	18.03	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Leak in chiller line in scrubber	NA	Introduction of contamination from scrubber solution into the recirculation loop due to the leak in line which results in ALARA/worker exposure concern	TI-230-1 and TI-230-2 on chiller TE-230-5 and recorder for scrubber temperature Chiller line pressure is higher than scrubber solution pressure limiting leakage of NaOH into chiller system	None	S1	F3	Not sure what all of the ramifications are for this event since scrubber may or may not heat up if liquid is continued to be recirculated through chiller (even though it has NaOH in it)

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	18.04.a	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Leak in chiller line in glovebox outside scrubber	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor	Recirculation loop has limited volume to minimize criticality concerns Sump level alarm TI-230-1 and TI-230-2 on chiller TE-230-5 and recorder for scrubber temperature		S1	F3	
I	18.04.b	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Leak in chiller line in glovebox outside scrubber	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Loss of cooling to scrubber resulting in decreased removal of water vapor and acid vapor allowing vapors to enter plant vacuum system	Sump level alarm TI-230-1 and TI-230-2 on chiller TE-230-5 and recorder for scrubber temperature	Operator training and procedures	S1	F3	
I	18.05.a	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Isolation valves in recirculation loop closed (human error)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor	FIC 230-2 TI-230-1 and TI-230-2 on chiller TE-230-5 and recorder for scrubber temperature Vacuum system designed to be resistant to HNO_3 attack	Operator training and procedures	S1	F3	
I	18.05.b	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Isolation valves in recirculation loop closed (human error)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Loss of cooling to scrubber resulting in decreased removal of water vapor and acid vapor allowing vapors to enter plant vacuum system	Scrubber temperature monitoring (TE-230-5 and recorder)	Operator training and procedures	S1	F3	
I	18.06.a	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Failure of refrigeration unit (random failures associated with mechanical and electrical equipment)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor	TI-230-1 and TI-230-2 on chiller TE-230-5 and recorder for scrubber temperature Vacuum system designed to be resistant to HNO_3 attack	Operator training and procedures	S1	F3	
I	18.06.b	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Failure of refrigeration unit (random failures associated with mechanical and electrical equipment)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Loss of cooling to scrubber resulting in decreased removal of water vapor and acid vapor allowing vapors to enter plant vacuum system	TE-230-5 and recorder for scrubber temperature Vacuum system designed to be resistant to HNO_3 attack	Operator training and procedures	S1	F3	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	18.07.a	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Loss of refrigeration unit working fluid (freon leak)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) No scrubbing of NOx and nitric acid vapor, NOx and nitric acid release to process vacuum system, NOx release through stack Accelerated corrosion of vacuum system components due to NOx and nitric acid vapor	TE-230-5 and recorder for scrubber temperature Vacuum system designed to be resistant to HNO_3 attack	Operator training and procedures	S1	F3	
I	18.07.b	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Loss of refrigeration unit working fluid (freon leak)	NOx and nitric acid vapors produced in calciner at injection rate of 4 L/hr	Loss of cooling to scrubber resulting in decreased removal of water vapor and acid vapor allowing vapors to enter plant vacuum system	TE-230-5 and recorder for scrubber temperature Vacuum system designed to withstand exposures to nitric acid and NO_x vapors	Operator training and procedures	S1	F3	
J	18.08	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Lack of sufficient cooling	Loss of refrigeration unit working fluid (freon leak)	NA	Exposure of personnel to refrigeration gas (probably not a health issue unless creates lack of oxygen condition which is of very low likelihood)	E-3 ventilation system	None	S0	F3	Working fluid leak not a significant safety or health hazard
J	19.00	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Level/low	Tank leak (due to corrosion, seismic event, impact, etc.)	Variable quantities of nitric acid solutions at various concentrations	Spill of nitric acid to room floor Potential operator chemical burns	None	Operator training and procedures	S1	F3	Chemical exposure below safety significant concern level
J	19.01	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Level/high	Tank overflow due to operator error	Variable quantities of nitric acid solutions at various concentrations	Spill of nitric acid to room floor Potential operator chemical burns	None	Operator training and procedures	S1	F3	Chemical exposure below safety significant concern level
H	19.02.a	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Flow/reverse	Isolation valve V-5 left open or flush tank being filled at same time allows backflow of PU nitrate solution into chemical addition tank	0-30 L Pu nitrate solution at 450 g/L	Overflow of feed receipt and flush tank during transfer from HC-227S Backflow of Pu nitrate solution from HC-227S in chemical addition tank and increased operator exposure Potential overflow of tank with spill to room floor with Pu aerosol release to room atmosphere and operator exposures Release of NOx offgas from Pu nitrate solution to room atmosphere	Holding capacity of flush tank, feed pump tank, and chemical addition tank Normal transfers from HC-227S are from receipt tank RT-3; normal transfer volume is insufficient to overflow both the feed receipt tank and flush tank; release would require that both tanks contain liquid or that transfer from HC-227S originate from larger batch tank BT-3 Isolation valves on line between chem add tank and flush tank closed except during short periods when flush tank is being charged E-4 ventilation system and filters limit release through stack	Operator training and procedures Operator surveillance of tank levels during filling of feed receipt tank	S1*	F2	Backflow potential depends on relative heights of chemical addition tank and vent catch tank (backflow assumed here) A funnel has been added (since this HAZOP was originally developed) in the line between the flush tank and chemical addition tank that provides air gap and prevents backflow of radiological solutions to the chemical addition tank

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Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
J	19.02.b	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Flow/reverse	Isolation valve V-5 left open or flush tank being filled at same time allows backflow of PU nitrate solution into chemical addition tank	Small quantities of NOx	Overflow of feed receipt and flush tank during transfer from HC-227S Backflow of Pu nitrate solution from HC-227S in chemical addition tank and increased operator exposure Potential overflow of tank with spill to room floor with Pu aerosol release to room atmosphere and operator exposures Release of NOx offgas from Pu nitrate solution to room atmosphere	Holding capacity of flush tank, feed pump tank, and chemical addition tank Normal transfers from HC-227S are from receipt tank RT-3; normal transfer volume is insufficient to overflow both the feed receipt tank and flush tank; release would require that both tanks contain liquid or that transfer from HC-227S originate from larger batch tank BT-3 Isolation valves on line between chem add tank and flush tank closed except during short periods when flush tank is being charged E-4 ventilation system and filters limit release through stack	Operator training and procedures Operator surveillance of tank levels during filling of feed receipt tank	S1*	F2	Backflow potential depends on relative heights of chemical addition tank and vent catch tank (backflow assumed here)
J	19.03.a	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Flow/reverse	Venting of offgases from feed receipt tank, feed pump tank, flush tank or vent catch tank to chem add tank due to open isolation valves (e.g., open V-5)	Small quantities of NOx	Release of NOx to room atmosphere	Glovebox ventilation (E-4) system maintains slight negative pressure which mitigates potential venting through chemical addition tank Two manual isolation valves normally closed except during flushing	Operator training and procedures	S1	F2	
H	19.03.b	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Flow/reverse	Venting of offgases from feed receipt tank, feed pump tank, flush tank or vent catch tank to chem add tank due to open isolation valves (e.g., open V-5)	Vapors in tank head spaces	Release of Pu contamination to room atmosphere	Glovebox ventilation (E-4) system maintains slight negative pressure which mitigates potential venting through chemical addition tank	Operator training and procedures	S1	F2	
J	19.04	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	Temperature/high	chemical reaction in chem add tank due to addition of incompatible chemical to residual nitric acid (from prior flush) in tank	Depends on chemical and quantity	Potential splatter release and worker injury if concentrated NaOH added to tank NOx and other toxic fumes emitted if reducing agent added	None	Operator training and procedures	S1	F3	
A2	19.05	Chemical Addition Tank	Contain solutions for use in flushing calciner feed system	pH/high	NaOH inadvertently added to tank instead of dilute nitric acid	NA	Potential flush of calciner with caustic solution causing cake and slag formation in calciner vessel, plugging of feed nozzle, seizing of calciner agitator operational upset	None	Operator training and procedures	S1	F3	S1 ranking for operator exposures to recover from upset

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	20.00	Plant process air system	Provide compressed air to various air powered pumps and gloveboxes HC-230C-2 and HC-227S	Pressure/low/no	Loss of plant air supply due to various causes (e.g., compressor failure, loss of power to compressor, plant air valved out upstream of calciner glovebox, supply line failures, etc.	Small quantity of scrubber solution	Programmatic impact if P-230-E (solution return pump) inoperable when needed Programmatic impact - inability to collect accurate samples from spent scrub solution receiver tanks if pump P-230-C shut down when needed Potential overflow of phase separator fluid into vacuum system if DOVs 230-H and 230-HB close when required - resulting spread of contaminated caustic solution to vacuum system	Pressure indication on various PRVs on process air supply line Indication of loss of air supply at the MICON control station and at other instrument panels in PFP Vacuum trap high level interlock shuts off caustic feed supply pump to prevent gross overflow into vacuum system Vacuum system seal pots and E-4 HEPA filters mitigate potential radioactive particulate/aerosol release to environment through building exhaust system	Operator monitoring of phase separator and vacuum trap liquid levels Training and procedures for shut down of calcination process on indication of loss of plant air	S1	F3	Transfer pump 227-P-B in HC-227S bleeds down halting Pu nitrate solution transfer to the feed receipt tank in glovebox HC-230C-2 Affect on glovebox ventilation system is unknown. It is assumed that glovebox exhaust flow is maintained at reduced capacity. The following events take place upon air pressure loss: - Valve AOBV-230L opens if previously closed (stays open if already open) ensuring vacuum system flow - Spent scrub solution recirculation pump P-230-D shuts down if in use - Solution return pump P-230-E shuts down if in use at time of air supply failure - Valve DOV-230-H and 230-? close preventing pump down of phase separator on high level - Drain valve DOV 230-F between feed receipt tank and feed pump tank closes preventing draining of feed receipt tank - Valve AOBV-230-J in supply line to feed receipt tank closes cutting off Pu nitrate solution transfer from HC-227S - Transfer pump 227-P-B in HC-227S bleeds down halting Pu nitrate solution transfer to the feed receipt tank in glovebox HC-230C-2

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
I	20.01	Plant process air system	Provide compressed air to various air powered pumps and gloveboxes HC-230C-2 and HC-227S	Flow/low/no	Loss of plant air supply due to various causes (e.g., compressor failure, loss of power to compressor, plant air valved out upstream of calciner glovebox, supply line failures, etc.)	Small quantity of scrubber solution	Programmatic impact if P-230-E (solution return pump) inoperable when needed Programmatic impact - inability to collect accurate samples from spent scrub solution receiver tanks if pump P-230-C shut down when needed Potential overflow of phase separator fluid into vacuum system if DOVs 230-H and 230-? close when required - resulting spread of contaminated caustic solution to vacuum system	Pressure indication on various PRVs on process air supply line Indication of loss of air supply at the MICON control station and at other instrument panels in PFP Vacuum trap high level interlock shuts off caustic feed supply pump to prevent gross overflow into vacuum system Vacuum system seal pots and E-4 HEPA filters mitigate potential radioactive particulate/aerosol release to environment through building exhaust system	Operator monitoring of phase separator and vacuum trap liquid levels Training and procedures for shut down of calcination process on indication of loss of plant air	S1	F3	Transfer pump 227-P-B in HC-227S bleeds down halting Pu nitrate solution transfer to the feed receipt tank in glovebox HC-230C-2 Affect on glovebox ventilation system is unknown. It is assumed that glovebox exhaust flow is maintained at reduced capacity. The following events take place upon air pressure loss: - Valve A0BV-230L opens if previously closed (stays open if already open) ensuring vacuum system flow - Spent scrub solution recirculation pump P-230-D shuts down if in use - Solution return pump P-230-E shuts down if in use at time of air supply failure - Valve DOV-230-H and 230-? close preventing pump down of phase separator on high level - Drain valve DOV 230-F between feed receipt tank and feed pump tank closes preventing draining of feed receipt tank - Valve AOBV-230-J in supply line to feed receipt tank closes cutting off Pu nitrate solution transfer from HC-227S - Transfer pump 227-P-B in HC-227S bleeds down halting Pu nitrate solution transfer to the feed receipt tank in glovebox HC-230C-2
K	21.00.a	Calciner bottled compressed air supply	Safely contain pressurized air Supply filter pulse air and atomizing air to VDC	Containment/breach	Failure of air bottles or supply valves due to mechanical impact or other manufacturing flaws	3/8 inch Pu oxide powder on bottom of glovebox	High pressure gas release to corridor and collateral damage to facility and equipment due to bottle "missile"	Bottle design limits potential for spurious failures Bottle racks minimize potential for bottle to topple or be impacted by other objects Zone 3 ventilation system and building limit ultimate release of radioactive material to the atmosphere should confinement boundaries be compromised	Operator training and procedures regarding the handling, storage and setup of compressed gases	S1*	F2	Other safety functions and failure modes for compressed air supply are addressed elsewhere in this table--see nodes associated with pulse air system and calciner injector nozzle
H	21.00.b	Calciner bottled compressed air supply	Safely contain pressurized air Supply filter pulse air and atomizing air to VDC	Containment/breach	Failure of air bottles or supply valves due to mechanical impact or other manufacturing flaws	Pu oxide in glovebox atmosphere	Potential severe operator injury Potential missile impact into gloveboxes after penetrating RMC line wall	Bottle design limits potential for spurious failures Bottle racks minimize potential for bottle to topple or be impacted by other objects	Operator training and procedures regarding the handling, storage and setup of compressed gases	S1*	F2	

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K	21.00.c	Calciner bottled compressed air supply	Safely contain pressurized air Supply filter pulse air and atomizing air to VDC	Containment/breach	Failure of air bottles or supply valves due to mechanical impact or other manufacturing flaws	Radioactive material contained in RMC line area	Potential damage to facility walls and processing equipment leading to spread of radioactive material from Zone 4 and 3a areas to less contaminated areas and facility worker exposures	Bottle design limits potential for spurious failures Bottle racks minimize potential for bottle to topple or be impacted by other objects Zone 3 ventilation system and building limit ultimate release of radioactive material to the atmosphere should confinement boundaries be compromised	Operator training and procedures regarding the handling, storage and setup of compressed gases	S1*	F2	
B	21.01	Calciner bottled compressed air supply	Safely contain pressurized air Supply filter pulse air and atomizing air to VDC	Composition/other than standard air	Bottles containing pure oxygen installed in place of bottles containing air - human error	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Potential catastrophic damage to calciner due to accelerated oxidation of vessel and nozzle with release of Pu oxide to the glovebox if vessel seals or body fail Potential for excessive heating in glovebox from heat produced by accelerated oxidation process	Thermocouples measuring temperature in calciner Bottle threads are different for different bottles to prevent hookup of wrong bottle	Bottles are color coded and marked Training of plant personnel	S1	F3	
A1	21.02	Calciner bottled compressed air supply	Safely contain pressurized air Supply filter pulse air and atomizing air to VDC	Composition/other than standard air	Bottles containing non oxidizing gasses installed in place of bottles containing air - human error	NA	No apparent consequence - the chemistry of the calcination process does not require additional oxygen to produce Pu oxide from Pu nitrate	Bottle threads are different for different bottles to prevent hookup of wrong bottle	Bottles are color coded and marked Training of plant personnel	S0	F3	
XREF	21.03	Calciner bottled compressed air supply	Other failures addressed previously in this table	Containment/breach		———						
A1	22.00	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids in critically safe manner Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/low (excessive vacuum)	E-4 exhaust system imbalance (dampers in E-4 system set incorrectly or dampers fail open) Failure of dry air supply to RMC line gloveboxes (air supplied via conveyer glovebox HC-2)	NA	No significant consequence-- glovebox not expected to fail at credible vacuums	Glovebox to room DP gauge Self regulating valve on dry air supply to RMC line	Procedure requires operator to verify glovebox to room DP prior to initiating glovebox operations	S0	F3	
NA	22.01	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids in critically safe manner Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/low (excessive vacuum)	Damper control failures in E-5 reduce pressure in both E-4 and E-3 areas	NA	NO significant consequences as relative pressure difference maintained			NA	NA	

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
H	22.02	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--DP between room and glovebox > -0.5 in W.G)	Ventilation imbalance between Zone 3 and Zone 4 (dampers in E-4 and/or E-3 ventilation set or modulated incorrectly)	Pu oxide in glovebox atmosphere	Potential for reverse flow through glovebox penetrations to room 230; contamination spread to room 230	Glovebox connected to multiple gloveboxes and their exhausts minimizing potential for glovebox to go more positive than Zone 3 Glovebox structure and penetration design minimizes potential contamination spread should room pressure drop below glovebox pressure Glovebox to room DP gauge CAMS in room 230 to detect contamination spread Emergency exhaust dmpr valves in RMC line open at vacuum in RMC line gloveboxes approach -0.5 in w.g.	Procedure requires operator to verify glovebox to room DP prior to initiating glovebox operations (procedures Z0-190-502 and Z0-190-506)	S1	F3	
NA	22.03	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--DP between room and glovebox > -0.5 in W.G)	Damper control failures in E-3 increase pressure in both E-4 and E-3 areas	NA	No contamination spread--relative pressure in glovebox still more negative than room pressure			S0	F3	
H	22.04	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--DP between room and glovebox > -0.5 in W.G)	Plant air or compressed air leak inside glovebox (catastrophic line failure and possibly air regulator failures)	Pu oxide in glovebox atmosphere	Contamination spread to room 230C through glovebox seals and penetrations blow out gloves	Glovebox HC-230C-2 connected to conveyor system and other gloveboxes providing large volume for compressed gases to expand into Pressure gauges on plant air and compressed air lines Glovebox to room DP gauge	Operator/audio detection of catastrophic leak	S1*	F2	S1* based on potential operator exposure to airborne Pu
XREF	22.05	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--DP between room and glovebox > -0.5 in W.G)	Pressurized releases from calciner due to various causes	———	See calciner Pressure/high (Nodes 6.08-6.14)					

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
XREF	22.06	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--DP between room and glovebox > -0.5 in W.G)	Releases from other glovebox tanks due to chemical reactions	———	See nodes for glovebox tanks previously in table					Total volume of HC-230C-2 glovebox, conveyer glovebox and other connected gloveboxes minimize potential for pressurization as does E-4 ventilation system capacity
H	22.07	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high	Imbalance between exhaust from and dry air supply to RMC line gloveboxes caused by: - Loss of exhaust flow (resulting from exhaust fan failures, damper closures, etc.) combined with continued dry air supply to conveyer glovebox or - Excessive dry air supply to the RMC line due to dry air supply regulator failure	Pu oxide in glovebox atmosphere	Pressurization of HC-230C-2 glovebox (and other gloveboxes in the RMC line) with spread of contamination to Zone 3 areas (e.g., room 230C)	Dry air supply and E-4 exhaust system instrumentation HC-230C-2 glovebox pressure gauge and indicator Exhaust system damp valves open as RMC line glovebox vacuum approaches -0.5 inches w.g. Self regulating valve on dry air supply to RMC line	Operator training and procedures regarding glovebox and ventilation system instrument readings and alarms	S1*	P3	HC-230C-2 is connected to other RMC line gloveboxes via conveyor gloveboxes HC-3 and HC-2
F	22.08.a	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Fire in room 230 due to ignition of combustibles in the room	Total inventory of Pu in glovebox	Potential loss of confinement by glovebox breach by failure of seals, windows, gloves, etc.	Room fire suppression system Glovebox dry fire suppression system Glovebox constructed primarily of metal and has fire resistance windows	Housekeeping procedures limit combustible loading	S1*	P2	S1*/P2 ranking for fire that engulfs glovebox
XREF	22.08.b	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Fire in glovebox (due to loss of control of calciner heaters, or combustibles in contact with hot equipment described previously in table)	———	See calciner temp/high (Node 6.18) See feed pump temperature/high (Node 4.06)					

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
D-XREF	22.09	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Butene explosion in calciner causes release of hot gases, steam, and very hot PU oxide to glovebox atmosphere	———	See calciner temperature/high (Node 6.10)					
XREF	22.10	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Overheated calciner due to temperature control failures on calciner heaters	———	See calciner temperature/high (Nodes 6.17-6.20)					
XREF	22.11	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Thermal degradation of materials and components inside glovebox such as flexible hose, electrical wiring insulation, elastomer gloves, elastomeric seals, etc.	———	Electrical shock hazard to operator during manual operations inside glovebox Possible failure of pump seals allowing sprays and leaks of material being pumped	Glovebox temperature elements and recorders E-4 ventilation system instrumentation Procurement specifications requiring materials placed in glovebox be able to survive the environment Glovebox gloves act as insulator Electrical equipment has protective switch gear to trip on faults	Operator training and procedures	S1*	F3	S1* based on possibility of electrocution
H	22.12	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Loss of glovebox ventilation (loss of E-4 exhaust fans or exhaust path valved closed) Loss of dry air supply to RMC line reduces airflow through glovebox	Pu oxide in glovebox atmosphere	Heat given off by calciner and piping surfaces increases temperature in the glovebox Glovebox confinement boundary potentially compromised due to thermal expansion of structural components and effect on heat on glovebox seals	Glovebox temperature elements and recorders Room Cams to detect spread of contamination from glovebox Glovebox pressure gauges, indicators and annunciators E-4 ventilation system instrumentation Glovebox HC-230C-2 connected via conveyor glovebox HC-2 to several other RMC line gloveboxes, providing additional volume for thermal expansion of air	Operator training and procedures regarding glovebox and ventilation system instrument readings and alarms	S1	F3	Significant pressurization of glovebox not expected due to expansion volume provided by other connected gloveboxes

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HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
NA	22.13	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Liquid level/low/no	Intended condition	NA				NA	NA	
XREF	22.14	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Level/high	Spills of Pu nitrate solution, caustic makeup solution, scrubber solution, spent scrubber solution, flush solution, or Pu oxide due to various vessel failure modes	_____	See prior nodes relating to solution spills					
XREF	22.15	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Glovebox fire	_____	See calciner temp/high (Node 6.18) See feed pump temp/high (Node 4.06)					
D-XREF	22.16	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Calciner butene explosion	_____	See calciner pressure/high (Node 6.10)					
H-XREF	22.17	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Accumulator rupture damages containment	_____	See pulse air system pressure/high (Node 15.03)					

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
H	22.18.a	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Bag in /bag out operation allows spread of contamination to room 230	Minor quantities of Pu oxide powder	Minor spread of contamination to room and possible operator exposure	CAMs in room E-4 ventilation maintains sufficient negative pressure and face velocity to prevent contamination migration PRV regulating valve on air inlet to conveyer glovebox closes on increased glovebox pressure ensuring glovebox negative pressure is maintained despite flow path into glovebox	Operator training and procedures	S1	F3	
H	22.18.b	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	External impact on glovebox by moving object (hand truck, tool, etc.)	Pu oxide in glovebox atmosphere	Potential loss of glovebox confinement (due to breach of glove or window) with release of contamination to room	Sturdy metal glovebox design Glovebox has seismically qualified tiedown to the room floor preventing toppling Glovebox structure is seismically qualified to withstand design basis earthquake	Procedures governing use of material handling equipment Personnel training and procedures regarding the use of items that could cause glovebox breach	S1	F3	S1/F3 ranking for minor contamination spread to room Glovebox is assumed to remain upright due to support structure being bolted to floor
E	22.19	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox	Fissile material/Excess accumulation	Spills of fissile material not cleaned up or not completely cleaned up resulting in accumulation of fissile material Pu accountability errors Accumulation of containers of Pu due to conveyer belt failure with continued processing of Pu nitrate	NA	Potential for criticality		Operator training and procedures regarding the cleanliness of the glovebox Observation of material buildup Criticality prevention specifications	S1*	F1	
A2	22.20	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Radioactive material/excess accumulation	Spills of radioactive material not completely cleaned up resulting in accumulation of radioactive material in glovebox	3/8 inch layer Pu oxide powder on glovebox floor	Potential for significant ionizing radiation fields around glovebox and increased operator exposure	Glovebox has built-in lead shielding	Operator training and procedures regarding glovebox housekeeping Periodic radiation surveys	S1	F3	S1 based on ALARA concerns

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	22.21	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minim	Confinement integrity/water intrusion	Flood in room 230 due to activation of room fire suppression system	NA	Potential initiator for criticality	Glovebox support structure elevates glovebox several feet above floor Glovebox top is sealed No open paths in top of glovebox for water intrusion (exhaust duct is seismically qualified) Vessels in glovebox are designed to be geometrically unfavorable to criticalities even if fully moderated Glovebox criticality drain	Mass of fissile material controlled by crit specifications and procedures Specifications require use of movable vessels with shapes and volumes that are criticality unfavorable	S1*	F1	If large ingress of fire water occurs criticality drain may not keep up with flowrate Are there drains in this room? Potential ingress of water in other parts of the RMC line should be investigated.
NA	22.22	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minim	Confinement integrity/explosion external to glovebox	Explosion in room 230 due to ignition of bottled heating gasses (portable torch system)	NA	Addressed in PFP FSAR Section 9.2.1F					
H	22.23	Glovebox HC-230C-2	Provide confinement of gasses and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minim	Confinement integrity/water intrusion	Flood in room 230 due to activation of room fire suppression system	Pu oxide powder in calciner	Potential for spread of Pu oxide to room 230	Glovebox support structure elevates glovebox several feet above floor Glovebox top is sealed Room CAMs alert workers to airborne hazard	Operator training	S1	F3	
H	23.00	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/low/no	Loss of E-4 exhaust fans loss of power	Pu oxide in glovebox atmosphere	Stagnation of glovebox with possible contamination release to room 230 (assumes that some contamination exists in the glovebox at all times) Overheating glovebox due to no air movement in box resulting in migration of contamination to room	CAMs in room Ventilation system failure alarm Glovebox temperature detection elements and recorders Glovebox pressure indication	Operator training and alarm response procedures Procedure requires checking dP before working in glovebox	S1	F3	S1 based on simple migration of contamination
H	23.01	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/low/no	Plugged glovebox E-4 exhaust filter	Pu oxide in glovebox atmosphere	Overheating glovebox due to no air movement in box resulting in greater migration of contamination to room	Other gloveboxes in communication with conveyer system sustain negative pressure on the system Glovebox high temperature alarm and calciner heater shutdown interlock	Operator training and alarm response procedures Procedure requires checking dP before working in glovebox	S1	F3	Overheating glovebox due to no air movement in box (glovebox remains negative with respect to room due to communication with conveyer glovebox)

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
H	23.02	B-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/low/no	B-3 or E-4 flow dampers closed or set incorrectly	Pu oxide in glovebox atmosphere	Overheating glovebox due to no air movement in box resulting in greater migration of contamination to room	Glovebox pressure gauge and indicator Ventilation system instrumentation (E-3 and E-4 systems) Glovebox high temperature alarm and calciner heater shutdown interlock	Operator training and alarm response procedures Procedure requires checking dP before working in glovebox	S1	F3	
H	23.03	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/low/no	Dry air supply PRV in glovebox HC-2 fails to regulate inlet flow to RMC line to setpoint value (fails closed)	Pu oxide in glovebox atmosphere	Overheating glovebox due to no air movement in box resulting in greater migration of contamination to room	Other gloveboxes in communication with conveyer system main. negative pressure on the system Glovebox high temperature alarm and calciner heater shutdown interlock	Operator training and alarm response procedures Procedure requires checking dP before working in glovebox	S1	F3	
A1	23.04	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	E-4 ventilation system exhaust dampers open fully	NA	No significant effect		Operator training and procedures Procedure requires checking dP before working in glovebox	S0	F3	
A1	23.05	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	Failure of glovebox gloves or windows	NA	No significant effect		Operator training and procedures	S0	F3	
A1	23.06	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	Gross failure of compressed instrument air piping or gross failure of plant compressed air system	NA	No significant effect	Piping design of compressed air supply PRVs on plant and compressed air supplies limit potential flowrates	Operator training and procedures	S0	F3	Pressurization of glovebox not expected unless bottled air supply PRVs fail. Even then line so small probably can't cause pressurization
H	23.07	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	Dry air supply PRV to RMC-RMA conveyor fails to regulate inlet flow to RMC line to setpoint value (fails open)	Pu oxide in glovebox atmosphere	Potential pressurization of RMC line gloveboxes with release of contamination to Zone 3 areas	Room CAM Glovebox pressure indication E-3 ventilation system and HEPA filters		S1	F3	

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
B	23.08	E-4 exhaust duct at outlet of Glovebox HC-230C-2	Prevents movement of contamination from glovebox to room 230 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Filtration/lack of	Glovebox exhaust filter failure	Normal concentration of Pu in glovebox atmosphere	Elevated contamination release to E-4 system (normal operation) Elevated Pu oxide, Pu nitrate aerosol release to E-4 system if failed filter in place at time of process upsets identified elsewhere in this table	E-4 stage 1 HEPA filters (in duct level) Final E-4 ventilation system filters to limit release to environment Stack exhaust CAM	Periodic aerosol testing of E-4 exhaust filters	S0	F3	S0 based on no significant release through stack due to safety class E-4 filters
B	23.00	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Containment/lack of	Spill during transfer of collection jar contents to slip lid can	Less than 5 kg Pu oxide powder	Release of Pu oxide particulate to glovebox atmosphere	glovebox exhaust filter E-4 exhaust system filters (2 stages) Glovebox structure, seals, and E-4 exhaust to maintain confinement	Operator training and procedures	S1	F3	
B	24.01	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Containment/lack of	Drop or topple slip lid can during movement to conveyer Slip lid can toppled by air line leak; entrained Pu oxide in glovebox atmosphere	2.5 kg Pu oxide powder	Release of Pu oxide particulate to glovebox atmosphere	Glovebox exhaust filter E-4 exhaust system filters (2 stages) Glovebox structure, seals, and E-4 exhaust to maintain confinement	Operator training and procedures	S1	F3	
B-XREF	24.02	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Confinement/lack of	Broken product collection jar while connected to calciner	———	Spill of Pu oxide to glovebox atmosphere Inrush of air into calciner	See calciner confinement/low (Node 6.30)				
B-XREF	24.03	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Confinement/lack of	Improperly attached product collection jar while processing occurring in calciner	———	Spill of Pu oxide to glovebox atmosphere Inrush of air into calciner	See calciner confinement/low (Node 6.31)				
NA	24.04	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Temperature/high	Normal condition of the product collection jar while collecting Pu oxide from calciner process	NA	NA			NA	NA	
G	24.05	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Temperature/high	Inadequate time allowed for cooling prior to transferring Pu oxide to convenience can	NA	Operator burns	None	Operator training and procedures	S1	F3	
XREF	24.06	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Temperature/high	Inadequate time allowed for cooling prior to transferring Pu oxide to convenience can	———	Small fire in glovebox if combustibles in glovebox (gloves, rags, egg cartons) contact hot can	See calciner Temperature/high (Node 6.18) See feed pump Temperature/high (Node 4.06)				

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
G	24.07	Product collection jars and slip lid convenience cans (handling within glovebox and transfer to conveyor system)	Contain Pu oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Temperature/high	Failure to use high temperature gloves while removing product collection jar from calciner drop pipe	NA	Melt gloves and burn operator	None	Operator training and procedures	S1	F3	
B	25.00	Vacuum sensing line between calciner and vacuum regulator valve VRV-230-1	Transmit accurate calciner vacuum signal to vacuum regulator valve	Vacuum/not representative	Solenoid valve EV-230-C remains closed following pressure pulse through ceramic filter (due to valve failure or controller failure)	Pu oxide contained in calciner and nitric acid vapor from 4 L/hr injection rate	Pressure rise in calciner not corrected by vacuum regulating valve VRV-230-1; potential overpressurization of calciner with release of NOx, Pu oxide, acid vapor and steam to glovebox atmosphere through pressure relief cap	Glovebox structure and E-4 ventilation system and filters maintain confinement and mitigate radiological releases through the building exhaust stack	None	S1	F3	
L	25.01	Vacuum sensing line between calciner and vacuum regulator valve VRV-230-1	Transmit accurate calciner vacuum signal to vacuum regulator valve	Vacuum/not representative	Solenoid valve EV-230-C remains closed following pressure pulse through ceramic filter (due to valve failure or controller failure)	4.5 kg/can Pu oxide powder	Higher pressures in calciner may force steam back into Pu oxide bed causing wet Pu oxide powder to be produced Potential for canister ruptures in storage vault	TGA testing prior to oxide canning Storage vault ventilation system and filters mitigate potential release to the environment	None	S1*	F3	
L	25.02	Vacuum sensing line between calciner and vacuum regulator valve VRV-230-1	Transmit accurate calciner vacuum signal to vacuum regulator valve	Vacuum/not representative	Solenoid valve EV-230-C fails to close during pulse cleaning of ceramic filters due to valve failure, timer failure or controller failure	4.5 kg/can Pu oxide powder	High pressure pulses travel down sensing line causing vacuum regulator to cycle resulting in vacuum fluctuations in calciner Vacuum fluctuations may cause increased particle loading on filters with subsequent plugging and momentary or continuous pressurization of the calciner vessel with release of Pu oxide and NOx to the glovebox atmosphere through the calciner relief cap, and inconsistent Pu oxide product that doesn't meet stabilization criteria	Glovebox structure and E-4 ventilation system and HEPA filters maintain confinement and mitigate radiological releases through the building exhaust stack Differential pressure indication across ceramic filters and between the calciner vessel and the glovebox atmosphere (DPT 230-1, DPT 230-2, and DP recorder DPR 230-1)	Visual detection of steam in product collection jar or surging in phase separator tank	S1	F3	
L	25.03	Vacuum sensing line between calciner and vacuum regulator valve VRV-230-1	Transmit accurate calciner vacuum signal to vacuum regulator valve	Vacuum/not representative	Solenoid valve EV-230-C fails to close during pulse cleaning of ceramic filters due to valve failure, timer failure or controller failure	4.5 kg/can Pu oxide powder	Vacuum fluctuations may result in the production of Pu oxide that does not meet stabilization criteria for moisture content Potential subsequent canister ruptures during storage	TGA testing prior to oxide canning B-3 ventilation system and HEPA filters mitigate potential release during handling of canisters in the 234-5Z building Storage vault ventilation and HEPA filters mitigate potential release to the environment during storage	Operator training and procedures regarding TGA testing Visual detection of "steam" in product collection jar or surging in phase separator tank	S1*	F3	S1* based on exposure from canister ruptures

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
L	25.04	Vacuum sensing line between calciner and vacuum regulator valve VRV-230-1	Transmit accurate calciner vacuum signal to vacuum regulator valve	Vacuum/not representative	Solenoid valve EV-230-C fails to close during pulse cleaning of ceramic filters due to valve failure, timer failure or controller failure	4.5 kg/cm Pu oxide powder	Open valve allows solids to contaminate sensing line making vacuum control erratic Plugged line may result in persistent excessive vacuum in calciner (no significant safety problems identified) or persistent overpressurization of calciner		Visual detection of "steam" in product collection jar or surging in phase separator tank	S1*	F3	S1* based on exposure from canister ruptures
NPH	1000.1.00	NA	NA	NA	Seismic event	Pu contained in calciner glovebox, nitric acid, 55 gallons NaOH	The seismic event has multiple consequences. The PFP FSAR has an existing seismic event analysis in Chapter 9.0. The calciner glovebox will be evaluated to determine the additional source term that should be added to the existing analysis.					
XTRN	1000.2.00	NA	NA	NA	Facility wide loss of power	———	The effects on the PFP due to a loss of facility power is not significantly altered by the addition of the calciner glovebox to PFP. The effects of loss of power to the HC-230C-2 glovebox as an internal event are addressed in this HAZOP.					
NPH	1000.3.00	NA	NA	NA	Ash fall	NA	The effects of Ash Fall on the PFP are described in Chapter 3.0 of the PFP FSAR. In general, ashfall represents a roof loading concern, abrasive concern to moving equipment, and an electrical concern due to the conductivity of the ash. The addition of the HC-230C-2 glovebox does not significantly alter the effects of ashfall on the PFP.					
XTRN	1000.4.00	NA	NA	NA	Range fire	———	A range fire can affect facility power supply and may represent a fire threat to Building 234-5Z. The affects of fires has been analyzed in Chapter 9.0 of the PFP FSAR. The addition of the HC-230C-2 glovebox does not significantly change the results of the existing fire analysis. Fires initiated internally to the glovebox are addressed in this HAZOP.					

Table 9D-4

HazOp of Vertical Denitration Calciner Process

Bin ID[1]	Node ID	Node Description	Design Function	Parameter/Guide Word	Possible Causes/ Hazardous Event	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[2]	Freq Cat[3]	Remarks
NPH	1000.5.00	NA	NA	NA	High wind	NA	The effects of High Wind on PFP are described in Chapter 3.0 of the PFP FSAR. The addition of the HC-230C-2 glovebox does not materially affect the consequences of high wind.					
XTRN	1000.6.00	NA	NA	NA	Aircraft crash	———	Impact with PFP is considered to be incredible when flight restrictions prohibit helicopter operation in proximity to the PFP, see FSAR Section 9.2.7					

1. Hazards binning ID key:

A1	Process Upset - programmatic impact only
A2	Programmatic impact with increased worker exposures during recovery
B	Spill or leak or other release inside glovebox - that does not challenge glovebox confinement
C	Radiological release in Zone 3 area
D	Deflagration in calciner
E	Criticality hazard
F	Glovebox fire (internally initiated) or very high temperature due to calciner loss of temperature control
G	Industrial hazards
H	Glovebox loss of confinement/containment (due to internal events) excludes categories D's and F's
I	Scrubber solution, acid solution, or elevated NOx release to process vacuum system
J	Chemical release to Zone 3
K	Potential severe worker injury due to industrial hazard
L	Production of out of specification Pu oxide with potential for storage canister ruptures
NA	Node is used as a place keeper - the result of the deviation is not of concern
NPH	Natural Phenomena initiator: Seismic event, Ash Fall, and High Wind
XREF	Node causes/consequences/features are cross referenced to other nodes
XTRN	Event external to the facility (non facility related initiator that are not Seismic, Ashfall, or High Wind)

2. Consequence category is based on "no controls".
3. Frequency category is based on "no controls".

References Used During HAZOP

Documents:

HNF-SD-CP-SDD-021, Rev 0, DRAFT, JF Durnil and CD Meng, System Design Description For PFP Vertical Denitration Calciner

WHC-SD-CP-ER-043, EDT 613534, BL Aftanas, DRAFT, Engineering Report (Conceptual Design) PFP Solution Stabilization

OSD-Z-184-00013 Rev I-3, Operating Specifications for Plutonium Finishing Plant

Internal Memo 15F00-96-032, CS Sutter to EC Vogt, Summary Reports of the Solution Stabilization Testing Performed in Support of 94-1 Program Activities

WHC-SD-CP-TA-009, EDT 700526, Jan 29, 1996, FD Fisher, Technical Assessment of the PFP Vertical Denitration Calciner

WHC-SD-CP-PHA-004, EDT 700526, Jan 27, 1996, JF Durnil, HAZOP, Liquid Scrap Utilization, Vertical Denitration Calciner, VDC

PFD-Z-300-002, Rev A-0, Undated, AM Stubbs, Plutonium Finishing Plant Process Flow Document, Plutonium Nitrate Ion Exchange Process PFP Room 228A

WHC-SD-CP-SAR-021, Rev 0, Plutonium Finishing Plant Final Safety Analysis Report

WHC-SD-CP-FDC-003, EDT 613533, 3/20/96, DL Koreis, Functional Design Criteria PFP Solution Stabilization

Procedures:

Z0-060-308, Z0-188-002, Z0-188-012, Z0-188-015, Z0-188-020, Z0-190-502, DRAFT, Z0-190-503, DRAFT, Z0-190-504, DRAFT, Z0-190-505, DRAFT, and CPS-Z-165-80601.

Drawings:

H-2-3994, H-2-16132, H-2-19955, H-2-20950, H-2-26101, H-2-26104, H-2-26106, H-2-26108, H-2-26417, H-2-26418, H-2-28440, H-2-28818, H-2-58129, H-2-80310, H-2-80312, H-2-96418 Sheets 1 through 13, H-2-93504 as modified by ECN 636624, 12/10/96, H-2-95623 Sheets 1 through 4, H-2-95624 Sheets 1 through 6, H-2-95926, H-2-140541, H-2-140544 Sheets 1 through 6

APPENDIX 9E

CALCULATION OF RUPTURED COMPRESSED AIR CYLINDER ACCELERATION, VELOCITY, AND TRAVEL DISTANCE AS A FUNCTION OF TIME

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9E.1 PURPOSE

One of the accidents considered in this FSAR is a handling accident involving a compressed air cylinder being brought into the 234-5Z Building to support operation of the Vertical Denitration Calciner. The postulated handling accident results in the supply valve being sheared off the cylinder. In such an accident, compressed air expelled from the cylinder through the sheared off supply valve would cause the cylinder to accelerate as a missile, potentially injuring facility workers and causing damage to the facility. Clearly, a ruptured cylinder presents a significant hazard to facility workers. The purpose of this appendix is to develop the equations for estimating the cylinder's potential momentum as a function of distance from the point of the handling accident, to allow an assessment of potential damage to the facility to be made.

Specifically provided in this appendix are the calculations for determining the compressed air cylinder's acceleration, velocity, and travel distance as a function of time after the supply valve is sheared off. The cylinder's velocity within a reasonable distance from the point of a potential handling accident inside the PFP is used in Section 9.2.9.3 to determine if vault walls protecting radiological material within the PFP can be penetrated.

9E.2 METHODOLOGY

Equations for Estimating Cylinder Acceleration As a Function of Time

At any given time, the thrust produced by the compressed air expelled through the sheared off supply valve is equal to the product of the mass ejection rate and the velocity of the expelled gases relative to the cylinder missile:

$$\text{Thrust} = - v_a \, (dM_a/dt)$$

where,

v_a = velocity of the expelled air relative to the velocity of the cylinder
M_a = mass of air in the cylinder
dM_a/dt = mass ejection rate of air from the cylinder

The sign in the above equation is negative because the gas is ejected in the opposite direction to the thrust force on the cylinder.

The acceleration, a, of the cylinder at any given time is equal to the thrust force divided by the mass of the cylinder and its contained air at that instant:

$$a = - v_a \, (dM_a/dt)/(M_c + M_a) \qquad \text{(Eqn. 1)}$$

where, M_c = mass of the cylinder, without air.

M_a and dM_a/dt change with time as the cylinder depressurizes and the air is expelled from the cylinder. The following equation (equation 3-22, from Crane 1985) can be used to estimate dM_a/dt:

$$dM_a/dt = 0.525\, Y d_1^2\, C \sqrt{\frac{\Delta P}{V_s}} \qquad \text{(Eqn. 2)}$$

where,

dM_a/dt = mass flowrate of air from the cylinder, in lb/s
d_1 = diameter of the orifice, in inches
Y = net expansion factor for compressible flow through the orifice, constant while flow through orifice is sonic
C = flow coefficient for the orifice, constant for a given sized orifice
ΔP = pressure drop across the orifice, in psi
V_s = specific volume of gas expelled, in ft^3/lb

The expansion factor Y is a function of the specific heat ratio, k, of the air, the ratio of the orifice or throat diameter to inlet diameter, ß, and the ratio of downstream to upstream absolute pressures. k is a constant for a given gas. ß is constant for a given orifice or throat. In this case, air flow through the sheared off supply valve will be choked, limited to sonic velocity, while the majority of the cylinder depressurization. Hence, the pressure drop across the orifice is constant over most of the accident and Y can be treated as a constant as well. The value of Y used in the analysis is provided in Section 9E.4 (Input Data). The flow coefficient C is also a constant for a given orifice or throat, dependent only on ß, provided flow is turbulent through the orifice.

The pressure drop for choked flow of compressible gas through an orifice or nozzle is given by (see pg. A-21 of Crane):

$$\Delta P = P_1(1 - r_c) \qquad \text{(Eqn. 3)}$$

where P_1 equals the pressure of the air in the cylinder and r_c equals the critical pressure ratio. The critical pressure ratio is the largest ratio of downstream pressure to upstream pressure capable of producing sonic velocity. Flow in this case is sonic until $P_1(n) \times r_c = 14.7$ psi. It will be shown that r_c in this case is 0.527, so flow is sonic until cylinder pressure drops below 28 psia (14.7 psia/0.527).

V_s can be related to P_1 using the ideal gas law, as follows:

$$V_s = R\, T/(144\, M_w\, P_1) \qquad \text{(Eqn. 4)}$$

where R is the universal gas constant, 1545 ft-lb_f/lbmole-R, M_w equals the molecular weight of air, 28.8 lb_m/lbmole, T equals the absolute temperature of the gas in degrees Rankine (given in Section 9E.4), and the constant 144 converts the pressure term, P_1, from psi to lb/ft^2.

Substituting Equations 3 and 4 into Equation 2 gives:

$$dM_a/dt = - 0.525\ Y\ d_1^2\ C\ (P_1^2\ M_w\ 144\ (1 - r_c)/(R\ T))^{1/2} \qquad \text{(Eqn. 5)}$$

P_1 can in turn be converted to a mass basis also using the ideal gas law:

$$P_1 = (M_a\ R\ T/(M_w\ V_1\ 144)) \qquad \text{(Eqn. 6)}$$

where V_1 equals the interior volume of the cylinder, in ft^3.

Substituting equation 6 into equation 5 gives:

$$dM_a/dt = - 0.525\ Y\ d_1^2\ C \sqrt{\frac{M_a^2\ R\ T\ (1-r_c)}{M_w\ V_1^2\ 144}}$$

Simplifying the above equation gives:

$$dM_a/dt = - K\ M_a \qquad \text{(Eqn. 7)}$$

where,

$$K = 0.525\ Y\ d_1^2\ C\ [R\ T\ (1 - r_c)/(M_w\ V_1^2\ 144)]^{1/2}$$

Separating variables and integrating Eqn. 7 gives:

$$M_a(t) = M_{a,o}\ e^{-Kt} \qquad \text{(Eqn. 8)}$$

where $M_a(t)$ denotes the mass of air in the bottle as a function of time, $M_{a,o}$ equals the initial mass of air in the cylinder (at t = 0, when the cylinder is completely full), and t is the time in seconds after the supply valve has been sheared off the cylinder.

Substituting Eqn. 8) into Eqn. 1) gives:

$$a(t) = - [M_{a,o}\ v_a/(M_c + M_{a,o}\ e^{-Kt})]d(e^{-Kt})/dt$$

However, $d(e^{-Kt})/dt = -K\ e^{-Kt}$; therefore:

$$a(t) = M_{a,o}\ v_a\ K\ e^{-Kt}/(M_c + M_{a,o}\ e^{-Kt}) \qquad \text{(Eqn. 9)}$$

As discussed previously, the relative velocity of the gas ejected from the cylinder is sonic until most of the gas has been expelled. The sonic velocity of an ideal gas is a function only of its temperature. While flow is choked, the sonic velocity of the air, v_a, is given by the following equation (Crane, Eqn. 3-8):

$$v_a = (k\ g_c\ R\ T/M_w)^{1/2} \qquad \text{(Eqn. 10)}$$

where,

k = ratio of specific heat at constant pressure to specific heat at constant volume (c_p/c_v), which for air = 1.4
g_c = gravitational constant, 32.2 ft-lb_m/s^2-lb_f
R = universal gas constant = 1545 ft-lb_f/lbmole-R
T = absolute temperature, in degrees Rankine
M_w = molecular weight of air, 28.8 lb_m/lbmole

Equations for Estimating Cylinder Velocity As a Function of Time

The acceleration of the cylinder represents its change in velocity with respect to time:

$$d(v_{cyl})/dt = a(t) = M_{a,o}\ v_a\ K\ e^{-Kt}/(M_c + M_{a,o}\ e^{-Kt})$$

The velocity attained by the cylinder, v_{cyl}, over a given time frame can therefore be determined by integrating the acceleration equation, Eqn. 9), with respect to time, as follows:

$$v_{cyl}(t) = v_a \int \frac{K M_{a,o}\ e^{-Kt}}{M_c + M_{a,o}\ e^{-Kt}}\ dt$$

Let $U = M_{a,o}\, e^{-Kt}$; then $dU = -K\, M_{a,o}\, e^{-Kt}\, dt$, and:

$$v_{cyl} = -v_a \int \frac{1}{M_c + U} dU$$

Integrating the above equation between the limits of U_f and U_i gives:

$$v_{cyl}(t) = -\, v_a\, \ln[(M_c + U_f)/(M_c + U_i)]$$

Substituting back in the original relationship for U, between the limits of $t_f = t$ and $t_i = 0$, gives:

$$v_{cyl}(t) = -\, v_a\, \ln[(M_c + M_{a,o}e^{-Kt})/(Mc + M_{a,o})] \qquad \text{(Eqn. 11)}$$

Methodology for Estimating Cylinder Travel Distance As a Function of Time

The distance travelled by the cylinder over a give time frame can be estimated by integrating Eqn. 11. An analytical solution is not possible, so the integral is solved numerically. A numerical approximation is facilitated by breaking the accident down into small time steps. The change in distance travelled between two time steps is approximated by taking an average of the velocities for the two time steps, and multiplying by the difference of the two time steps, as follows:

$$\Delta D_{n,n-1} = 1/2(v_{cyl,n-1} + v_{cyl,n})(t_n - t_{n-1})$$

where,

$\Delta D_{n,n-1}$ is the incremental change in distance between time steps n-1 and n. The subscripts n and n-1 indicate the current and previous time steps, respectively. The cumulative travel distance over a given elapsed time is the sum of incremental distance changes estimated for successive time steps up to the total desired elapsed time, i.e:

$$D_n = \sum_{i=0}^{n} \frac{(v_{cyl,i-1} + v_{cyl,i})}{2} (t_i - t_{i-1})$$

9E.3 ASSUMPTIONS

The following assumptions are used in this analysis:

1. The compressed air cylinder is assumed to be a standard size specialty gas cylinder meeting DOT Specification 3AA2265.

2. Flow characteristics and frictional losses through the sheared off supply valve are assumed to be analogous to compressible fluid flow through a square edged orifice.

3. The diameter of the hole left by the sheared off valve is assumed to be 1 in.

4. The compressed air in the bottle acts as a ideal gas.

5. The temperature of the gas in the bottle remains constant at 535 °R (75 °F) during the accident. Ideal gases do not decrease in temperature during an isenthalpic pressure change.

9E.4 INPUT DATA

To solve for cylinder acceleration and velocity as a function of time using Equations 9 and 11, values are first needed for the constants ß, k, r_c, Y, d_1, C, R, T, M_w, V_1, $M_{a,o}$, and M_c, g_c, and v_a:

- The constants ß, and k are used along with r_c to determine the net expansion factor Y. ß is the ratio of the orifice diameter to the diameter of the cylinder upstream from the orifice. For a specialty gas cylinder meeting DOT Specification 3AA2265 (Assumption 1), the inner diameter of the cylinder is approximately 9 in. The orifice diameter is 1 inch (Assumption 3). Therefore ß is 1/9, or 0.11. The specific heat ratio, k, for air is 1.4. The critical pressure ratio, r_c, is used to determine the ratio of the absolute pressure downstream from the orifice to the absolute pressure upstream of the orifice ($\Delta P/P_1$). $\Delta P/P_1 = 1 - r_c$. Values for r_c and Y can be determined from charts on Pg. A-21 of Crane (1985). For a gas with a k = 1.4 and an orifice with a ß = 0.11, r_c was determined from the appropriate chart to be 0.527. This gives a $\Delta P/P_1 = 0.473$, which is constant as the cylinder depressurizes (until flow goes subsonic at P_1 = 28 psia). From another chart on pg. A-21 of Crane, Y was determined to be approximately 0.86 for a square edged orifice with a ß less than 0.2. This value gives conservative (high) volumetric flow estimates because the sheared off supply nozzle is expected to have flow resistance intermediate between a square edged orifice and a nozzle. Net expansion factors for nozzles are lower than for square edged orifices.

- For d_1, the diameter of the hole left by sheared of supply valve, a value of 1 inch is used (see Assumption 3).

- The flow coefficient, C, for a square edged orifice depends on ß and the Reynolds number. Flow through the orifice will be turbulent. For a square edged orifice with a ß less than 0.2, the appropriate chart on Pg. A-20 gives a C = 0.6.

- R is the universal gas constant and is equal to 1545 ft-lb_f/lbmole-R.

- The temperature of gas in cylinder at the time of the accident, T, is set at 535 R (Assumption 5).

- The molecular weight of air, M_w, is 28.8 lb/lbmole.

- The internal volume of the compressed air cylinder, V_1, is 1.55 ft^3 (average internal volume for high pressure specialty gas cylinder meeting DOT Specification 3AA2265, see Assumption 1).

- The capacity of the compressed air cylinder is 250 standard cubic feet (scf) (from Stubbs (1997)). Standard conditions are 14.7 psia and 60 °F, or 520 °R. Using the ideal gas law:

$$M_{a,o} = P\ V\ M_w/(RT)$$

$$= (14.7\ lb_f/in^2)(250\ ft^3)(28.8\ lb/lbmole)(144\ in^2/ft^2) /[(1545\ ft\text{-}lb_f/lbmole\text{-}R)(520\ R)]$$

$$= 19\ lb.$$

- The weight of cylinder without air (average tare weight for specialty gas cylinder meeting DOT Specification 3AA2265), M_c, equals 119 lb.

- The gravitational constant, g_c, = 32.17 lb_m-ft/lb_f-s^2.

- Using Eqn. 10), at the assumed gas temperature of 535 °R, the sonic velocity of the air expelled from the cylinder is

$$v_a = [(1.4)(32.17\ ft\text{-}lb_m/lb_f\text{-}s^2)(1545\ ft\text{-}lb_f/lbmol\text{-}R)(535\ R) /(28.8\ lb_m/lbmol)]^{1/2}$$

$$= 1137\ ft/s.$$

9E.5 RESULTS

To examine the cylinder's acceleration and velocity as a function of time, Eqn's 9 and 11 were solved in time increments of 0.4 s using a spreadsheet. Equation 6 was also solved at each time step to track cylinder air pressure. Cumulative travel distance at the end of each time step was estimated using the numerical approximation method discussed at the end of Section 9E.2. The results of the analysis are summarized in Table 9E-1. The calculations are only reported up to 2.8 s as the cylinder air pressure has dropped below 28 psia and air flow from the cylinder is subsonic at that point. The majority of the air has been expelled at that point and the cylinder velocity is approaching its asymptotic value of 167 ft/s, so further calculations are not necessary. The spreadsheet results show that the cylinder will travel approximately 366 ft in 2.8 s if not constrained. The spreadsheet results also show that the cylinder needs room to develop momentum. The cylinder requires approximately 16 ft of free space to accelerate to a velocity 50% of its maximum asymptotic value. The cylinder

has to travel approximately 56 ft without impacting anything to reach a speed of 123 ft/s, 74% of its maximum value.

The results of the analysis are depicted graphically in Figure 9E-1.

9E.6 REFERENCES

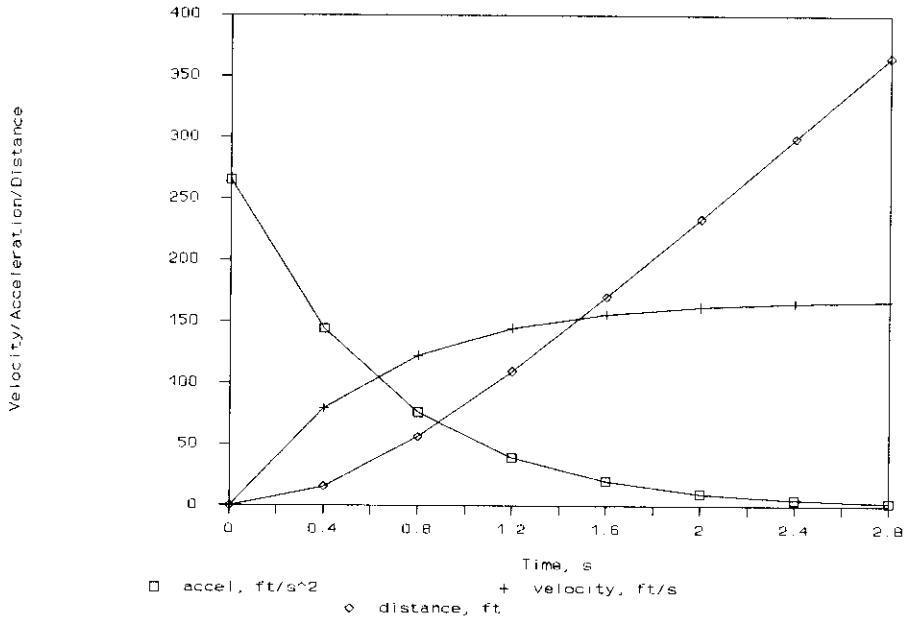
Crane, 1985, *Flow of Fluids Through Valves, Fittings, and Pipe*, Technical Paper No. 410, Crane Co. New York, New York.

Stubbs, A. M., 1997, *Plutonium Finishing Plant Process Flow Document--Calcination of Plutonium Nitrate Solution*, PFD-Z-300-001, Babcock and Wilcox Hanford Company, Richland, Washington.

Table 9E-1. Cylinder Air Pressure, Acceleration, Velocity and Travel Distance As a Function of Time

Time (s)	Cylinder Air Pressure (psia)	Acceleration (ft/s^2)	Velocity (ft/s)	Travel Distance (ft)
0	2443	265	0	0
0.4	1239	144	79.9	16.0
0.8	629	76.1	123	56.5
1.2	319	39.4	145	110
1.6	162	20.2	156	170
2.0	82.0	10.3	162	234
2.4	41.6	5.23	165	299
2.8	21.1	2.66	166	366

Figure 9E-1. Plot of Cylinder Acceleration, Velocity and Travel Distance as a Function of Time



APPENDIX 9F

Preliminary Hazards Analysis for Thermal Stabilization of Plutonium Oxide

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PRELIMINARY HAZARDS ANALYSIS FOR THERMAL STABILIZATION OF PLUTONIUM OXIDE

9F.1 STABILIZATION OF PLUTONIUM OXIDE PHA

The hazards associated with thermally stabilizing Pu Oxide in the Glovebox HC-21C muffle furnaces were identified and evaluated using a Preliminary Hazards Analysis (PHA) approach. A detailed discussion of the PHA technique can be found in *Guidelines for Hazard Evaluation Procedures* (AIChE 1992).

9F.2 PHA METHODOLOGY

The PHA process is a systematic approach in which a system or process is broken down into basic elements and the hazards associated with operations in the system or process are identified, potential causes of those hazards are determined, potential consequences of the hazards are evaluated, and possible corrective and/or preventative measures are examined. The PHA was developed using a table to guide and record the results of a "brainstorming" process. Brainstorming was performed by individuals with detailed knowledge of the system or process being examined, and was supported by a multi-disciplinary team.

9F.2.1 PHA Data Description

The purpose and contents of each column in the PHA table, Table 9F-1, are described in detail in the following paragraphs.

Column 1, Item #: This column provides an alpha-numeric identifier for each hazard postulated in the table. The identifier is primarily used for cross referencing within the table and as an identifier for accident sequences discussed in Chapter 9 of the PFP FSAR.

Column 2, Process Step/Equipment: The step or steps and the important equipment involved in performing each set of operations is identified in this column. Listing each piece of equipment involved ensures that all relevant hardware failures are considered in the analysis and that the operational faults associated with use of each piece of equipment are considered.

Column 3, Failure/hazardous condition: The hardware failures or operational faults of concern are identified in this column. The hazards are identified first by postulating failures of the safety function(s) listed in the previous column. Simply postulating functional failure of hardware, however, is insufficient for identifying the wide range of things that can go wrong. Additional hazards are identified by asking "what-if" type questions, such as, "what if the operation is not performed," "what if the operation is performed out of order," "what if the operation is performed too fast". Guideword deviations such as are used in HAZOP analysis (AIChE 1992) were also utilized to identify hazardous conditions. Guidewords are process parameters such as pressure, temperature, flow, concentration etc. Relevant deviations include "low/no," "high," "other than."

Column 4, Causes: This column identifies the causes for the failures/hazardous conditions postulated in Column 4. Identifying causes is important to identifying potential preventative controls for significant hazards. In many cases, multiple hardware of operational fault's are required to produce a hazardous event. This column identifies the sequence of hardware and operational faults required to produce the postulated hazardous event.

Column 5, Consequences: This column describes the potential consequences that could result from the postulated hazards identified in Column 4. The focus of this column is to identify effects to the glovebox confinement system and to facility workers. None of the hazards associated with opening cans containing Pu metal and with processing the metal were found to be energetic enough to compromise building confinement or to pose a threat to onsite workers outside the plant or to the offsite public.

Column 6, Existing Engineered Features: This column identifies the engineered features (hardware items) intended or available to prevent or mitigate the consequences identified in Column 6. The engineered features in this column are candidates for designation as Safety Significant items for hazards that pose a significant threat to the health of facility workers.

Column 7, Existing Administrative Controls: This column identifies the administrative requirements that reduce the likelihood of the hazardous event identified in Column 4, or that help minimize the potential consequences of the hazardous event. The controls listed in this column are candidates for operational safety requirement (OSR) designation for hazardous events with the potential to significantly harm facility workers.

Column 8, Consequence Rank: This column is used to capture a code designator for the level of consequence associated with a hazardous event. The consequence ranking is a "first cut," qualitative estimate of the safety severity of the consequences. An alphanumeric system has been used at the PFP to designate the severity of hazardous events. The system has the following "S" rankings characterizing safety consequences:

S0 No effect outside the glovebox confinement systems; negligible safety concerns for the facility worker.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker. Such a hazard would be an operator injury where glovebox gloves are penetrated by the can punch causing worker injury and possible skin/wound contamination.

S1* Potential severe harm or potential death from industrial injury, radiological dose or chemical exposure to the facility worker. Hazards of this severity level warrant Safety Significant controls. Hazards at this severity level for the process examined in this analysis are typically those that result in significant pressurization or damage to the glovebox structure causing release of radiological material from the glovebox. All events with enough energy to cause a significant release of radiological material from the glovebox are assigned an S1* consequence rank. This is conservative as such events will not necessarily cause severe harm to facility workers.

S2 Potential significant radiological dose consequences or chemical exposure to onsite workers located outside the facility. No hazards postulated for processing Pu oxide were found to be energetic enough to compromise building confinement and lead to an S2 consequence.

S3 Potential significant radiological dose consequences or chemical exposure to the offsite population. No events were postulated with potential S3 consequences.

The engineered safety features and controls specific to the processing of plutonium oxide are not credited in assigning the above consequence rankings. This is to allow determination of whether the controls warrant Safety Significant designation.

The mitigative effects of features previously designated as Safety Significant or Safety Class in the PFP FSAR (WHC 1995) are credited in assigning the consequence rankings. For example, the glovebox structure E-4 ventilation system, and E-4 HEPA filters are credited with mitigating the effects of releases inside gloveboxes. This means that a spill of Pu oxide powder inside a glovebox (e.g., due to dumping the furnace boat after removal from the furnace) results in an S0 consequence ranking because the glovebox structure and E-4 ventilation system can be expected to prevent a significant exposure to facility workers. The effects of energetic events (such as flammable gas deflagration in a muffle furnace) on the glovebox structure, however, are assessed to determine if the hazardous event can compromise the Safety Significant confinement function provided by the glovebox structure and ventilation system. Similarly, the Safety Class Building 234-5Z structure and E-3 ventilation system are credited with protecting onsite workers and the offsite public outside the PFP from accidents that breach glovebox confinement.

Column 9, Frequency Ranking: The frequency ranking is a first cut, qualitative estimate of the likelihood of the hazardous event. The following ranking system is used.

F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is 1E-02/yr to 0.1/yr.

F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1E-04/yr to 1E-02/yr.

F1 Events not expected to occur during the lifetime of the facility, categorized as "extremely unlikely." The frequency range associated with this category is 1E-06/yr to 1E-04/yr.

F0 Events categorized as "beyond extremely unlikely," with a frequency less than 1E-06/yr. Events in this category (such as meteor strike) are so unlikely they generally do not require special controls.

The frequency estimate, like the consequence ranking, is assigned taking no credit for active engineered features. The frequency ranges shown above

are based on the risk acceptance criteria for the onsite receptor from the PFP FSAR (WHC 1995).

Column 10, Comments: This column contains miscellaneous observations or clarifying comments for a given hazard. There are many hazards identified in the PHA that are adequately covered in the PFP FSAR (WHC 1995) or in other authorization basis documents (e.g., CSERs). The comments column is used to flag those hazards that are adequately addressed in other documentation.

9F.2.2 SCOPE OF THE PRELIMINARY HAZARDS ANALYSIS

The PHA covers the operations performed within the RMC line glove boxes, from seal-in of containers of Pu Oxide into Glovebox HC-21A to bag-out of the thermally stabilized plutonium oxide from Glovebox HC-18M. Within the RMC Line glove boxes, the Pu Oxide is handled, thermally stabilized, and placed in sealed containers. Transfer of containers between the vaults and RMC line and storage of containers in vaults (before and after thermal stabilization) is not covered in this PHA, as the hazards associated with these operations are adequately covered in the PFP FSAR (WHC 1995). The specific activities evaluated within this PHA are identified in Section 9F.3.

9F.3 PHA ORGANIZATION

The PHA table used in this analysis is provided in Table 9.F1. The PHA table is structured to ensure a systematic and thorough review of potential hazards. The thermal stabilization of plutonium oxide within the RMC line is broken down into logical sets of operations performed at specific locations. The breakdown of operational steps covered in the analysis were identified from verbal descriptions provided by the cognizant engineers, and other available information. The operational steps evaluated and documented in the PHA table (Table 9F.2) are identified with an alpha-numeric designator in rows that traverse the width of the table. The groups of operations performed in each Glovebox and evaluated in the PHA are listed below:

Glovebox HC-21A:

- Seal-in Pu oxide storage container into Glovebox HC-21A.
- Open outer cans and make empty cans into "non-containers".
- Weigh storage container (inner can and overpacks) and furnace boat (before and after filling) for accountability and operational requirements.
- Open innermost Pu oxide storage containers, sieve, and place material in furnace boat..
- Identify and remove contaminants from oxide in furnace boat.

Conveyer Glovebox HC-2:

- Transfer covered furnace boat from Glovebox HC-21A to Glovebox HC-21C.

- Transfer covered furnace boat from Glovebox HC-21C to Glovebox HC-18BS.

Glovebox HC-21C:

- Uncover furnace boat and thermally stabilize material in the muffle furnace in Glovebox HC-21C.

Glovebox HC-18BS:

- Transfer furnace boat from Glovebox HC-2 to Glovebox HC-18M (includes temporary storage of boat and canned stabilized material awaiting LOI awaiting LOI sample results in Glovebox HC-18BS).

Glovebox HC-18M:

- Sieve, grind (as necessary), sample, and can material in Glovebox HC-18M.

- Bag-out canned material from Glovebox HC-18M for transfer to storage vault.

As a part of the thermal stabilization process evaluation, the E-4 ventilation system that exhausts the glove boxes, the power supply to the RMC Line equipment, and the 26-inch-Hg vacuum system that exhausts the muffle furnaces in Glovebox HC-21C were included in the evaluation.

9F.4 HAZARDS EVALUATION RESULTS

9F.4.1 BINNING RESULTS

The PHA is a discovery tool. Many failures or hazardous conditions that are identified in the PHA lead to similar consequences and controls. It is useful to group similar hazardous events for further discussion and analysis. The failures/hazardous conditions identified in the 3rd column of the PHA table and the consequences identified in the 5th column of the PHA table can be used to define hazardous events. Events with similar phenomenology and consequences that challenge similar mitigative barriers or that require similar preventative controls can be logically grouped together.

Event bins were also given an Event Type designation in keeping with the designations used in the PFP FSAR Chapter 9 Analysis. Events bins that contained hazardous conditions that resulted in process upsets but posed no significant radiological or toxic chemical threat to the facility worker were assigned an Event Type designator of NA. Accident designator NA is not currently addressed in the PFP FSAR. Events bins having hazardous conditions representing only industrial hazards were also assigned this designation. Events bins with the potential for only minor consequence to the facility worker were assigned the designator AB. Events bins with the potential for onsite consequences or severe worker impact were assigned the designator AC. The Event Type designations are shown in parenthesis following the event bin description. If an Event bin contained hazardous conditions that met the criteria of more than one Event Type, the appropriate designator for each Event Type was assigned.

The hazardous conditions were grouped together into 18 Event bins. The bins are:

Contaminated Wound (**NA**)
Criticality (**AC**)
Dispersal of Pu Oxide Powder - Inside Glove Box (**AB**)
Dispersal of Pu Oxide Powder - Outside Glove Box (**AB**)
Dropped Container Outside Glove Box (**NA**)
External Events - Aircraft Crash, Facility Wide Power Loss, Range Fire (**AC**)
Flammable Gas Deflagration in Glove Box (**AC**)
Flammable Gas Deflagration in Waste Drum (**AB**)
Loss of Glove Box Confinement - Mechanical Breach (**AB**)
Loss of Glove Box Confinement - Ventilation Failure (**AC**)
Natural Phenomena - Seismic, Ashfall, High Wind (**AC**)
Occupational Hazards (**NA**)
Operational Upset (**NA**)
Pyrophoric Reaction in Furnace (**AB**)
Pyrophoric Reaction in Glove Box (AB - **AC**)
Radiation Protection (**NA**)
Rupture of Container in Storage Vault (AB - **AC**)
Uncontrolled Fire in Glove Box (**AC**)

Tables 9F.3 - 9F.20 present the hazardous conditions by bin category with hazardous conditions ordered by consequence and frequency.

9F.4.2 Natural Phenomena and External Events

There are three natural phenomena that are grouped under the Event bin Natural Phenomena. These are Seismic Event, Ash Fall, and High Wind. Each of these phenomena can cause multiple consequences. In the case of the High Wind and Ash Fall events, the PFP FSAR provides sufficient information to show that the effect of adding thermal stabilization of Plutonium Oxide in glovebox HC-21-C will not materially affect the consequences from these events. High Wind and Ash Fall effects are described in Chapter 3.0 of the PFP FSAR. Ash Fall represents a roof loading concern, abrasive concern for moving equipment, and an electrical concern because of the conductivity of the ash. High Wind represents a threat to the 234-5Z Building but not to an individual glovebox inside the building. Chapter 9.0 considers the effect of a wind-driven plank striking the 234-5Z Building and concludes that no significant consequences result. The seismic event is considered in detail in Chapter 9.0 of the PFP FSAR. The addition of thermal stabilization of plutonium oxide in glovebox HC-21-C does not represent a significant change in the quantity of dispersible material as compared to other processes that have been authorized in the past in this glovebox.

There are three phenomena grouped under the Event bin External Events. These are Facility Wide Loss of Power, Range Fire, and Aircraft Crash. Facility wide loss of power, and Range Fire result in essentially the same effect, loss of power to the 234-5Z (and therefore the thermal stabilization process in HC-21-C). Range fire causing a building fire is not considered credible because a wide area devoid of vegetation exists and is maintained around the facility (vegetation control specified in Chapter 3.0 of the FSAR). The addition of plutonium oxide thermal stabilization does result in a potential hazardous condition due to facility wide power loss. If plastic contaminants are present in a batch of plutonium oxide being thermally

stabilized and a facility wide power loss occurs, there is a potential for flammable gas to be generated that will not be swept out of the furnace by the ventilation system. If a sufficient quantity of flammable gas builds up and a return of power occurs there could be and ignition of the flammable gas that could result in significant pressurization of the glove box. The effects of loss of power on the thermal stabilization of plutonium oxide due to internal initiators is also addressed in the PHA. Chapter 9.0 of the PFP FSAR currently addresses Aircraft Crash and determined that the frequency of such an accident is less than 1E-6 per year when flight restrictions that prohibit helicopter operation in proximity to PFP are implemented. Therefore, no further consideration of the Aircraft Crash is required.

9F.4.3 CONSEQUENCE GROUPING

Tables 9F.21 through 9F.23 break down the hazardous events identified in the PHA into consequence groups. Table 9F.21 summarizes the S0 event groups developed from the PHA. Table 9F.22 summarizes the S1 hazardous event groups, and Table 9F.23 summarizes the S1* hazardous event groups. The hazardous event groups are described in the 2nd column of each table. The third column in each table describes the hazardous conditions/failures. The fourth column in each table describes the causes of the hazardous conditions, i.e., the specific sequences of hardware failures or procedural errors that produce the hazardous event. The line item numbers in these tables correspond to those used in the PHA table, demonstrating that every line item from the table is covered in at least one of the hazardous conditions in the three tables. Some hazardous conditions in the PHA table warranted placement in two different groups due to the potential to produce hazardous conditions with different phenomenology or with different levels of severity (depending on how many concurrent failures were assumed). These items have lower case alphabetical characters added to the PHA table item number to maintain the relationship with the PHA table data. The sixth and seventh columns in each of the tables present the controls (engineered features and administrative controls) identified in the PHA table that can be used to prevent or mitigate each of the identified hazardous event sequences. The last column shows the frequency assigned to the hazardous condition.

9F.4.3.1 S0 Events

The S0 hazardous events are those that pose no significant threat to the facility worker. Events in this category are shown in Table 9F.21 and can be summarized as follows:

- Dispersal of Pu Oxide Powder - Inside Glovebox
  - Release of plutonium oxide from pressurized can when it is opened.
  - Spill of unstabilized plutonium oxide resulting in increase of contamination level in glovebox and process stoppage to perform cleanup.
  - Spill or entrainment of stabilized plutonium oxide in glovebox air causing an increase in the contamination level of the glovebox.

- Dropped container outside glovebox
  - Pu storage container handling accident outside glovebox resulting in no release of radiological material.
- Natural Phenomena - High Wind (already addressed in PFP FSAR)
- Operational Upsets
  - Equipment failures or human errors resulting in programmatic delays but no safety consequence other than increased direct dose exposures to operators incurred in recovering from the event.
  - Release of radioactive particulate into the 26-inch-Hg vacuum system.
  - Pu fluoride powder processed causing corrosion damage to glove box HC-21C stabilization furnaces.

The specific event sequences, engineered features and administrative controls that minimize the likelihood or consequences of the S1 events are shown in Table 9F.22.

9F.4.3.2 S1 Events

S1 hazardous events are those that can physically injure workers or that can result in chemical or radiological exposures that would not be considered severe (e.g., not immediately threatening to the workers health). Events in this category are shown in Table 9F.22 and can be summarized as follows:

- Contaminated Wound
  - Injuries resulting in Pu oxide being introduced below the skin surface of a worker. Hazardous conditions include punctures, cuts, and abrasions.
- Dispersal of Pu Oxide Powder Outside Glove Box
  - Escape of contamination during waste bagout operations.
  - Releases from sample bottles or product cans after bagout from glove box HC-18M.
- Flammable Gas Deflagration In Waste Drum
  - Hydrogen generation from radiolysis in waste bags combined with spark source results in flammable gas deflagration in waste drum in satellite accumulation area.
- Loss of Glove Box Confinement Due To Mechanical Breach
  - Damage to confinement boundary due to overheating panels or glove box structures (not associated with general glovebox

fire). Associated with radiant heat from stabilization furnace operation. This event results in the potential for release of minor amounts of contamination. Credit is taken for the mitigating effects of the E-4 ventilation system which prevents significant amounts of radiological materials from escaping the glovebox.

- Events that result in holes in gloves, glove box structure, significant release of contamination during glove replacement, seal in, or bagout operations. These events do not result in significant inhalation uptake of radiological materials outside of the glovebox.

- Loss of Glove Box Confinement Due To Ventilation Failure

  - Stagnant conditions due to ventilation flow imbalances with no other failures of present.

- Natural Phenomena - Ash Fall (already considered in PFP FSAR)

- Natural Phenomena - Seismic Event

  - Seismic events that cause dispersal of plutonium oxide powder inside glove box. Magnitude insufficient to damage glove box confinement integrity.

- Occupational Hazards (general category represented by electrical shock concerns)

- Pyrophoric Reaction In Furnace

  - Hazardous conditions involving pyrophoric contaminants in the plutonium oxide that may result in hydrogen release and burn in glove box. Failure of the glove box confinement boundary not expected due to small quantities of pyrophoric material postulated to be present.

- Pyrophoric Reaction In Glove Box

  - Pyrophoric reaction and hydrogen burn when can is opened. This event is not expected to result in significant pressurization of the glove box.

- Radiation Protection (captures concerns of worker exposure due to can handling activities)

- Rupture of Container In Storage Vault

  - Canister ruptures that result from unreacted metal being sealed in storage canister that eventually oxidizes and increases material volume in canister sufficiently to result in can failure. This is assumed to be a low energy event that will not involve energetic expulsion of Pu oxide from can.

- Uncontrolled Fire In Glove Box

  - Combustibles present in glove box are ignited as a result of pyrophoric reactions in glove box. Size of fire is assumed to be limited for the S1 case.

The specific event sequences and the engineered features and administrative controls that minimize the likelihood or consequences of the S1 events are shown in Table 9F.22.

9F.4.3.3 S1* Events

The S1* hazardous events are those with the potential to cause severe physical injury, or radiological or chemical exposures above acceptance limits to facility workers. The S1* hazardous events identified from the PHA table are shown in Table 9F.23 and can be summarized as follows:

- Criticality

  - Criticality in glovebox caused by exceeding Pu mass, spacing, or moderator limits in the glove boxes. This is a S1* hazard due to the potential for lethal worker exposures to ionizing radiation.

- Flammable Gas Deflagration In Glove Box

  - Flammable gas deflagrations in glovebox causing glovebox failure resulting from hydrogenous material contaminates in Pu oxide powder producing flammable gas during thermal stabilization.

  - Flammable gas deflagrations in glovebox causing glovebox failure resulting from hydrogen burn when containers are opened and built-up hydrogen is released and ignited.

- Loss of Glove Box Confinement Due To Mechanical Breach

  - Loss of glovebox confinement resulting from panel failure combined with inadvertent fire suppression system actuation.

- Loss of Glove Box Confinement Due To Ventilation Failure

  - Significant pressurization of glove box due to ventilation flow loss or imbalance. This event assumes that significant quantities of material escape from the glove box and result in large uptake by the operations personnel that are present.

  - Failure of the ventilation system allows temperature increases in the glove box that result in significant failure of the glove box structure.

- Natural Phenomena - Seismic Event

  - Failure of glovebox confinement due to seismic event. This is an S1* hazard due to the potential for large quantities of dispersable material to be introduced into the building atmosphere where workers can acquire large inhalation doses.

- Pyrophoric Reaction In Glove Box

  - As material is poured into the furnace boat a pyrophoric reaction occurs that results in significant pressurization of the glove box.

- Rupture of Container In Storage Vault

  - Rupture of container in storage vault due to over pressurization caused by inadequate stabilization of material. This is an S1* hazard due to the potential for large inhalation doses to workers entering the storage vaults after a canister rupture.

- Uncontrolled Fire In Glove Box

  - Uncontrolled fire in glovebox resulting in failure of the glovebox confinement boundary and release of radiological material from the glovebox.

- External Event - Aircraft Crash (Already addressed in PFP FSAR)

- External Event - Facility Wide Loss of Power (Currently addressed in the PFP FSAR with the following exception)

  - If plastic contaminants are present in a batch of plutonium oxide being thermally stabilized and a facility wide power loss occurs, there is a potential for flammable gas to be generated that will not be swept out of the furnace by the ventilation system. If a sufficient quantity of flammable gas builds up and a return of power occurs there could be and ignition of the flammable gas that could result in significant pressurization of the glove box.

- External Event - Range Fire (Currently addressed in PFP FSAR with the following exception)

  - Range fire could be an initiator of a facility wide loss of power. If plastic contaminants are present in a batch of plutonium oxide being thermally stabilized and a facility wide power loss occurs, there is a potential for flammable gas to be generated that will not be swept out of the furnace by the ventilation system. If a sufficient quantity of flammable gas builds up and a return of power occurs there could be and ignition of the flammable gas that could result in significant pressurization of the glove box.

The above S1* event categories warrant analysis as accidents due to their potential health threat to facility workers. Each of the S1* event categories is evaluated as an accident in Chapter 9 of the PFP FSAR.

9F.5 ENVIRONMENTAL PROTECTION

The facility features, such as a ventilation system with multiple stages of HEPA filtration that maintains a negative pressure relative to the atmosphere outside of the 234-5Z facility, protects the facility worker as well as serving to prevent and mitigate environmental releases of hazardous material. Under stagnant ventilation conditions the facility structure itself provides confinement of radioactive materials, limiting release to the environment. These features are listed in the PHA table (Table 9F.2) in the engineered and administrative safety features columns. These features are valid controls for environmental protection because in protecting the worker or public the environment is also protected. No release scenarios were identified where a release occurred that did not impact the worker but did impact the environment. In addition, there are institutional programs of environmental monitoring which help discover unacceptable discharges.

9F.6 REFERENCES USED DURING PHA

Table 9F.1. PHA Data Table

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments

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Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
A.1.01	Electrical Equipment in glove box .	Fire in glove box caused by electrical short	Failure to properly inspect power cords or failure to identify frayed cords results in condition that leads to an electrical short that ignites combustibles in the glovebox Failure to control combustibles in glove box allows significant fire that damages glove box confinement.	Burn through of gloves seal out bags resulting in breach of containment Ignition of Polymethyl Methacrylate or Polycarbonate glove box panels and spread of fire to other gloveboxes Release of soot, hot embers, and water vapor to the E-3 and E-4 ventilation systems. Pluggage or failure of glovebox and E-4 filterbox HEPA filters. Potential pluggage of E-3 room prefilters or E-3 filterbox HEPA filters, with spread of contamination to clean portions of the plant. Worker uptake of airborne Pu	Glovebox dry fire suppression system Glovebox (E-4) ventilation system maintains negative glovebox pressure and confines release until several gloves or bag ports are burned out or window panels are breached, giving operators time to manually extinguish fire. Long length of E-3/E-4 ductwork between RMC line and filter room filters and dilution airflow from other E-3/E-4 areas of the plant are expected to cool offgasses from the fire enough to prevent heat damage to, or plugging of the E-3/E-4 filter-room HEPA filters. E-3/E-4 filter-room HEPA filters mitigate release to the environment CAMS alert workers to presence of airborne contamination.	MgO sand available in gloveboxes for extinguishing small fires Bayonet fire extinguisher is near glovebox for manually extinguishing fire. Housekeeping practices minimize combustible loading in glovebox. Senior supervisory watch OSHA inspections can identify frayed cords. Electrical safety program of cord inspection reduces the likelihood of the presence of frayed cords. Institutional occupational safety program of requirements and inspections reduces the likelihood of the presence of frayed cords. Hanford fire department located within a few miles of PFP	S1*	F3	Polymethyl Methacrylate panels are easier to ignite and spread flames more readily than Polycarbonate panels. Polymethyl Methacrylate panels have been replaced by Polycarbonate panels in Gloveboxes HC-21A and HC-21C (verify this). Several kg of burning plastic can generate enough radiant heat to ignite Polycarbonate panels. See RMC line fire accident analysis in Section 9.2.2 of the PFP FSAR.
A.1.02	Electrical Equipment in glovebox	Electrical shock to operator	Cord frayed in the glovebox Frayed cord contacts glovebox frame while operators body or leg is in contact with the glovebox frame.	Operator injury	None	Senior supervisory watch OSHA inspections can identify frayed cords. Electrical safety program of cord inspection reduces the likelihood of the presence of frayed cords. Institutional occupational safety program of requirements and inspections reduces the likelihood of the presence of frayed cords.	S1	F3	Commonly accepted industrial hazard. The likelihood of electrical shock injury is reduced by the presence of rubber mats that are placed on floor grating to protect shoe covers Hypalon glovebox gloves may provide some protection

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
A.1.03	Glovebox Confinement Boundary	Hole in glovebox confinement boundary leads to spread of contamination from glovebox	Degradation of port bags, ice cream cartons used to seal sphincter port, or gloves due to aging, radiation, or heat.	Minor Spread of contamination from glovebox and potential uptake by workers.	E-4 ventilation system maintains negative pressure in glovebox and maintains confinement velocity across small holes	Gloves and bags have scheduled replacement dates which minimizes likelihood of degradation. Pre-job walkdown visual inspection of gloves, bags, and ice cream cartons. Air flow through leaks can cause a whistling sound which aids in detecting leaks in gloves, port bags, etc. during pre-job walkdown. Radiological control program: operators hands are surveyed every 15 minutes during glovebox operations and when changing glovebox locations to identify leaks. Surveys with alpha poppy probes before leaving radiological control area prevents spread of contamination to clean areas of the plant.	S1	F3	Ice cream cartons currently are replaced with each successive seal-in.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
A.1.04	Glovebox Confinement Boundary	Breach in glovebox confinement boundary during waste bagout, port bag replacement, or glove change.	Sharp object punctures bag Bag not properly horse tailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers.	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	
A.2.01	Glovebox CPS and dispersible inventory limit	Violation of criticality safety mass or spacing limit Violation of dispersible inventory limit	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	S1*	F2	Controls providing double contingency protection against criticalities are identified in separate CSER reports for each glovebox.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
A.3.01	Glovebox (E-4) ventilation system	Stagnant glovebox or pressurized glovebox during operations causes spread of contamination from glovebox	Loss of E-4 ventilation flow or imbalance between E-4 supply and exhaust (caused by loss of power or equipment or control failures). Failure to detect HVAC upset during pre-job walkdown	Spread of contamination from glovebox during seal in or seal out of container, glove change, or change of port bag. Worker exposure to dispersible Pu. Overheating of Glovebox HC-21C during furnace operations (see item D.3.06).	E-4 HVAC controls Interlock shuts off supply fans if exhaust fans go down, which prevents glovebox pressurization. Pressure regulating valve on supply air regulates pressure in RMC line gloveboxes. Addition exhaust capacity provided via emergency exhaust valves in Room 228A should imbalance develop between supply and exhaust flow. Alarm activates in power control room on detection of low glovebox negative in control room. PAX announcement made if alarm activates. E-3 filter room filters mitigate release to environment if only E-4 ventilation is lost. Building shell mitigates release if glovebox and building goes stagnant. Backup power operates emergency exhaust fans that maintain negative pressure in gloveboxes if plant loses primary power. Room CAMs alert workers to airborne contamination.	Pre-job walkdown to verify proper glovebox ventilation flow and DP Operator training and procedures	S1 S1*	F3 F2	S1/F3 for stagnant glovebox case. S1*/F2 for pressurized glovebox case (pressurization is not large). Plant is evacuated if E-3/E-4 exhaust is lost, which minimizes potential worker inhalation doses.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B. Activities in Glovebox HC-21A									
B.1.01	Seal container into Glovebox HC-21A through bag in port or sphincter seal	Drop of Pu storage container outside glovebox during seal in.	Human error.	No significant release from Pu storage container expected.	Overpack containers protect inner container.	Operator training and procedures Inner containers have been drop tested and found not to leak.	S0	F3	Hazards associated with handling containers of Pu metal or oxide outside gloveboxes is adequately covered in the PFP FSAR.
B.1.02	Seal container into Glovebox HC-21A through bag in port or sphincter seal	High worker direct dose during handling of cans	Container containing metal or PuF_4 handled instead of PuO_2 (PuF_4 much higher dose than oxide from alpha-n reactions). Cans handled for extended time period during handling/seal-in of cans.	Worker dose rate limit (Radiological work permit) potentially exceeded	Leaded gloves limit dose when handling cans inside the glovebox. Glovebox structure shields body of operator Inner can and first overpack are wrapped with leaded tape to minimize direct dose	ALARA principles applied to Pu storage container handling process. Periodic dose measurements taken on glovebox to establish acceptable worker exposure periods. Labeling of cans in vault (RAM tags) Cans surveyed for contact dose several times during movement and before loading into HC-21A. Blend plan identifies intended cans Institution radiological control program	S1	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.1.03	Seal container into Glovebox HC-21A through bag in port or sphincter seal	Glovebox loss of confinement during seal in.	Sphincter seal failure Ice cream carton or can in sphincter seal inadvertently pushed into glovebox without can or carton behind it results in open sphincter seal. Seal in bag torn or pulled off port during seal in (also applies to change out of port bags) (see item A.1.04). Pressurized glovebox during seal in (see item A.3.01)	Minor release of contamination from the glovebox into the room. Potential worker uptake of Pu.	Glovebox ventilation system maintains negative pressure and confinement velocity across failed sphincter seal or port bag which minimizes the potential contamination spread. Backup glovebox (E-4) ventilation system maintains confinement on loss of primary ventilation. Room CAMs alert operators to presence of airborne contamination. PRV on supply restricts flow rate on low glovebox DP. Emergency exhaust valves open on low glovebox negative. Sphincter seal design prevents release unless no can or carton in seal.	Operator training and procedures	S1	F3	S1 ranking assumes minor release of contamination from glovebox. Hazards associated with seal in of containers into gloveboxes is covered in the PFP FSAR. This accident is not unique to seal in of containers containing PuO_2. Room CAMs are designated safety significant in the PFP FSAR.
B.2.01	Open outer cans and make empty cans into "Non containers"	Flammable gas (i.e. H_2) release and burn when overpack can opened.	Radiolysis of plastic bag around slip lid can and organic can seal during storage in vault. Ignition due to mechanical spark from can opener, static release from ejected powders, or electrical spark.	Potential deflagration involving H_2 released from can causing pressurization of glovebox, potential failure of port bags or gloves and release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of hydrogen are easily identified due to bulging.	S1*	F2	Recommend bulged containers not be opened in air. "Ruler test" can be used to eliminate highly pressurized cans. Catastrophic failure of glovebox structure not expected due to limited quantity of H_2 possible in the can. Many pressurized cans have been opened at PFP without a resultant deflagration. Ignition of hydrogen released from the can by the can opener or static discharge is unlikely.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.2.02	Open outer cans and make empty cans into "Non containers"	Operator injury and damage to glovebox glove compromising glovebox confinement integrity.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound Small hole in glovebox confinement boundary Small contamination release from glovebox as hands withdrawn from glovebox gloves	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Surgical excision of contaminated tissue. Leather gloves used when crushing or folding cans	S1	F3	
B.2.03	Open outer cans and make empty cans into "Non containers"	Outer cans not properly made into non-container	Can not crushed and folded, can with bottom removed set upright instead of on its side, can not turned upside down.	CPS infraction Margin of criticality safety reduced	None	Operator training and procedures Glovebox CPS posting (tells operator maximum open container volume to unit mass ratio)	S0	F3	
B.2.04	Open outer cans and make empty cans into "Non containers"	Operator injury and damage to glovebox glove compromising glovebox confinement integrity.	Operator suffers injury and ruptures glove while crushing empty can with hammer	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox.	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	S1	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.3.01	Weigh storage container (inner and overpacks) and furnace boat (before and after filling) for Pu accountability and operational requirements	No safety hazard identified for this step.	--	--	--	--	--	--	Pu content of item is set by Accountability prior to placing container in vault. Scale can't necessarily detect overbatch of Pu or potential criticality hazard since it only measures gross weight.
B.4.01	Open innermost can (can containing PuO_2)	Operator injury and damage to glovebox glove compromising glovebox confinement integrity.	Worker penetrates glove while opening sealed can with can opener, taped slip lid can with scissors, while handling can or lid.	Operator injury with contamination of wound Small hole in glovebox confinement boundary Small contamination release from glovebox	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves use when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	S1	F3	
B.4.02	Open innermost can (can containing PuO_2)	Hydrogen gas release and burn when can opened	Radiolytic degradation of plastic contaminant, brush bristles, tool handle, bottle caps, etc. in oxide during storage generates hydrogen in can. Hydrogen ignited during release from can due to static or electrical discharge High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Potential deflagration involving H_2 released from can causing pressurization of glovebox, potential failure of port bags or gloves and release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of hydrogen are easily identified due to bulging.	S1*	F2	Recommend bulged containers not be opened in air. "Ruler test" can be used to eliminate highly pressurized cans. Catastrophic failure of glovebox structure not expected due to limited quantity of H2 possible in the can. Many pressurized cans have been opened at PFP, all without a resultant deflagration. Ignition of hydrogen released from the can by the can opener or static discharge is unlikely.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.4.03	Open innermost can (can containing PuO_2)	PuO_2 particulate release from pressurized can when it is opened	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	S0	F3	
B.4.04	Open innermost can (can containing PuO_2)	Flammable gases (alkanes, H_2, etc) from organic in container released and ignited when can opened (can pressurized)	Container containing organic (e.g., sludge, floor sweeps) inadvertently sealed into glovebox and opened. Wrong container selected due to inaccurate labeling or human error. Flammable gases generated due to radiolytic decay of organic material (e.g., sludge) in the container. Ignition due to mechanical or electrical spark, or static discharge.	Pressurization of glovebox Potential damage to glovebox confinement boundary Pu release into room and worker inhalation uptake.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material.	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of flammable are easily identified due to bulging. Blend plan identifies appropriate cans to stabilize in PuO_2 campaign. Labeling of containers Operator training and procedures Shift technical advisor sign off for material acceptability required by procedure. Sludges which may contain organic are stored in vented polyjars which are easily distinguishable from cans containing PuO_2.	S1*	F2	Recommend bulged containers not be opened in air. "Ruler test" can be used to eliminate highly pressurized cans. Catastrophic failure of glovebox structure not expected due to limited quantity of flammable gas possible in the can. Many pressurized cans have been opened at PFP, all without a resultant deflagration. Ignition of flammable gas released from the can by the canopener or static discharge is unlikely.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.4.05	Open innermost can (can containing PuO_2)	Pyrophoric reaction and hydrogen burn when can opened	PuH_2 hydride contaminant in can Pu metal may be in can due to incomplete prior stabilization. PuH_2 forms from metal if plastic or organic contaminants are also present in can. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. Can under vacuum due to catalyzed formation of oxides and nitrides in the container. When can is opened air is sucked in which reacts with the hydrided material. Hyride reactions releases heat and hydrogen gas which is ignited on exiting the can.	If sufficient hydride contamination present, slight pressurization of the glovebox could occur. Potential burn through of gloves and operator injury due to contact with hot embers. Embers burn through PVC ports Minor contamination spread from glovebox if gloves or port bags damaged. Potential ignition of combustibles in glovebox producing glovebox fire.	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Shift technical advisor sign off for material acceptability required by procedure. Combustible loading in glovebox is controlled by procedure.	S1 S1*	F3 F2	S1/F3 for sparking reaction and small hydrogen flash with maximum consequence being burn through of glove or port bag S1*/F2 for ignition of significant combustibles in the glovebox causing glovebox fire. Evaluate use of Pu net wt% to detect presence of Pu hydride in can before opening. Cans with relatively large quantities of hydride will be "panelled," making them easy to identify and not open in this campaign.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.5.01	Transfer contents to furnace boat	Pyrophoric reaction as material poured through air	Pu metal, PuH_2, Uranium hydride; Pu_2O_3 contaminant in can Pu or U metal may be in can due to incomplete prior stabilization. PuH_2, UH_3 forms from metal if plastic or organic contaminants are also present in. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can.	Sparks potentially initiating a glovebox fire. Hot embers entrained in air may burn hole in glovebox HEPA filters. Dispersal of Pu in glovebox Potential burn through of gloves and operator injury due to contact with hot embers. Burn through of PVC port bags. Minor contamination spread from glovebox if gloves or port bags damaged Potential ignition of combustibles in glovebox producing glovebox fire If sufficient hydride contamination present, slight pressurization of the glovebox could occur	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Cans with relatively large quantities of hydride will be "paneled" and easily identified. Combustible loading in glovebox is controlled by procedure	S1 S1*	F3 F2	Evaluate use of Pu net wt% to detect presence of Pu or U metal in can before opening. S1/F3 for sparking reactions with maximum consequence being burn through of glove or port bag. S1*/F2 for ignition of significant combustibles in the glovebox.
B.5.02	Transfer contents to furnace boat	Can/boat contents spilled to glovebox floor	Human error	Violation of criticality prevention specification limit regarding depth of powder allowed on glovebox floor Increased operator exposures during cleanup of spill	E-4 ventilation system and glovebox confinement release	Housekeeping Operator training and procedures	S0	F3	Operational upset only Significant dose to operator in cleaning up spill not expected.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.5.03	Transfer contents to furnace boat	Material other than Pu oxide poured into furnace boat (e.g., metal button, sludge or glovebox floor sweeps) resulting in process upset.	Wrong can opened due to mislabeling or human error.	Process upset. Material would have to be canned up and bagged out of the glovebox for later processing. Potential adverse reaction in furnace in Glovebox HC-21C if wrong material not noticed by operator.	--	Labeling and paperwork associated with each container identify contents making it unlikely for wrong material to be processed. Operator training and procedures.	S0	F2	X-ray or Pu mass ratio information could be used to provide added assurance against processing materials other than Pu oxide. Sludges are stored in polyjars in Glovebox HA-23S, not in the vaults with the Pu oxide. Highly unlikely that container of sludge would get mixed up with container of oxide. Glovebox floor sweeps are stored in gloveboxes, not in the vaults with the Pu oxide, making selection of can with floor sweeps very unlikely. H/X ratio on sludges will indicate high organic loading. Hazards associated with inadvertently processing Pu fluoride are covered in this PHA since it may be difficult to visually tell the difference between fluoride and oxide through the yellowed glovebox windows (see items B.1.02 and D.3.10).

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.6.01	Identify and remove contaminants from oxide in furnace boat	Contaminants not identified or removed from oxide result in reaction hazards in Glovebox HC-21C furnaces. Contaminants can include unburned metal pieces from prior stabilization run, metal hydrides, and plastics including: tool handles, brush bristles, PVC or polyethylene bag fragments, polycarbonate pieces, etc.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Pyrophoric reaction in furnace in Glovebox HC-21A. See item D.3.08. Fires or deflagrations of flammables the furnaces in Glovebox HC-21C. See item D.3.07.	See items D.3.07 and D.3.08 for engineered features to mitigate reactions in the HC-21C furnaces.	Previous LOI testing results provide confidence that significant quantities of plastic contaminant are not in product to be stabilized in this campaign. Procedures with sign off by Shift Technical Advisor.	S1* S1*	F2 F2	S1*/F2 for pyrophoric reactions in furnace. S1*/F2 for flammable gas deflagration in furnace resulting from excessive plastic contaminant in oxide feed to furnace.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.7.01	Bag out waste (crushed cans, tape, plastic); replace port bag.	Breach in glovebox confinement boundary during waste bagout or glove change.	Sharp object punctures bag Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	
B.7.02	Bag out waste (crushed cans, tape, plastic); replace port bag.	Spread of contamination from waste bag	Waste bag squeezed causing release of radiological material through taped vent Isolated transport container (ITC) dropped during handling causing bag to vent or rupture	Contamination of workers and potential uptake of radiological material	E-3 ventilation system filters release to environment. Room CAMs alert workers to airborne contamination.	Operator training and procedures Waste bags are put in Isolated transport container (ITC) immediately after applying second bag. ITCs have lids to minimize spread of release from pail. Radiological control program. Survey of workers with alpha poppy probes to detect skin contamination. Worker decontamination by RCT if necessary.	S1	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
B.7.03	Bag out waste (crushed cans, tape, plastic); replace port bag.	Hydrogen deflagration inside waste drum in satellite accumulation area.	Hydrogen generation from radiolysis in waste bags in waste drum. Ignition caused by spark generated while moving drum.	Pressurization of drum, drum damage and release of radiological material from waste drum in satellite accumulation area (Room 166) Potential worker injury	Waste drum is vented through a filter to prevent hydrogen accumulation Room CAMs alert workers of airborne contamination in room 166 Room 166 ventilated by the E-3 system which confines and filters any release from waste drum.	Drum seal is verified. Periodic surveillance of rooms to detect bulging drums.	S1	F2	S1 ranking instead of S1* due to small quantity of Pu in drum. This hazard is not unique to the thermal stabilization process as it applies to drums containing bagged out waste from all gloveboxes. Hazards associated with drum storage are covered in the PFP FSAR. The Pu content of the bagged waste is so low that significant pressurization of a drum is not expected during its storage life at PFP even if vent plugs.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
C. Activities in Glovebox HC-2									
C.1.01	Transfer furnace boat down conveyor to Glovebox	Glove damaged during conveyor operation compromising glovebox confinement	Glovebox glove(s) pinched in conveyor during transfer.	Worker injury and contamination Potential spread of contamination from glovebox through hole in glove leading to potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and confinement velocity across ruptured gloves. CAMs alert workers to presence of airborne contamination.	Conveyor disabled when workers have hands in gloves - 3 key interlocks (in different rooms) must be enabled to operate conveyor. Gloves secured outside conveyor glovebox with bungee cords before conveyor is turned on. Operator training and certification.	S1	F3	
C.1.02	Transfer furnace boat down conveyor to Glovebox	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped off conveyor .	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	S0	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D. Activities in Glovebox HC-21C									
D.1.01	Take boat out of boat house, adjust furnace hearth, and place boat in furnace	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat spilled while loading into furnace	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal should the boat tip over on the conveyor.	S0	F3	
D.2.01	Prepare for furnace operation, includes: - close furnace door - adjust offgas (vacuum) flowrate - check ceramic offgas filter DP - pull gloves out of glovebox and secure with bungee cords - remove combustibles from glovebox	Operator injury/glove damage	Glove pinched in door when closed or glove punctured by sharp object.	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox.	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	S1	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.2.02	Prepare for furnace operation, includes: - close furnace door - adjust offgas (vacuum) flowrate - check ceramic offgas filter DP - pull gloves out of glovebox and secure with bungee cords - remove combustibles from glovebox	Breach in glovebox confinement boundary during bagout of combustibles or while withdrawing gloves from glovebox.	Sharp object punctures port bag while bagging out combustibles or while changing bag. Bag not properly horsetailed or taped after removing combustibles from glovebox. Bag inadvertently pulled off port during bagout of combustibles. Glove tears while being pulled out of the glovebox to prevent contact with hot furnace.	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	
D.2.03	Prepare for furnace operation, includes: - close furnace door - adjust offgas (vacuum) flowrate - check ceramic offgas filter DP - pull gloves out of glovebox and secure with bungee cords - remove combustibles from glovebox	Gloves melted by contact with furnace compromising glovebox confinement.	Gloves not withdrawn from glovebox before starting furnace; gloves contact hot surface of furnace and melts. Gloves not secured properly with bungee cords after being pulled out of the glovebox; negative pressure causes gloves to be pulled into glovebox contacting hot spot on furnace.	Burned out glove allows contamination to spread from glovebox; potential uptake by workers. Operator burned while trying to pull glove back from furnace.	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and prevents contamination spread unless several gloves are lost. Emergency exhaust valves on RMC line opens up on low glovebox vacuum. Fire brick insulates outer surfaces of furnace from the intense heat produced in the furnace. Only limited areas around the door of the furnace are hot enough to melt or burn gloves. Room CAMs alert workers to presence of airborne contamination. E-3 ventilation system filters any release from Zone 3 area to the environment.	Operator training and procedures. Gloves are pulled out of glovebox and secured with bungee cords before operating furnaces.	S1	F3	Hypalon gloves are expected to melt not burn on contact with hot surface of furnace.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.2.04	Prepare for furnace operation, includes: - close furnace door - adjust offgas (vacuum) flowrate - check ceramic offgas filter DP - pull gloves out of glovebox and secure with bungee cords - remove combustibles from glovebox	Fire in glovebox compromises glovebox confinement.	Combustibles not controlled in glovebox come in contact with hot surface of furnace while it is operating. Combustible loading allows fire to spread. Port bag comes un-horsetailed gets sucked in and contacts hot surface of furnace.	Potential burn through of gloves or port bags, softening or ignition of glovebox windows leading to spread of Pu from compromised glovebox confinement boundary.	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and prevents contamination spread unless several gloves or port bags are lost. Emergency exhaust valves on RMC line opens up on low glovebox vacuum. Fire brick insulates outer surfaces of furnace from the intense heat produced in the furnace. Only limited areas around the door of the furnace are hot enough to ignite combustibles. Room CAMs alert workers to presence of airborne contamination. E-3 ventilation system filters any release from Zone 3 area to the environment.	Operator training and procedures. Combustible loading in glovebox is minimized by procedure.	S1*	F2	
D.3.01	Set furnace controller, ramp up furnace temperature and stabilize oxide for 2 hours at > 950 C. (Temperature controller upsets)	Temperature ramped up too fast (temperature controller fails high)	Controller failure. Programmer error. Relay contact fails closed.	Burn out of furnace coils leading to shutdown of process. No hazard found for heating oxide too fast.	Furnace temperature controller and furnace thermocouples: Controller shuts off furnace if program temperature and furnace temperature differ by more than 200 C. Controller limits maximum current to 17 amps which prevents coil burnout. Temperature alarm switch (TAS) shuts off power to furnace if temperature exceeds 1050 C. Temperature deviation alarm provides indication of furnace temperature treater than 20 degrees from controller setpoint at any given time.	Operator training and procedures. Calibration of controller.	S0	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.3.02	Set furnace controller, ramp up furnace temperature and stabilize oxide for 2 hours at > 950 C. (Temperature controller upsets)	Inadequate stabilization of material leads to rupture of container in storage vault.	Failure of furnace heating element. Loss of power during stabilization. Temperature controller failure (temperature not held high enough for required 2 h). Power shut off early by operator.	Rupture of container sometime after it is place in storage vault if furnace upset not detected and LOI test fails to determine high moisture content. PuO_2 reacts with water to form a binary oxide and hydrogen gas which overpressurizes the container. Potential worker inhalation hazard upon entering vault.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product. Temperature deviation alarm provides indication of furnace temperature treater than 20 degrees from controller setpoint at any given time.	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs. Furnace chart recorder readings are used to verity proper furnace operation and soak time. LOI testing is performed on representative sample of material after stabilization in the furnace. Material found to lose more than 0.5 wt% in LOI testing will be run back through the furnace.	S1*	F2	
D.3.03	(Furnace vacuum system upsets)	Reduced air flow or no air flow during stabilization of material in furnace.	Plugged ceramic filter. Vacuum system valved out or otherwise blocked. Failure of vacuum pump or loss of power to vacuum pump. Other loads placed on 26 in vacuum system reduce airflow through furnace. Airflow not set properly before operating furnace.	Hot air from furnace vents into glovebox while heating oxide. Furnace not cooled down in intended time period after stabilization oxide. Potential damage to glovebox gloves and operator burn when boat removed from furnace.	DP across ceramic filter allows identification of plugged filter. Flow meter on vacuum line. Glovebox (E-4) ventilation system adequately removes hot air vented from furnace preventing overheating of glovebox. Temperature recorder tells operator when furnace is cooled down. DP and orifice place in vacuum system indicate flowrate.	Flow through vacuum system is verified to be in proper range before each furnace use. By procedure, operators are not allowed to remove furnace boat until furnace is below 200 C.	S1	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.3.04	(Furnace vacuum system upsets)	Excessive airflow through vacuum system	Flow rate set too high by operator.	Entrainment of flighty Pu oxide powder in furnace. Elevated release of particulates to vacuum system. Potential pluggage of ceramic filter leading to loss of vacuum flow (see item D.3.03)	Baffle in furnace reduces airflow directly over furnace boat minimizing suspension of particulates. Ceramic offgas filter removes majority of particulates before they enter the vacuum system header. DP gauge across ceramic filter provides indication of plugging. Demister and HEPA filters in vacuum system remove residual particulates from vacuum system air before discharge to the environment. DP and orifice place in vacuum system indicate flowrate.	Operator verifies correct flowrate throughout the vacuum system via rotameter before operating furnace.	S0	F3	
D.3.05	(Furnace vacuum system upsets)	Unfiltered flow through/around ceramic filter.	Filter cracked due to thermal stress Filter cracked or not properly installed in canister during installation/replacement.	Pu release into vacuum system Potential plugging of vacuum line between furnace and vacuum header.	Ceramic filter designed for high heat environment. DP gauge across ceramic filter provides indication of plugging. DP and orifice place in vacuum system indicate flowrate to detect plugging of vacuum line. Demister and HEPA filters in vacuum system remove residual particulates from vacuum system air before discharge to the environment.	Maintenance procedure for proper replacement of ceramic filter Operator training and procedures	S0	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.3.06	(E-4 ventilation upsets)	Overheating of glovebox	Loss of E-4 ventilation flow during operation of furnace due to equipment failures, damper closures, etc.	Overheating of glovebox leading to possible failure of port bags and gloves and inadvertent operation of the glovebox dry fire suppression system. Potential softening and sagging of glovebox windows. Release of contamination through failed gloves or bag ports (or failed windows). Potential Pu uptake by workers. Evacuation of Zone 3 process areas leading to unattended glovebox which could result in inability to control fire if combustibles ignited.	Insulating blankets protect glovebox panels from heat damage from nearby hot vacuum lines. Backup E-4 exhaust fans run by emergency generators or steam kicks on on loss of normal exhaust flow protecting glovebox from overheating. Alarms if dP is lost Halon system designed to put out fire by displacing a fraction of the air in the glovebox. It is designed not to discharge enough material to pressurize the glovebox. .	Alarms in power control room activate on loss of E-4 exhaust flow. Process areas are evacuated on loss of E-4 ventilation protecting workers from Pu potentially released from the glovebox. Work to restore ventilation flow on dampers or other equipment can occur as they are outside process areas. Operators are trained to hit "kill switch" shutting down furnaces before evacuating. Emergency plan	S1*	F3	
D.3.07	(contaminants in Pu oxide)	Plastic contaminants in Pu oxide feed result in fire/deflagration in furnace.	Plastic contaminants not noticed in feed or not removed by operator (plastic contaminants can include PVC, polyethylene, polycarbonate, polystyrene, Polymethyl Methacrylate).	Fire or deflagration involving flammable gases (alkanes, alkenes, hydrogen, carbon monoxide) generated inside the furnace. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace. Furnace vacuum system sweeps air through the furnace to dilute flammable gas concentration or to completely oxidize (burn) plastic contaminant in a controlled manner.	Plastic contaminants are looked for and removed when the oxide is poured and sieved into the furnace boat in Glovebox HC-21A. Previous LOI testing results provide confidence that significant quantities of plastic contaminant are not in product to be stabilized in this campaign. Shift technical advisor sign off for material acceptability required by procedure.	S1*	F2	Recommend that material be poured through a sieve in Glovebox HC-21A to help identify plastic or other contaminants. Combination of airflow rate and ramp up rate should be used to ensure complete and controlled oxidation of plastic in furnace, taking into account the maximum quantity of plastic likely to slip past detection in Glovebox HC-21A.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.3.08	(contaminants in Pu oxide)	Metal contaminant in feed results in pyrophoric reactions in the furnace.	Metal turnings or pieces not noticed or removed from feed in Glovebox HC-21A.	Reaction of pyrophoric metal or hydrided metal contaminant in furnace, leading to hydrogen release and burn in the furnace. Potential furnace damage. Failure of glovebox not expected due to small quantity of hydrided metal expected in feed.	Glovebox ventilation system confines material dispersed from furnace.	Visual identification of "non oxides" in Glovebox HC-21A when material poured into furnace boat. Blend plan identifies previously stabilized oxide to restabilize in this campaign. Labeling of cans. Operator training and procedures.	S1	F3	
D.3.09	(Materials other than primarily oxide processed through furnace)	Glovebox sweeps containing organic (plastics or sludge) processed through furnace results in flammable gas deflagration in furnace.	Wrong can selected from storage area opened in Glovebox HC-21A due to mislabeling or human error. Plus Failure to notice plastic contaminant or sludge in furnace boat during visual inspection in Glovebox HC-21C.	Deflagration in furnace, failure of furnace, and potential burn through of gloves, bag ports, or glovebox panels. Release of Pu from glovebox and potential uptake by operators.	E-3 ventilation system filters release to environment should Pu be released into room from glovebox.	Labelling and paperwork associated with each can identify contents: glovebox sweeps are indicated in labelling and paperwork minimizing likelihood or processing wrong material. Glovebox sweeps are not stored in same vault with Pu oxides to be processed in this campaign. Sweeps from wet gloveboxes are stored in polyjars which are difficult to mistake for a PuO_2 container.	S1*	F2	Sweeps could contain much more plastic contaminant than the oxide planned to be processed in this campaign.
D.3.10	(Materials other than primarily oxide processed through furnace)	Pu fluoride powder processed through furnace.	Wrong can selected for processing due to mislabeling or human error.	Fluorine gas release due to reaction with water vapor in air run through furnace. Damage to furnace vacuum exhaust system. Increased direct dose to operators. Pu fluoride produces higher direct dose than oxide (due to alpha-n reactions). See item B.1.02.	None	Labeling and paperwork associated with each container identify contents making it unlikely for wrong material to be processed.	S0	F2	PuF_4 powders may be difficult to distinguish from PuO_2 through yellow glovebox windows.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.4.01	Remove boat from furnace and let cool for one hour on boat stand.	Glove damage/operator burn	Boat removed from furnace too early or boat not allowed to cool on boat stand before handling.	Operator burns hole in glove and suffers injury while removing boat from furnace. Hole in glove compromises glovebox confinement.	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Glovebox ventilation system removes enough heat to prevent overheating of glovebox air with furnace door open. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	By procedure, operators are not allowed to remove furnace boat until furnace is below 200 C. Hot mill gloves used with boat handling tool to remove boat from furnace. By procedure, boat is left on boat stand to cool for one hour before being handled by glove.	S1	F3	
D.4.02	Remove boat from furnace and let cool for one hour on boat stand.	Glovebox fire or radiant heat damage to glovebox confinement boundary	Door opened during heating cycle to remove boat	Radiant heat from coils melts gloves and burns operator, softens and potentially ignites glovebox panels Potential activation of glovebox dry fire suppression system (Halon system). Potential ignition of combustibles in glovebox. Release of Pu to room air and uptake by workers.	Furnace interior temp indication Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	Operators trained not to remove boat from furnace or to open furnace door until temperature has dropped below 200 C. Combustible loading in glovebox is controlled.	S1* S1	F2 F2	Each furnace produces about 1800 W of heat. From the PFP FHA, a 34 kW/m^2 heat flux is sufficient to ignite a polycarbonate panel in 10 minutes. S1*/F2 for glovebox fire S1/F2 for softening of panels or failure of port bags.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
D.5.01	Place boat into boat house and transfer boat to Glovebox HC-18BS through Conveyor Glovebox	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped off conveyor Air supply to RMC line blows powder out of boat near Glovebox HC-18BS.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	S0	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
E. Activities in Glovebox HC-18BS									
E.1.01	Transfer boats on surpentine conveyor to Glovebox HC-18M for LOI testing	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped off conveyor.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	S0	F3	
E.2.01	Temporarily store cans containing Pu oxide pending results of LOI tests in Glovebox HC-18M	Violation of criticality safety mass limit or violation of glovebox dispersible inventory limit	Too many containers stored too close together. Failure to adhere to glovebox postings. See item A.2.01.	see item A.2.01	see item A.2.01	see item A.2.01	-	-	--

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
F. Activities in Glovebox HC-18M									
F.1.01	Take boat out of boat cover, weigh boat, and transfer material into sieve tray	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped or material spilled while transferring contents into sieve tray.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	S0	F3	No hazards identified for weighing step. Pu Accountability error only.
F.2.01	Place cover on sieve tray and turn on shaker	Dispersal of Pu oxide powder in glovebox.	Cover left off sieve tray while shaker on produces dust that spreads Pu throughout glovebox.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	S0	F3	

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
F.3.01	Remove sieve tray(s) from shaker, remove pieces too large to fit through sieve (> 4 mesh) and grind using mortar and pestle for reprocessing through furnace, transfer contents that passed through sieve (< 4 mesh) to product can.	Spill/dispersal of Pu oxide powder in glovebox	Material spilled while transferring contents into product can.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	S0	F3	No hazards identified for weighing step. Pu Accountability error only.
F.3.02	Remove sieve tray(s) from shaker, remove pieces too large to fit through sieve (> 4 mesh) and grind using mortar and pestle for reprocessing through furnace, transfer contents that passed through sieve (< 4 mesh) to product can.	Pu metal added to product can causing rupture of container in storage vault.	Material not heated long enough or at high enough temperature in furnace to completely oxidize metal due to furnace failure or failure of furnace temperature controller. Sieve and size reduction step skipped due to human error results in metal pieces not being detected. Metal pieces not removed from oxide material before transferring material to product can.	Rupture of container in storage vault due to the formation of Pu oxide (assuming storage cans is not airtight). PuO_2 is less dense and takes up more volume than metal causing can rupture. Contamination of vault air. Potential uptake by workers on entry into vault. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verity proper furnace operation and soak time.	Operator training and procedures Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs. Shift technical advisor sign off required by procedure.	S1	F2	S1/F2 based on no significant compressed gas present when can ruptures.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
F.3.03	Remove sieve tray(s) from shaker, remove pieces too large to fit through sieve (> 4 mesh) and grind using mortar and pestle for reprocessing through furnace, transfer contents that passed through sieve (< 4 mesh) to product can.	Non-representative sample taken from product can for LOI testing.	Material not heated long enough or at high enough temperature to be adequately stabilized due to furnace or temperature controller failure. Material not sieved or ground properly. Large (> 4 mesh) agglomerations of PuO_2 can give false high or false low LOI readings depending on furnace operation and how long the sample was exposed to humid air after removal from the furnace.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verity proper furnace operation and soak time	Operator training and procedures Radiological control program: routing sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	S1*	F2	
F.4.01	Take 5 to 10 g sample for LOI test and perform LOI test	"Wet" oxide transferred to product can and stored in vault, resulting in rupture of container in vault.	Material not stabilized long enough or at high enough temperature in furnace due to temperature controller or furnace failure. LOI test fails to detect inadequate stabilized material due to non-representative sample being taken (see above) or material canned without benefit of LOI testing due to human error. Or LOI test results or can labels mixed up resulting in wrong can being authorized for storage in vault.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verity proper furnace operation and soak time	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	S1*	F2	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
F.5.01	If material found to contain greater than 0.5 wt% water by LOI test, reprocess material through furnace and repeat LOI testing.	"Wet" oxide transferred to product can and stored in vault, resulting in rupture of container in vault.	Inadequately stabilized material not run back through the furnace due to human error.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being re-canned even if undetected furnace upset occurs. Furnace chart recorder readings are used to verify proper furnace operation and soak time	S1*	F2	
F.6.01	Temporarily store Pu oxide material in product cans in Glovebox HC-18BS pending results of LOI testing.	Covered in items E.1.1 and E.2.1							

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
F.7.01	Bag out of sample bottles from Glovebox HC-18M for transfer to the lab for LOI analysis Bag out of product cans from Glovebox HC-18M for transfer to storage vault.	Breach in glovebox confinement boundary during waste bagout, bag change, or glove change.	Bag punctured by sharp object Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers.	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
F.7.02	Bag out of sample bottles from Glovebox HC-18M for transfer to the lab for LOI analysis Bag out of product cans from Glovebox HC-18M for transfer to storage vault.	Pu release from sample bottle or product can after bagout	Sample bottle or product can dropped after bagout causing bottle to break or slip lid to come off and bag to rupture.	Contamination of workers and potential uptake of radiological material	E-3 ventilation system filters mitigate release to environment should material be release to Zone 3 area. Room CAMs alert workers to airborne contamination.	Operator training and procedures Radiological control program. Survey of workers with alpha poppy probes to detect skin contamination. Worker decontamination by RCT if necessary. Bagged sample bottles are placed in ice cream carton and then in special wagon for transport to the analytical lab. Carton reduces chances of airborne release in a drop. Product cans are double bagged in the process of being sealed out of the glovebox. Taped slip lid can and double bag minimize the likelihood of a release should the container be dropped.	S1	F3	
G. Natural Phenomena									
G.1.01	Plutonium oxide being thermally stabilized.	Seismic event causes explosion and stagnet glovebox.	Seismic event results in loss of electrical power and potentially a loss of ventilation. Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Seismic ventilation supply shutdown switch. Building structure.	Emergency procedures for evacuation.	S1*	F2	S1*/F2 based on seismic initiator frequency. F2 frequency assumed to be on the low side of the range.
G.1.02	Plutonium oxide in any unconfined state in gloveboxes	Seismic event causes dispersal of plutonium oxide powder in glovebox.	Seismic event results in dispersal of plutonium oxide powder into glovebox atmosphere.	Potential additional exposure to workers due to cleanup requirements.	Seismic ventilation supply shutdown switch. Building structure Glovebox structure	Emergency procedures	S1	F2	S1/F2 based on seismic initiator frequency. F2 frequency assumed to be on high side of range for events that do not fail glovebox.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
G.2.01	Plutonium oxide being thermally stabilized.	NPH - Ash Fall		Ash Fall represents a roof loading concern, abrasive concern for moving equipment, and an electrical concern because of the conductivity of the ash.					
G.3.01	Plutonium oxide being thermally stabilized.	NPH - High Wind		High Wind represents a threat to the 234-5Z Building but not to an individual glovebox inside the building. Chapter 9.0 of the PFP FSAR considers the effect of a wind-driven plank striking the 234-5Z Building and concludes that no significant consequences result.					
External Events									
H.1.01	Plutonium oxide being thermally stabilized.	Facility wide external loss of power with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in glovebox HC-21C.	External event causes facility wide loss of power resulting in loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Building structure. Backup ventilation system connected to emergency.	Emergency procedures	S1*	F3	
H.2.01	Plutonium oxide being thermally stabilized.	Facility wide loss of powerdue to range fire with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in glovebox HC-21C.	Range fire causes facility wide loss of power resulting in loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Building structure.	Emergency procedures Vegitation control programs	S1*	F3	This is not a threat to the 234-5Z building due to the large open areas that are kept clear of vegitation or combustible material buildup.

Table 9F.2
PHA - Thermal Stabilization of PuO_2

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glove box Hazards									
H.3.01	Plutonium oxide being thermally stabilized.	Aircraft crashes into facility causing fire and loss of confinement. (General to all gloveboxes)	Pilot error or mechanical failure	Significant release of material		Controls preventing overflight of facility	S1*	F0	This event is considered to be beyond extremely unlikely in the PFP FSAR and therefore is not being considered for further analysis.

Table 9F.3. Contaminated Wound

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.2.02.b	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	S1	F3
B.2.04.b	Operator injury in glovebox HC-21A.	Operator suffers injury and ruptures glove while crushing empty can with hammer	Operator injury with contamination of wound	S1	F3
B.4.01.b	Operator injury in glovebox HC-21A.	Worker penetrates glove while opening sealed can with can opener, taped slip lid can with scissors, while handling can or lid.	Operator injury with contamination of wound	S1	F3

Table 9F.4. Criticality

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
A.2.01	Violation of criticality safety mass or spacing limit results in criticality. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	S1*	F2
E.2.01	Violation of criticality safety mass limit or violation of glovebox HC-18BS dispersible inventory limit results in criticality.	Too many containers stored too close together. Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	S1*	F2
F.6.01.b	Violation of criticality safety mass limit or violation of glovebox HC-18M dispersible inventory limit results in criticality.	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	S1*	F2

Table 9F.5. Dispersal of Pu Oxide Powder Inside Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.4.03	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	S0	F3
B.5.02	Can/boat contents spilled to glovebox HC-21A	Human error	Violation of criticality prevention specification limit regarding depth of powder allowed on glovebox floor Increased operator exposures during cleanup of spill	S0	F3
C.1.02	Spill/dispersal of Pu oxide powder in glovebox HC-2	Furnace boat dumped off conveyor	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3
D.1.01	Spill/dispersal of Pu oxide powder in glovebox HC-21C	Furnace boat spilled while loading into furnace	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3
D.5.01	Spill/dispersal of Pu oxide powder in glovebox HC-21C	Furnace boat dumped off conveyor Air supply to RMC line blows powder out of boat near Glovebox HC-18BS.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3
E.1.01	Spill/dispersal of Pu oxide powder in glovebox 18-BS	Furnace boat dumped off conveyor.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3
F.1.01	Spill/dispersal of Pu oxide powder in glovebox HC-18M	Furnace boat dumped or material spilled while transferring contents into sieve tray.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3
F.2.01	Dispersal of Pu oxide powder in glovebox HC-18M.	Cover left off sieve tray while shaker on produces dust that spreads Pu throughout glovebox.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3
F.3.01	Spill/dispersal of Pu oxide powder in glovebox HC-18M	Material spilled while transferring contents into product can.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3

Table 9F.5. Dispersal of Pu Oxide Powder Inside Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
F.6.01.a	Spill/dispersal of Pu oxide powder in glovebox HC-18M	Furnace boat dumped off conveyor.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	S0	F3

Table 9F.6. Dispersal of Pu Oxide Powder Outside Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.7.02	Spread of contamination from waste bag during bagout of waste from glovebox HC-21A	Waste bag squeezed causing release of radiological material through taped vent Isolated Transport Container (ITC) dropped during handling causing bag to vent or rupture	Contamination of workers and potential uptake of radiological material	S1	F3
F.7.02	Pu release from sample bottle or product can after bagout from glovebox HC-18M	Sample bottle or product can dropped after bagout causing bottle to break or slip lid to come off and bag to rupture.	Contamination of workers and potential uptake of radiological material	S1	F3

Table 9F.7. Dropped Containers Outside Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.1.01	Drop of Pu storage container outside glovebox HC-21A during seal in.	Human error.	No significant release from Pu storage container expected.	S0	F3

Table 9F.8. External Events

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
H.1.01	Facility wide loss of power with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in glovebox HC-21C.	Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	S1*	F3
H.2.01	Facility wide loss of power due to range fire with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in glovebox HC-21C.	Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	S1*	F3
H.3.01	Aircraft crashes into facility causing fire and loss of confinement. (General to all gloveboxes)	Pilot error or mechanical failure	Significant release of material	S1*	F0

Table 9F.9. Flammable Gas Deflagration in Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.2.01	Flammable gas (i.e. H_2) release and burn when overpack can opened in glovebox HC-21A.	Radiolysis of plastic bag around slip lid can and organic can seal during storage in vault. Ignition due to mechanical spark from can opener, static release from ejected powders, or electrical spark.	Potential deflagration involving H_2 released from can causing pressurization of glovebox, potential failure of port bags or gloves and release of Pu into the room air. Inhalation uptake of Pu by workers.	S1*	F2
B.4.02	Hydrogen gas release and burn when can opened in glovebox HC-21A.	Radiolytic degradation of plastic contaminant, brush bristles, tool handle, bottle caps, etc. in oxide during storage generates hydrogen in can. Hydrogen ignited during release from can due to static or electrical discharge High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Potential deflagration involving H_2 released from can causing pressurization of glovebox, potential failure of port bags or gloves and release of Pu into the room air. Inhalation uptake of Pu by workers.	S1*	F2
B.4.04	Flammable gases (alkanes, H_2, etc) from organic in container released and ignited when can opened (can pressurized) in glovebox HC-21A.	Container containing organic (e.g., sludge, floor sweeps) inadvertently sealed into glovebox and opened. Wrong container selected due to inaccurate labeling or human error. Flammable gases generated due to radiolytic decay of organic material (e.g., sludge) in the container. Ignition due to mechanical or electrical spark, or static discharge.	Pressurization of glovebox Potential damage to glovebox confinement boundary Pu release into room and worker inhalation uptake	S1*	F2
B.6.01.b	Flammable gas deflagration due to plastic contaminants not identified or removed from oxide that result in reaction hazards in Glovebox HC-21C furnaces. Contaminants can include tool handles, brush bristles, PVC or polyethylene bag fragments, polycarbonate pieces, etc.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Fires or deflagrations of flammables in the furnaces in Glovebox HC-21C. See item D.3.07.	S1*	F2
D.3.07	Plastic contaminants in Pu oxide feed result in fire/deflagration in stabilization furnace in glovebox HC-21C.	Plastic contaminants not noticed in feed or not removed by operator (plastic contaminants can include PVC, polyethylene, polycarbonate, polystyrene, Polymethyl Methacrylate).	Fire or deflagration involving flammable gases (alkanes, alkenes, hydrogen, carbon monoxide) generated inside the furnace. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	S1*	F2

Table 9F.9. Flammable Gas Deflagration in Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
D.3.09	Glovebox sweeps containing organic (plastics or sludge) processed through furnace results in flammable gas deflagration in stabilization furnace in glovebox HC-21C.	Wrong can selected from storage area opened in Glovebox HC-21A due to mislabeling or human error. Plus Failure to notice plastic contaminant or sludge in furnace boat during visual inspection in Glovebox HC-21C.	Deflagration in furnace, failure of furnace, and potential burn through of gloves, bag ports, or glovebox panels. Release of Pu from glovebox and potential uptake by operators. Possibly more plastics than in normal oxide	S1*	F2

Table 9F.10. Flammable Gas Deflagration in Waste Drum

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.7.03	Hydrogen venting or deflagrating inside waste drum in 234-5Z satellite accumulation area.	Hydrogen generation from radiolysis in waste bags in waste drum. Ignition caused by spark generated while moving drum.	Pressurization of drum, drum damage and release of radiological material from waste drum in satellite accumulation area (Room 166) Potential worker injury.	S1	F2

Table 9F.11. Loss of Glove Box Confinement Due to Mechanical Breach

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
A.1.03	Hole in glovebox confinement boundary leads to spread of contamination from glovebox (general glovebox hazard).	Degradation of port bags, ice cream cartons used to seal sphincter port, or gloves due to aging, radiation, or heat.	Minor Spread of contamination from glovebox and potential uptake by workers.	S1	F3
A.1.04	Breach in glovebox confinement boundary during waste bagout, port bag replacement, or glove change (general glovebox hazard).	Sharp object punctures bag Bag not properly horse tailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	S1	F3
B.1.03	Glovebox HC-21A loss of confinement during seal in.	Sphincter seal failure Ice cream carton or can in sphincter seal inadvertently pushed into glovebox without can or carton behind it results in open sphincter seal. Seal in bag torn or pulled off port during seal in (also applies to changeout of port bags) (see item A.1.04). Pressurized glovebox during seal in (see item A.3.01)	Minor release of contamination from the glovebox into the room. Potential worker uptake of Pu.	S1	F3
B.2.02.a	Damage to glovebox glove compromising glovebox HC-21A confinement integrity.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Small hole in glovebox confinement boundary Small contamination release from glovebox as hands withdrawn from glovebox gloves	S1	F3
B.2.04.a	Damage to glovebox glove compromising glovebox HC-21A confinement integrity.	Operator ruptures glove while crushing empty can with hammer	Small hole in glovebox confinement boundary leading to contamination release from glovebox.	S1	F3
B.4.01.a	Damage to glovebox glove compromising glovebox HC-21A confinement integrity.	Worker penetrates glove while opening sealed can with can opener, taped slip lid can with scissors, while handling can or lid.	Small hole in glovebox confinement boundary Small contamination release from glovebox	S1	F3

Table 9F.11. Loss of Glove Box Confinement Due to Mechanical Breach

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.7.01	Breach in glovebox HC-21A confinement boundary during waste bagout or glove change.	Sharp object punctures bag Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	S1	F3
C.1.01	Glove damaged during conveyor operation compromising glovebox HC-2 confinement	Glovebox glove(s) pinched in conveyor during transfer	Worker injury and contamination Potential spread of contamination from glovebox through hole in glove leading to potential inhalation uptake by workers	S1	F3
D.2.01	Glove damage during load in/ load out of the stabilization furnaces in glovebox HC-21C.	Glove pinched in furnace door when closed or glove punctured by sharp object.	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox.	S1	F3
D.2.02	Breach in glovebox HC-21C confinement boundary during bagout of combustibles or while withdrawing gloves from glovebox.	Sharp object punctures port bag while bagging out combustibles or while changing bag. Bag not properly horsetailed or taped after removing combustibles from glovebox. Bag inadvertently pulled off port during bagout of combustibles. Glove tears while being pulled out of the glovebox to prevent contact with hot furnace.	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	S1	F3
D.2.03	Gloves melted by contact with furnace compromising glovebox HC-21C confinement.	Gloves not withdrawn from glovebox before starting furnace; gloves contact hot surface of furnace and melts. Gloves not secured properly with bungee cords after being pulled out of the glovebox; negative pressure causes gloves to be pulled into glovebox contacting hot spot on furnace.	Burned out glove allows contamination to spread from glovebox; potential uptake by workers. Operator burned while trying to pull glove back from furnace.	S1	F3

Table 9F.11. Loss of Glove Box Confinement Due to Mechanical Breach

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
D.3.03	Reduced air flow or no air flow during stabilization of material in furnace in glovebox HC-21C.	Plugged ceramic filter. Vacuum system valved out or otherwise blocked. Failure of vacuum pump or loss of power to vacuum pump. Other loads placed on 26 in vacuum system reduce airflow through furnace. Airflow not set properly before operating furnace.	Hot air from furnace vents into glovebox while heating oxide. Furnace not cooled down in intended time period after stabilization oxide. Potential damage to glovebox gloves and operator burn when boat removed from furnace.	S1	F3
D.4.01	Glove damage/operator burn in glovebox HC-21C	Boat removed from furnace too early or boat not allowed to cool on boat stand before handling.	Operator burns hole in glove and suffers injury while removing boat from furnace. Hole in glove compromises glovebox confinement.	S1	F3
F.7.01	Breach in glovebox HC-18M confinement boundary during waste bagout, bag change, or glove change.	Bag punctured by sharp object Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it.	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers.	S1	F3
D.4.02. b	Glovebox fire or radiant heat damage to glovebox HC-21C confinement boundary.	Door opened during heating cycle to remove boat	Radiant heat from coils melts gloves and burns operator, softens glovebox panels Potential activation of glovebox dry fire suppression system (Halon system). Potential ignition of combustibles in glovebox. Release of Pu to room air and uptake by workers.	S1	F2

Table 9F.12. Loss of Glove Box Confinement Due to Ventilation Failure

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
D.3.06	Overheating of glovebox HC-21C.	Loss of E-4 ventilation flow during operation of furnace due to equipment failures, damper closures, etc.	Overheating of glovebox leading to possible failure of port bags and gloves and inadvertent operation of the glovebox dry fire suppression system. Potential softening and sagging of glovebox windows. Release of contamination through failed gloves or bag ports (or failed windows). Potential Pu uptake by workers. Evacuation of Zone 3 process areas leading to unattended glovebox which could result in inability to control fire if combustibles ignited.	S1*	F3
A.3.01.b	Pressurized glovebox during operations causes spread of contamination from glovebox (general glovebox hazard)	Loss of E-4 ventilation flow or imbalance between E-4 supply and exhaust (caused by loss of power or equipment or control failures). Failure to detect HVAC upset during pre-job walkdown	Pressurized glovebox causing spread of contamination from glovebox during seal in or seal out of container, glove change, or change of port bag. Worker exposure to dispersible Pu. Overheating of Glovebox HC-21C during furnace operations (see item D.3.06).	S1*	F2
A.3.01.a	Stagnant glovebox during operations causes spread of contamination from glovebox (general glovebox hazard).	Loss of E-4 ventilation flow or imbalance between E-4 supply and exhaust (caused by loss of power or equipment or control failures). Failure to detect HVAC upset during pre-job walkdown	Spread of contamination from glovebox during seal in or seal out of container, glove change, or change of port bag. Worker exposure to dispersible Pu. Overheating of Glovebox HC-21C during furnace operations (see item D.3.06).	S1	F3

Table 9F.13. Natural Phenomena

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
G.1.01	Seismic event causes explosion and stagnet glovebox. (General to all gloveboxes)	Seismic event results in loss of electrical power and potentially a loss of ventilation. Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	S1*	F2
G.1.02	Seismic event causes dispersal of plutonium oxide powder in glovebox. (General to all gloveboxes)	Seismic event results in dispersal of plutonium oxide powder into glovebox atmosphere.	Potential additional exposure to workers due to cleanup requirements.	S1	F2
G.2.01	Natural Phenomena - Ash Fall	Ash Fall effects are described in Chapter 3.0 of the PFP FSAR.	Ash Fall effects are described in Chapter 3.0 of the PFP FSAR. Ash Fall represents a roof loading concern, abrasive concern for moving equipment, and an electrical concern because of the conductivity of the ash.	S1	F2
G.3.01	Natural Phenomena - High Wind	High Wind effects are described in Chapter 3.0 of the PFP FSAR.	High Wind effects are described in Chapter 3.0 of the PFP FSAR. High Wind represents a threat to the 234-5Z Building but not to an individual glovebox inside the building. Chapter 9.0 considers the effect of a wind-driven plank striking the 234-5Z Building and concludes that no significant consequences result.	S0	F2

Table 9F.14. Occupational Hazards

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
A.1.02	Electrical shock to operator while working in glovebox HC-21A	Cord frayed in the glovebox Frayed cord contacts glovebox frame while operators body or leg is in contact with the glovebox frame.	Operator injury	S1	F5

Table 9F.15. Operational Upset

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.2.03	Outer cans not properly made into non- container in glovebox HC-21A result in operational upset.	Can not crushed and folded, can with bottom removed set upright instead of on its side, can not turned upside down.	CPS infraction Margin of criticality safety reduced	S0	F3
D.3.01	Stabilization furnace temperature ramped up too fast (temperature controller fails high) resulting in furnace failure in glovebox HC-21C and process upset.	Controller failure. Programmer error. Relay contact fails closed.	Burn out of furnace coils leading to shutdown of process. No hazard found for heating oxide too fast.	S0	F3
D.3.04	Excessive airflow through furnace in glovebox HC-21C resulting I elevated particulate release to vacuum system causes process upset.	Flow rate set too high by operator.	Entrainment of flighty Pu oxide powder in furnace. Elevated release of particulates to vacuum system. Potential pluggage of ceramic filter leading to loss of vacuum flow (see item D.3.03)	S0	F3
D.3.05	Unfiltered flow through/around ceramic filter in glovebox HC-21C results in operational upset.	Filter cracked due to thermal stress Filter cracked or not properly installed in canister during installation/replacement.	Pu release into vacuum system Potential plugging of vacuum line between furnace and vacuum header.	S0	F3
B.5.03	Material other than Pu oxide poured into furnace boat in glovebox HC-21A (e.g., metal button, sludge or glovebox floor sweeps) resulting in process upset.	Wrong can opened due to mislabeling of can or human error.	Process upset. Material would have to be canned up and bagged out of the glovebox for later processing. Potential adverse reactions in furnace in Glovebox HC-21C if wrong material not noticed by operator.	S0	F2
D.3.10	Pu fluoride powder processed through furnace causes corrosion damage to furnace in glovebox HC-21C results in operational upset..	Wrong can selected for processing due to mislabeling or human error.	Fluorine gas release due to reaction with water vapor in air run through furnace. Damage to furnace vacuum exhaust system. Increased direct dose to operators. Pu fluoride produces higher direct dose than oxide (due to alpha-n reactions). See item B.1.02.	S0	F2

Table 9F.16. Pyrophoric Reaction in Furnace

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
D.3.08	Metal contaminant in feed results in pyrophoric reactions in the furnace in glovebox HC-21C.	Metal turnings or pieces not noticed or removed from feed in Glovebox HC-21A.	Reaction of pyrophoric metal or hydrided metal contaminant in furnace, leading to hydrogen release and burn in the furnace. Potential furnace damage. Failure of glovebox not expected due to small quantity of hydrided metal expected in feed.	S1	F3
B.6.01.a	Contaminants not identified or removed from oxide result in reaction hazards in Glovebox HC-21C furnaces. Pyrophoric contaminants can include unburned metal pieces from prior stabilization run, metal hydrides, uranium hydrides, or Pu_2O_3.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Pyrophoric reaction in furnace in Glovebox HC-21A. See item D.3.08. Fires in the furnaces in Glovebox HC-21C. See item D.3.07.	S1	F2

Table 9F.17. Pyrophoric Reaction in Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.5.01.b	Pyrophoric reaction as material poured through air in glovebox HC-21A.	Pu metal, PuH_2, Uranium hydride; Pu_2O_3 contaminant in can Pu or U metal may be in can due to incomplete prior stabilization. PuH_2, UH_3 forms from metal if plastic or organic contaminants are also present in. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can.	Sparks potentially initiating a glovebox fire. Hot embers entrained in air may burn hole in glovebox HEPA filters. Dispersal of Pu in glovebox Potential burn through of gloves and operator injury due to contact with hot embers. Burn through of PVC port bags. Minor contamination spread from glovebox if gloves or port bags damaged Potential ignition of combustibles in glovebox producing glovebox fire If sufficient hydride contamination present, slight pressurization of the glovebox could occur	S1*	F2
B.4.05.a	Pyrophoric reaction and hydrogen burn when can opened in glovebox HC-21A.	PuH_2 hydride contaminant in can Pu metal may be in can due to incomplete prior stabilization. PuH_2 forms from metal if plastic or organic contaminants are also present in can. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. Can under vacuum due to catalyzed formation of oxides and nitrides in the container. When can is opened air is sucked in which reacts with the hydrided material. Hyride reactions releases heat and hydrogen gas which is ignited on exiting the can.	If sufficient hydride contamination present, slight pressurization of the glovebox could occur. Potential burn through of gloves and operator injury due to contact with hot embers. Embers burn through PVC ports Minor contamination spread from glovebox if gloves or port bags damaged.	S1	F3

Table 9F.18. Radiation Protection

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.1.02	High worker direct dose during handling of cans in glovebox HC-21A.	Container containing metal or PuF_4 handled instead of PuO_2 (PuF_4 much higher dose than oxide from alpha-n reactions). Cans handled for extended time period during handling/seal-in of cans.	Worker dose rate limit (Radiological work permit) potentially exceeded	S1	F3

Table 9F.19. Rupture of Container In Storage Vault

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
D.3.02	Inadequate stabilization of material in glovebox HC-21C furnace leads to rupture of container in storage vault.	Failure of furnace heating element. Loss of power during stabilization. Temperature controller failure (temperature not held high enough for required 2 h). Power shut off early by operator.	Rupture of container sometime after it is place in storage vault if furnace upset not detected and LOI test fails to determine high moisture content. PuO_2 reacts with water to form a binary oxide and hydrogen gas which overpressurizes the container. Potential worker inhalation hazard upon entering vault.	S1*	F2
F.3.03	Non-representative sample taken from product can for LOI testing in glovebox HC-18M.	Material not heated long enough or at high enough temperature to be adequately stabilized due to furnace or temperature controller failure. Material not sieved or ground properly. Large (> 4 mesh) agglomerations of PuO_2 can give false high or false low LOI readings depending on furnace operation and how long the sample was exposed to humid air after removal from the furnace.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	S1*	F2
F.4.01	"Wet" oxide transferred to product can in glovebox HC-18M and stored in vault, resulting in rupture of container in vault.	Material not stabilized long enough or at high enough temperature in furnace due to temperature controller or furnace failure. LOI test fails to detect inadequate stabilized material due to non-representative sample being taken or material canned without benefit of LOI testing due to human error. Or LOI test results or can labels mixed up resulting in wrong can being authorized for storage in vault.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	S1*	F2
F.5.01	"Wet" oxide transferred to product can in glovebox HC-18M and stored in vault, resulting in rupture of container in vault.	Inadequately stabilized material not run back through the furnace due to human error.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault.	S1*	F2

Table 9F.19. Rupture of Container In Storage Vault

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
F.3.02	Pu metal added to product can in glovebox HC-18M causing rupture of container in storage vault.	Material not heated long enough or at high enough temperature in furnace to completely oxidize metal due to furnace failure or failure of furnace temperature controller. Sieve and size reduction step skipped due to human error results in metal pieces not being detected. Metal pieces not removed from oxide material before transferring material to product can.	Rupture of container in storage vault due to the formation of Pu oxide (assuming storage cans is not airtight). PuO_2 is less dense and takes up more volume than metal causing can rupture. Contamination of vault air. Potential uptake by workers on entry into vault. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	S1	F2

Table 9F.20. Uncontrolled Fire in Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
A.1.01	Fire in glove box HC-21A caused by electrical short.	Failure to properly inspect power cords or failure to identify frayed cords results in condition that leads to an electrical short that ignites combustibles in the glovebox Failure to control combustibles in glove box allows significant fire that damages glove box confinement.	Burn through of gloves seal out bags resulting in breach of containment Ignition of Polymethyl Methacrylate or Polycarbonate glove box panels and spread of fire to other gloveboxes Release of soot, hot embers, and water vapor to the E-3 and E-4 ventilation systems. Pluggage or failure of glovebox and E-4 filterbox HEPA filters. Potential pluggage of E-3 room prefilters or E-3 filterbox HEPA filters, with spread of contamination to clean portions of the plant. Worker uptake of airborne Pu	S1*	F3
B.4.05.b	Pyrophoric reaction and hydrogen burn when can opened which ignites combustibles in glovebox HC-21A.	PuH_2 hydride contaminant in can Pu metal may be in can due to incomplete prior stabilization. PuH_2 forms from metal if plastic or organic contaminants are also present in can. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. Can under vacuum due to catalyzed formation of oxides and nitrides in the container. When can is opened air is sucked in which reacts with the hydrided material. Hyride reactions releases heat and hydrogen gas which is ignited on exiting the can. AND Combustible loading in glovebox not controlled.	Potential ignition of combustibles in glovebox producing glovebox fire.	S1*	F2
D.2.04	Fire in glovebox compromises glovebox HC-21C confinement.	Combustibles not controlled in glovebox come in contact with hot surface of furnace while it is operating. Combustible loading allows fire to spread. Port bag comes un-horsetailed and gets sucked in and contacts hot surface of furnace.	Potential burn through of gloves or port bags, softening or ignition of glovebox windows leading to spread of Pu from compromised glovebox confinement boundary.	S1*	F2
D.4.02.a	Glovebox fire or radiant heat damage to glovebox HC-21C confinement boundary.	Furnace door inadvertently opened during heating cycle to remove boat.	Radiant heat from coils potentially ignites glovebox panels Potential activation of glovebox dry fire suppression system (Halon system). Potential ignition of combustibles in glovebox. Release of Pu to room air and uptake by workers.	S1*	F2

Table 9F.20. Uncontrolled Fire in Glove Box

Item #	Failure/ Hazardous Condition	Causes	Consequences	Cons Rank	Freq Rank
B.5.01.a	Pyrophoric reaction as material poured through air in glovebox HC-21A.	Pu metal, PuH_2, Uranium hydride; Pu_2O_3 contaminant in can Pu or U metal may be in can due to incomplete prior stabilization. PuH_2, UH_3 forms from metal if plastic or organic contaminants are also present in. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. AND Combustible loading in glovebox not controlled.	Sparks potentially initiating a glovebox fire. Hot embers entrained in air may burn hole in glovebox HEPA filters. Dispersal of Pu in glovebox Potential burn through of gloves and operator injury due to contact with hot embers. Burn through of PVC port bags. Minor contamination spread from glovebox if gloves or port bags damaged Potential ignition of combustibles in glovebox producing glovebox fire If sufficient hydride contamination present, slight pressurization of the glovebox could occur	S1	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
B.5.02	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Can/boat contents spilled to glovebox HC-21A	Human error	Violation of criticality prevention specification limit regarding depth of powder allowed on glovebox floor Increased operator exposures during cleanup of spill	E-4 ventilation system and glovebox confinement release	Housekeeping Operator training and procedures	F3
C.1.02	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox HC-2	Furnace boat dumped off conveyor	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before iniating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
D.1.01	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox HC-21C	Furnace boat spilled while loading into furnace	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before iniating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal should the boat tip over on the conveyor.	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
D.5.01	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox HC-21C	Furnace boat dumped off conveyor Air supply to RMC line blows powder out of boat near Glovebox HC-18BS.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before iniating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
E.1.01	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox 18-BS	Furnace boat dumped off conveyor.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before iniating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	F3
F.1.01	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox HC-18M	Furnace boat dumped or material spilled while transferring contents into sieve tray.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
F.2.01	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Dispersal of Pu oxide powder in glovebox HC-18M.	Cover left off sieve tray while shaker on produces dust that spreads Pu throughout glovebox.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	F3
F.3.01	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox HC-18M	Material spilled while transferring contents into product can.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
F.6.01.a	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	Spill/dispersal of Pu oxide powder in glovebox HC-18M	Furnace boat dumped off conveyor.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before iniating operations. Boat is transferred in a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	F3
B.1.01	**DROPPED CONTAINERS OUTSIDE GB**	Drop of Pu storage container outside glovebox HC-21A during seal in.	Human error.	No significant release from Pu storage container expected.	Overpack containers protect inner container.	Operator training and procedures Inner containers have been drop tested and found not to leak.	F3
G.3.01	**NPH - High Wind**	Addressed in Chapter 3.0 of PFP FSAR		High Wind effects are described in Chapter 3.0 of the PFP FSAR. High Wind represents a threat to the 234-5Z Building but not to an individual glovebox inside the building. Chapter 9.0 considers the effect of a wind-driven plank striking the 234-5Z Building and concludes that no significant consequences result.			F2

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
B.2.03	**OPERATIONAL UPSET**	Outer cans not properly made into non-container in glovebox HC-21A	Can not crushed and folded, can with bottom removed set upright instead of on its side, can not turned upside down.	CPS infraction Margin of criticality safety reduced	None	Operator training and procedures Glovebox CPS posting (tells operator maximum open container volume to unit mass ratio)	F3
B.5.03	**OPERATIONAL UPSET**	Material other than Pu oxide poured into furnace boat in glovebox HC-21A (e.g., metal button, sludge or glovebox floor sweeps) resulting in process upset.	Wrong can opened due to mislabeling of can or human error.	Process upset. Material would have to be canned up and bagged out of the glovebox for later processing. Potential adverse reactions in furnace in Glovebox HC-21C if wrong material not noticed by operator.	--	Labeling and paperwork associated with each container identify contents making it unlikely for unapproved material to be processed. Operator training and procedures	F2
D.3.01	**OPERATIONAL UPSET**	Stabilization furnace temperature ramped up too fast (temperature controller fails high) resulting in furnace failure in glovebox HC-21C	Controller failure. Programmer error. Relay contact fails closed.	Burn out of furnace coils leading to shutdown of process. No hazard found for heating oxide too fast.	Furnace temperature controller and furnace thermocouples: Controller shuts off furnace if program temperature and furnace temperature differ by more than 200 C. Controller limits maximum current to 17 amps which prevents coil burnout. Temperature alarm switch (TAS) shuts off power to furnace if temperature exceeds 1050 C. Temperature deviation alarm provides indication of furnace temperature greater than 20 degrees from controller setpoint at any given time.	Operator training and procedures. Calibration of controller.	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
D.3.04	**OPERATIONAL UPSET**	Excessive airflow through furnace in glovebox HC-21C resulting I elevated particulate release to vacuum system	Flow rate set too high by operator.	Entrainment of flighty Pu oxide powder in furnace. Elevated release of particulates to vacuum system. Potential pluggage of ceramic filter leading to loss of vacuum flow (see item D.3.03)	Baffle in furnace reduces airflow directly over furnace boat minimizing suspension of particulates. Ceramic offgas filter removes majority of particulates before they enter the vacuum system header. DP gauge across ceramic filter provides indication of plugging. Demister and HEPA filters in vacuum system remove residual particulates from vacuum system air before discharge to the environment. DP and orifice place in vacuum system indicate flowrate.	Operator verifies correct flowrate throughout the vacuum system via rotameter before operating furnace.	F3
D.3.05	**OPERATIONAL UPSET**	Unfiltered flow through/around ceramic filter in glovebox HC-21C.	Filter cracked due to thermal stress Filter cracked or not properly installed in canister during installation/replacement.	Pu release into vacuum system Potential plugging of vacuum line between furnace and vacuum header.	Ceramic filter designed for high heat environment. DP gauge across ceramic filter provides indication of plugging. DP and orifice place in vacuum system indicate flowrate to detect plugging of vacuum line. Demister and HEPA filters in vacuum system remove residual particulates from vacuum system air before discharge to the environment.	Maintenance procedure for proper replacement of ceramic filter Operator training and procedures	F3

Table 9F.21.
S0 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.4.03	**DISPERSAL OF Pu OXIDE POWDER - INSIDE GB**	PuO_2 particulate release from pressurized can when it is opened in glovebox HC-21A	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1 %) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled PuO_2.	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	F3
D.3.10	**OPERATIONAL UPSET**	Pu fluoride powder processed through furnace causes corrosion damage to furnace in glovebox HC-21C.	Wrong can selected for processing due to mislabeling or human error.	Fluorine gas release due to reaction with water vapor in air run through furnace. Damage to furnace vacuum exhaust system. Increased direct dose to operators. Pu fluoride produces higher direct dose than oxide (due to alpha-n reactions). See item B.1.02.	None	Labeling and paperwork associated with each container identify contents making it unlikely for wrong material to be processed.	F2

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
B.2.04.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator suffers injury and ruptures glove while crushing empty can with hammer	Operator injury with contamination of wound	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures HPT deconning of skin or injury Leather gloves used when crushing or folding cans	F3
B.4.01.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Worker penetrates glove while opening sealed can with can opener, taped slip lid can with scissors, while handling can or lid.	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves use when opening cans HPT deconning of skin or injury Leather gloves used when crushing or folding cans	F3
B.7.02	**DISPERSAL OF Pu OXIDE POWDER - OUTSIDE GB**	Spread of contamination from waste bag during bagout of waste from glovebox HC-21A	Waste bag squeezed causing release of radiological material through taped vent Isolated Transport Container (ITC) dropped during handling causing bag to vent or rupture	Contamination of workers and potential uptake of radiological material	E-3 ventilation system filters release to environment. Room CAMs alert workers to airborne contamination.	Operator training and procedures Waste bags are put in Isolated Transport Container (ITC) immediately after applying second bag. ITCs have lids to minimize spread of release from pail. Radiological control program. Survey of workers with alpha poppy probes to detect skin contamination. Worker decontamination by RCT if necessary.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
F.7.02	**DISPERSAL OF Pu OXIDE POWDER - OUTSIDE GB**	Pu release from sample bottle or product can after bagout from glovebox HC-18M	Sample bottle or product can dropped after bagout causing bottle to break or slip lid to come off and bag to rupture.	Contamination of workers and potential uptake of radiological material	E-3 ventilation system filters mitigate release to environment should material be release to Zone 3 area. Room CAMs alert workers to airborne contamination.	Operator training and procedures Radiological control program. Survey of workers with alpha poppy probes to detect skin contamination. Worker decontamination by RCT if necessary. Bagged sample bottles are placed in ice cream carton and then in special wagon for transport to the analytical lab. Carton reduces chances of airborne release in a drop. Product cans are double bagged in the process of being sealed out of the glovebox. Taped slip lid can and double bag minimize the likelihood of a release should the container be dropped.	F3
B.7.03	**FLAMMABLE GAS DEFLAGRATION IN WASTE DRUM**	Hydrogen venting or deflagrating inside waste drum in 234-5Z satellite accumulation area.	Hydrogen generation from radiolysis in waste bags in waste drum. Ignition caused by spark generated while moving drum.	Pressurization of drum, drum damage and release of radiological material from waste drum in satellite accumulation area (Room 166) Potential worker injury	Waste drum is vented through a filter to prevent hydrogen accumulation Room CAMs alert workers of airborne contamination in room 166 Room 166 ventilated by the E-3 system which confines and filters any release from waste drum.	Drum seal is verified. Periodic surveillance of rooms to detect bulging drums.	F2

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
D.4.02.b	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Glovebox fire or radiant heat damage to glovebox HC-21C confinement boundary.	Door opened during heating cycle to remove boat	Radiant heat from coils melts gloves and burns operator, softens glovebox panels Potential activation of glovebox dry fire suppression system (Halon system). Potential ignition of combustibles in glovebox. Release of Pu to room air and uptake by workers.	Furnace interior temp indication Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	Operators trained not to remove boat from furnace or to open furnace door until temperature has dropped below 200 C. Combustible loading in glovebox is controlled.	F2

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
A.1.03	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Hole in glovebox confinement boundary leads to spread of contamination from glovebox (general glovebox hazard).	Degradation of port bags, ice cream cartons used to seal sphincter port, or gloves due to aging, radiation, or heat.	Minor Spread of contamination from glovebox and potential uptake by workers.	E-4 ventilation system maintains negative pressure in glovebox and maintains confinement velocity across small holes	Gloves and bags have scheduled replacement dates which minimizes likelihood of degradation. Pre-job walkdown visual inspection of gloves, bags, and ice cream cartons. Air flow through leaks can cause a whistling sound which aids in detecting leaks in gloves, port bags, etc. during pre-job walkdown. Radiological control program: operators hands are surveyed every 15 minutes during glovebox operations and when changing glovebox locations to identify leaks. Surveys with alpha poppy probes before leaving radiological control area prevents spread of contamination to clean areas of the plant.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
A.1.04	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Breach in glovebox confinement boundary during waste bagout, port bag replacement, or glove change (general glovebox hazard).	Sharp object punctures bag Bag not properly horse tailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
B.1.03	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Glovebox HC-21A loss of confinement during seal in.	Sphincter seal failure Ice cream carton or can in sphincter seal inadvertently pushed into glovebox without can or carton behind it results in open sphincter seal. Seal in bag torn or pulled off port during seal in (also applies to changeout of port bags) (see item A.1.04). Pressurized glovebox during seal in (see item A.3.01)	Minor release of contamination from the glovebox into the room. Potential worker uptake of Pu.	Glovebox ventilation system maintains negative pressure and confinement velocity across failed sphincter seal or port bag which minimizes the potential contamination spread. Backup glovebox (E-4) ventilation system maintains confinement on loss of primary ventilation. Room CAMs alert operators to presence of airborne contamination. PRV on supply restricts flowrate on low glovebox DP. Emergency exhaust valves open on low glovebox negative. Sphincter seal design prevents release unless no can or carton in seal.	Operator training and procedures	F3
B.2.02.a	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Damage to glovebox glove compromising glovebox HC-21A confinement integrity.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Small hole in glovebox confinement boundary Small contamination release from glovebox as hands withdrawn from glovebox gloves	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin Leather gloves used when crushing or folding cans	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
B.2.04.a	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Damage to glovebox glove compromising glovebox HC-21A confinement integrity.	Operator ruptures glove while crushing empty can with hammer	Small hole in glovebox confinement boundary leading to contamination release from glovebox.	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin Leather gloves used when crushing or folding cans	F3
B.4.01.a	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Damage to glovebox glove compromising glovebox HC-21A confinement integrity.	Worker penetrates glove while opening sealed can with can opener, taped slip lid can with scissors, while handling can or lid.	Small hole in glovebox confinement boundary Small contamination release from glovebox	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves use when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin Leather gloves used when crushing or folding cans	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
B.7.01	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Breach in glovebox HC-21A confinement boundary during waste bagout or glove change.	Sharp object punctures bag Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	F3
C.1.01	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Glove damaged during conveyor operation compromising glovebox HC-2 confinement	Glovebox glove(s) pinched in conveyor during transfer	Worker injury and contamination Potential spread of contamination from glovebox through hole in glove leading to potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and confinement velocity across ruptured gloves. CAMs alert workers to presence of airborne contamination.	Conveyor disabled when workers have hands in gloves - 3 key interlocks (in different rooms) must be enabled to operate conveyor. Gloves secured outside conveyor glovebox with bungee cords before conveyor is turned on. Operator training and certification.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
D.2.01	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Glove damage during load in/ load out of the stabilization furnaces in glovebox HC-21C.	Glove pinched in furnace door when closed or glove punctured by sharp object.	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox.	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	F3
D.2.02	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Breach in glovebox HC-21C confinement boundary during bagout of combustibles or while withdrawing gloves from glovebox.	Sharp object punctures port bag while bagging out combustibles or while changing bag. Bag not properly horsetailed or taped after removing combustibles from glovebox. Bag inadvertently pulled off port during bagout of combustibles. Glove tears while being pulled out of the glovebox to prevent contact with hot furnace.	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
D.2.03	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Gloves melted by contact with furnace compromising glovebox HC-21C confinement.	Gloves not withdrawn from glovebox before starting furnace; gloves contact hot surface of furnace and melts. Gloves not secured properly with bungee cords after being pulled out of the glovebox; negative pressure causes gloves to be pulled into glovebox contacting hot spot on furnace.	Burned out glove allows contamination to spread from glovebox; potential uptake by workers. Operator burned while trying to pull glove back from furnace.	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and prevents contamination spread unless several gloves are lost. Emergency exhaust valves on RMC line opens up on low glovebox vacuum. Fire brick insulates outer surfaces of furnace from the intense heat produced in the furnace. Only limited areas around the door of the furnace are hot enough to melt or burn gloves. Room CAMs alert workers to presence of airborne contamination. E-3 ventilation system filters any release from Zone 3 area to the environment.	Operator training and procedures. Gloves are pulled out of glovebox and secured with bungee cords before operating furnaces.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
D.3.03	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Reduced air flow or no air flow during stabilization of material in furnace in glovebox HC-21C.	Plugged ceramic filter. Vacuum system valved out or otherwise blocked. Failure of vacuum pump or loss of power to vacuum pump. Other loads placed on 26 in vacuum system reduce airflow through furnace. Airflow not set properly before operating furnace.	Hot air from furnace vents into glovebox while heating oxide. Furnace not cooled down in intended time period after stabilization oxide. Potential damage to glovebox gloves and operator burn when boat removed from furnace.	DP across ceramic filter allows identification of plugged filter. Flow meter on vacuum line. Glovebox (E-4) ventilation system adequately removes hot air vented from furnace preventing overheating of glovebox. Temperature recorder tells operator when furnace is cooled down. DP and orifice place in vacuum system indicate flowrate.	Flow through vacuum system is verified to be in proper range before each furnace use. By procedure, operators are not allowed to remove furnace boat until furnace is below 200 C.	F3
D.4.01	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Glove damage/operator burn in glovebox HC-21C	Boat removed from furnace too early or boat not allowed to cool on boat stand before handling.	Operator burns hole in glove and suffers injury while removing boat from furnace. Hole in glove compromises glovebox confinement.	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Glovebox ventilation system removes enough heat to prevent overheating of glovebox air with furnace door open. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	By procedure, operators are not allowed to remove furnace boat until furnace is below 200 C. Hot mill gloves used with boat handling tool to remove boat from furnace. By procedure, boat is left on boat stand to cool for one hour before being handled by glove.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
F.7.01	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Breach in glovebox HC-18M confinement boundary during waste bagout, bag change, or glove change.	Bag punctured by sharp object Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers.	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
A.3.01.a	**LOSS OF GB CONFINEMENT - VENTILATION FAILURE**	Stagnant glovebox during operations causes spread of contamination from glovebox (general glovebox hazard).	Loss of E-4 ventilation flow or imbalance between E-4 supply and exhaust (caused by loss of power or equipment or control failures). Failure to detect HVAC upset during pre-job walkdown	Spread of contamination from glovebox during seal in or seal out of container, glove change, or change of port bag. Worker exposure to dispersible Pu. Overheating of Glovebox HC-21C during furnace operations (see item D.3.06).	E-4 HVAC controls Interlock shuts off supply fans if exhaust fans go down, which prevents glovebox pressurization. Pressure regulating valve on supply air regulates pressure in RMC line gloveboxes. Addition exhaust capacity provided via emergency exhaust valves in Room 228A should imbalance develop between supply and exhaust flow. Alarm activates in power control room on detection of low glovebox negative in control room. PAX announcement made if alarm activates. Plant is evacuated if E-3/E-4 exhaust is lost, which minimizes potential worker inhalation doses. E-3 filter room filters mitigate release to environment if only E-4 ventilation is lost. Building shell mitigates release if glovebox and building goes stagnant. Backup power operates emergency exhaust fans that maintain negative pressure in gloveboxes if plant loses primary power. Room CAMs alert workers to airborne	Pre-job walkdown to verify proper glovebox ventilation flow and DP Operator training and procedures	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
G.2.01	**NPH - Ash Fall**	Addressed in Chapter 3.0 of PFP FSAR		Ash Fall effects are described in Chapter 3.0 of the PFP FSAR. Ash Fall represents a roof loading concern, abrasive concern for moving equipment, and an electrical concern because of the conductivity of the ash.			F2
G.1.02	**NPH - Seismic**	Seismic event causes dispersal of plutonium oxide powder in glovebox. (General to all gloveboxes)	Seismic event results in dispersal of plutonium oxide powder into glovebox atmosphere.	Potential additional exposure to workers due to cleanup requirements.	Seismic ventilation supply shutdown switch. Building structure Glovebox structure	Emergency procedures	F2
A.1.02	**OCC**	Electrical shock to operator while working in glovebox HC-21A	Cord frayed in the glovebox Frayed cord contacts glovebox frame while operators body or leg is in contact with the glovebox frame.	Operator injury	None	Senior supervisory watch OSHA inspections can identify frayed cords. Electrical safety program of cord inspection reduces the likelihood of the presence of frayed cords. Institutional occupational safety program of requirements and inspections reduces the likelihood of the presence of frayed cords.	F3
B.6.01.a	**PYROPHORIC REACTION IN FURNACE**	Contaminants not identified or removed from oxide result in reaction hazards in Glovebox HC-21C furnaces. Pyrophoric contaminants can include unburned metal pieces from prior stabilization run, metal hydrides, uranium hydrides, or Pu_2O_3.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Pyrophoric reaction in furnace in Glovebox HC-21A. See item D.3.08. Fires in the furnaces in Glovebox HC-21C. See item D.3.07.	See items D.3.07 and D.3.08 for engineered features to mitigate reactions in the HC-21C furnaces.	Previous LOI testing results provide confidence that significant quantities of plastic contaminant are not in product to be stabilized in this campaign. Procedures with sign off by Shift Technical Advisor.	F2

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
D.3.08	**PYROPHORIC REACTION IN FURNACE**	Metal contaminant in feed results in pyrophoric reactions in the furnace in glovebox HC-21C.	Metal turnings or pieces not noticed or removed from feed in Glovebox HC-21A.	Reaction of pyrophoric metal or hydrided metal contaminant in furnace, leading to hydrogen release and burn in the furnace. Potential furnace damage. Failure of glovebox not expected due to small quantity of hydrided metal expected in feed.	Glovebox ventilation system confines material dispersed from furnace.	Visual identification of "non oxides" in Glovebox HC-21A when material poured into furnace boat. Blend plan identifies previously stabilized oxide to restabilize in this campaign.	F3
B.4.05.a	**PYROPHORIC REACTION IN GB**	Pyrophoric reaction and hydrogen burn when can opened in glovebox HC-21A.	PuH_2 hydride contaminant in can Pu metal may be in can due to incomplete prior stabilization. PuH_2 forms from metal if plastic or organic contaminants are also present in can. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. Can under vacuum due to catalyzed formation of oxides and nitrides in the container. When can is opened air is sucked in which reacts with the hydrided material. Hyride reactions releases heat and hydrogen gas which is ignited on exiting the can.	If sufficient hydride contamination present, slight pressurization of the glovebox could occur. Potential burn through of gloves and operator injury due to contact with hot embers. Embers burn through PVC ports Minor contamination spread from glovebox if gloves or port bags damaged.	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Shift technical advisor sign off for material acceptability required by procedure. Combustible loading in glovebox is controlled by procedure.	F3

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
B.1.02	**RADIATION PROTECTION**	High worker direct dose during handling of cans in glovebox HC-21A.	Container containing metal or PuF_4 handled instead of PuO_2 (PuF_4 much higher dose than oxide from alpha-n reactions). Cans handled for extended time period during handling/seal-in of cans.	Worker dose rate limit (Radiological work permit) potentially exceeded	Leaded gloves limit dose when handling cans inside the glovebox. Glovebox structure shields body of operator Inner can and first overpack are wrapped with leaded tape to minimize direct dose	ALARA principles applied to Pu storage container handling process. Periodic dose measurements taken on glovebox to establish acceptable worker exposure periods. Labeling of cans in vault (RAM tags) Cans surveyed for contact dose several times during movement and before loading into HC-21A. Blend plan identifies intended cans Institution radiological control program	F3
F.3.02	**RUPTURE OF CONTAINER IN STORAGE VAULT**	Pu metal added to product can in glovebox HC-18M causing rupture of container in storage vault.	Material not heated long enough or at high enough temperature in furnace to completely oxidize metal due to furnace failure or failure of furnace temperature controller. Sieve and size reduction step skipped due to human error results in metal pieces not being detected. Metal pieces not removed from oxide material before transferring material to product can.	Rupture of container in storage vault due to the formation of Pu oxide (assuming storage cans is not airtight). PuO_2 is less dense and takes up more volume than metal causing can rupture. Contamination of vault air. Potential uptake by workers on entry into vault. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verity proper furnace operation and soak time.	Operator training and procedures Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	F2

Table 9F.22.
S1 Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
B.2.02.b	**CONTAMINATED WOUND**	Operator injury in glovebox HC-21A.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans HPT deconning of skin or injury Surgical excision of contaminated tissue Leather gloves used when crushing or folding cans	F3
B.5.01.a	**UNCONTROLLED FIRE IN GB**	Pyrophoric reaction as material poured through air in glovebox HC-21A.	Pu metal, PuH_2, Uranium hydride; Pu_2O_3 contaminant in can Pu or U metal may be in can due to incomplete prior stabilization. PuH_2, UH_3 forms from metal if plastic or organic contaminants are also present in. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. AND Combustible loading in glovebox not controlled.	Sparks potentially initiating a glovebox fire. Hot embers entrained in air may burn hole in glovebox HEPA filters. Dispersal of Pu in glovebox Potential burn through of gloves and operator injury due to contact with hot embers. Burn through of PVC port bags. Minor contamination spread from glovebox if gloves or port bags damaged Potential ignition of combustibles in glovebox producing glovebox fire If sufficient hydride contamination present, slight pressurization of the glovebox could occur	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Cans with relatively large quantities of hydride will be "paneled" and easily identified. Combustible loading in glovebox is controlled by procedure	F3

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
E.2.01	**CRITICALITY**	Violation of criticality safety mass limit or violation of glovebox HC-18BS dispersible inventory limit.	Too many containers stored too close together. Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training	F2
F.6.01.b	**CRITICALITY**	Violation of criticality safety mass limit or violation of glovebox HC-18M dispersible inventory limit	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
B.6.01.b	**FLAMMABLE GAS DEFLAGRATION IN GB**	Plastic contaminants not identified or removed from oxide result in reaction hazards in Glovebox HC-21C furnaces. Contaminants can include tool handles, brush bristles, PVC or polyethylene bag fragments, polycarbonate pieces, etc.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Fires or deflagrations of flammables in the furnaces in Glovebox HC-21C. See item D.3.07.	See items D.3.07 for engineered features to mitigate reactions in the HC-21C furnaces.	Previous LOI testing results provide confidence that significant quantities of plastic contaminant are not in product to be stabilized in this campaign. Procedures with sign off by Shift Technical Advisor.	F2
B.2.01	**FLAMMABLE GAS DEFLAGRATION INSIDE GB**	Flammable gas (i.e. H_2) release and burn when overpack can opened in glovebox HC-21A.	Radiolysis of plastic bag around slip lid can and organic can seal during storage in vault. Ignition due to mechanical spark from can opener, static release from ejected powders, or electrical spark.	Potential deflagration involving H_2 released from can causing pressurization of glovebox, potential failure of port bags or gloves and release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of hydrogen are easily identified due to bulging.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
B.4.02	**FLAMMABLE GAS DEFLAGRATION INSIDE GB**	Hydrogen gas release and burn when can opened in glovebox HC-21A.	Radiolytic degradation of plastic contaminant, brush bristles, tool handle, bottle caps, etc. in oxide during storage generates hydrogen in can. Hydrogen ignited during release from can due to static or electrical discharge High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with PuO_2 and radiolysis of the water.	Potential deflagration involving H_2 released from can causing pressurization of glovebox, potential failure of port bags or gloves and release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of hydrogen are easily identified due to bulging.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
B.4.04	**FLAMMABLE GAS DEFLAGRATION INSIDE GB**	Flammable gases (alkanes, H_2, etc) from organic in container released and ignited when can opened (can pressurized) in glovebox HC-21A.	Container containing organic (e.g., sludge, floor sweeps) inadvertently sealed into glovebox and opened. Wrong container selected due to inaccurate labeling or human error. Flammable gases generated due to radiolytic decay of organic material (e.g., sludge) in the container. Ignition due to mechanical or electrical spark, or static discharge.	Pressurization of glovebox Potential damage to glovebox confinement boundary Pu release into room and worker inhalation uptake	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of flammable are easily identified due to bulging. Blend plan identifies appropriate cans to stabilize in PuO_2 campaign. Labeling of containers Operator training and procedures Shift technical advisor sign off for material acceptability required by procedure. Sludges which may contain organic are stored in vented polyjars which are easily distinguishable from cans containing PuO_2.	F2
D.3.07	**FLAMMABLE GAS DEFLAGRATION INSIDE GB**	Plastic contaminants in Pu oxide feed result in fire/deflagration in stabilization furnace in glovebox HC-21C.	Plastic contaminants not noticed in feed or not removed by operator (plastic contaminants can include PVC, polyethylene, polycarbonate, polystyrene, Polymethyl Methacrylate).	Fire or deflagration involving flammable gases (alkanes, alkenes, hydrogen, carbon monoxide) generated inside the furnace. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace. Furnace vacuum system sweeps air through the furnace to dilute flammable gas concentration or to completely oxidize (burn) plastic contaminant in a controlled manner.	Plastic contaminants are looked for and removed when the oxide is poured into the furnace boat in Glovebox HC-21A. Previous LOI testing results provide confidence that significant quantities of plastic contaminant are not in product to be stabilized in this campaign.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
D.3.09	**FLAMMABLE GAS DEFLAGRATION INSIDE GB**	Glovebox sweeps containing organic (plastics or sludge) processed through furnace results in flammable gas deflagration in stabilization furnace in glovebox HC-21C.	Wrong can selected from storage area opened in Glovebox HC-21A due to mislabeling or human error. Plus Failure to notice plastic contaminant or sludge in furnace boat during visual inspection in Glovebox HC-21C.	Deflagration in furnace, failure of furnace, and potential burn through of gloves, bag ports, or glovebox panels. Release of Pu from glovebox and potential uptake by operators. Possibly more plastics than in normal oxide	E-3 ventilation system filters release to environment should Pu be released into room from glovebox.	Labelling and paperwork associated with each can identify contents: glovebox sweeps are indicated in labelling and paperwork minimizing likelihood or processing wrong material. Glovebox sweeps are not stored in same vault with Pu oxides to be processed in this campaign. Sweeps from wet gloveboxes are stored in polyjars which are difficult to mistake for a PuO_2 container.	F2
D.4.02.a	**LOSS OF GB CONFINEMENT - MECHANICAL BREACH**	Glovebox fire or radiant heat damage to glovebox HC-21C confinement boundary.	Furnace door inadvertently opened during heating cycle to remove boat.	Radiant heat from coils potentially ignites glovebox panels Potential activation of glovebox dry fire suppression system (Halon system). Potential ignition of combustibles in glovebox. Release of Pu to room air and uptake by workers.	Furnace interior temp indication Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	Operators trained not to remove boat from furnace or to open furnace door until temperature has dropped below 200 C. Combustible loading in glovebox is controlled.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
A.3.01.b	**LOSS OF GB CONFINEMENT - VENTILATION FAILURE**	Pressurized glovebox during operations causes spread of contamination from glovebox (general glovebox hazard)	Loss of E-4 ventilation flow or imbalance between E-4 supply and exhaust (caused by loss of power or equipment or control failures). Failure to detect HVAC upset during pre-job walkdown	Pressurized glovebox causing spread of contamination from glovebox during seal in or seal out of container, glove change, or change of port bag. Worker exposure to dispersible Pu. Overheating of Glovebox HC-21C during furnace operations (see item D.3.06).	E-4 HVAC controls Interlock shuts off supply fans if exhaust fans go down, which prevents glovebox pressurization. Pressure regulating valve on supply air regulates pressure in RMC line gloveboxes. Addition exhaust capacity provided via emergency exhaust valves in Room 228A should imbalance develop between supply and exhaust flow. Alarm activates in power control room on detection of low glovebox negative in control room. PAX announcement made if alarm activates. E-3 filter room filters mitigate release to environment if only E-4 ventilation is lost. Building shell mitigates release if glovebox and building goes stagnant. Backup power operates emergency exhaust fans that maintain negative pressure in gloveboxes if plant loses primary power. Room CAMs alert workers to airborne contamination.	Pre-job walkdown to verify proper glovebox ventilation flow and DP Operator training and procedures Plant is evacuated if E-3/E-4 exhaust is lost, which minimizes potential worker inhalation doses.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
D.3.06	**LOSS OF GB CONFINEMENT - VENTILATION FAILURE**	Overheating of glovebox HC-21C.	Loss of E-4 ventilation flow during operation of furnace due to equipment failures, damper closures, etc.	Overheating of glovebox leading to possible failure of port bags and gloves and inadvertent operation of the glovebox dry fire suppression system. Potential softening and sagging of glovebox windows. Release of contamination through failed gloves or bag ports (or failed windows). Potential Pu uptake by workers. Evacuation of Zone 3 process areas leading to unattended glovebox which could result in inability to control fire if combustibles ignited.	Insulating blankets protect glovebox panels from heat damage from nearby hot vacuum lines. Backup E-4 exhaust fans run by emergency generators or steam kicks on on loss of normal exhaust flow protecting glovebox from overheating. Alarms if dP is lost Halon system designed to put out fire by displacing a fraction of the air in the glovebox. It is designed not to discharge enough material to pressurize the glovebox. .	Alarms in power control room activate on loss of E-4 exhaust flow. Process areas are evacuated on loss of E-4 ventilation protecting workers from Pu potentially released from the glovebox. Work to restore ventilation flow on dampers or other equipment can occur as they are outside process areas. Operators are trained to hit "kill switch" shutting down furnaces before evacuating. Emergency plan	F3
G.1.01	**NPH - Seismic**	Seismic event causes explosion and stagnet glovebox. (General to all gloveboxes)	Seismic event results in loss of electrical power and potentially a loss of ventilation. Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Seismic ventilation supply shutdown switch. Building structure.	Emergency procedures for evacuation.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
B.5.01.b	**PYROPHORIC REACTION IN GB**	Pyrophoric reaction as material poured through air in glovebox HC-21A.	Pu metal, PuH_2, Uranium hydride; Pu_2O_3 contaminant in can Pu or U metal may be in can due to incomplete prior stabilization. PuH_2/ UH_3 forms from metal if plastic or organic contaminants are also present in. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can.	Sparks potentially initiating a glovebox fire. Hot embers entrained in air may burn hole in glovebox HEPA filters. Dispersal of Pu in glovebox Potential burn through of gloves and operator injury due to contact with hot embers. Burn through of PVC port bags. Minor contamination spread from glovebox if gloves or port bags damaged Potential ignition of combustibles in glovebox producing glovebox fire If sufficient hydride contamination present, slight pressurization of the glovebox could occur	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Cans with relatively large quantities of hydride will be "paneled" and easily identified. Combustible loading in glovebox is controlled by procedure	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
D.3.02	**RUPTURE OF CONTAINER IN STORAGE VAULT**	Inadequate stabilization of material in glovebox HC-21C furnace leads to rupture of container in storage vault.	Failure of furnace heating element. Loss of power during stabilization. Temperature controller failure (temperature not held high enough for required 2 h). Power shut off early by operator.	Rupture of container sometime after it is place in storage vault if furnace upset not detected and LOI test fails to determine high moisture content. PuO_2 reacts with water to form a binary oxide and hydrogen gas which overpressurizes the container. Potential worker inhalation hazard upon entering vault.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product. Temperature deviation alarm provides indication of furnace temperature treater than 20 degrees from controller setpoint at any given time.	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs. Furnace chart recorder readings are used to verity proper furnace operation and soak time. LOI testing is performed on representative sample of material after stabilization in the furnace. Material found to lose more than 0.5 wt% in LOI testing will be run back through the furnace.	P2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
F.3.03	**RUPTURE OF CONTAINER IN STORAGE VAULT**	Non-representative sample taken from product can for LOI testing in glovebox HC-18M.	Material not heated long enough or at high enough temperature to be adequately stabilized due to furnace or temperature controller failure. Material not sieved or ground properly. Large (> 4 mesh) agglomerations of PuO_2 can give false high or false low LOI readings depending on furnace operation and how long the sample was exposed to humid air after removal from the furnace.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verity proper furnace operation and soak time	Operator training and procedures Radiological control program: routing sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	F2
F.4.01	**RUPTURE OF CONTAINER IN STORAGE VAULT**	"Wet" oxide transferred to product can in glovebox HC-18M and stored in vault, resulting in rupture of container in vault.	Material not stabilized long enough or at high enough temperature in furnace due to temperature controller or furnace failure. LOI test fails to detect inadequate stabilized material due to non-representative sample being taken or material canned without benefit of LOI testing due to human error. Or LOI test results or can labels mixed up resulting in wrong can being authorized for storage in vault.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verity proper furnace operation and soak time	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
F.5.01	**RUPTURE OF CONTAINER IN STORAGE VAULT**	"Wet" oxide transferred to product can in glovebox HC-18M and stored in vault, resulting in rupture of container in vault.	Inadequately stabilized material not run back through the furnace due to human error.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being re-canned even if undetected furnace upset occurs. Furnace chart recorder readings are used to verity proper furnace operation and soak time	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
A.1.01	**UNCONTROLLED FIRE IN GB**	Fire in glove box HC-21A caused by electrical short.	Failure to properly inspect power cords or failure to identify frayed cords results in condition that leads to an electrical short that ignites combustibles in the glovebox Failure to control combustibles in glove box allows significant fire that damages glove box confinement.	Burn through of gloves seal out bags resulting in breach of containment Ignition of Polymethyl Methacrylate or Polycarbonate glove box panels and spread of fire to other gloveboxes Release of soot, hot embers, and water vapor to the E-3 and E-4 ventilation systems. Pluggage or failure of glovebox and E-4 filterbox HEPA filters. Potential pluggage of E-3 room prefilters or E-3 filterbox HEPA filters, with spread of contamination to clean portions of the plant. Worker uptake of airborne Pu	Glovebox dry fire suppression system Glovebox (E-4) ventilation system maintains negative glovebox pressure and confines release until several gloves or bag ports are burned out or window panels are breached, giving operators time to manually extinguish fire. Long length of E-3/E-4 ductwork between RMC line and filter room filters and dilution airflow from other E-3/E-4 areas of the plant are expected to cool offgasses from the fire enough to prevent heat damage to, or plugging of the E-3/E-4 filter-room HEPA filters. E-3/E-4 filter-room HEPA filters mitigate release to the environment CAMS alert workers to presence of airborne contamination.	MgO sand available in gloveboxes for extinguishing small fires Bayonet fire extinguisher is near glovebox for manually extinguishing fire. Housekeeping practices minimize combustible loading in glovebox. Senior supervisory watch OSHA inspections can identify frayed cords. Electrical safety program of cord inspection reduces the likelihood of the presence of frayed cords. Institutional occupational safety program of requirements and inspections reduces the likelihood of the presence of frayed cords. Hanford fire department located within a few miles of PFP	F3

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
B.4.05.b	**UNCONTROLLED FIRE IN GB**	Pyrophoric reaction and hydrogen burn when can opened which ignites combustibles in glovebox HC-21A.	PuH_2 hydride contaminant in can Pu metal may be in can due to incomplete prior stabilization. PuH_2 forms from metal if plastic or organic contaminants are also present in can. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. Can under vacuum due to catalyzed formation of oxides and nitrides in the container. When can is opened air is sucked in which reacts with the hydrided material. Hyride reactions releases heat and hydrogen gas which is ignited on exiting the can. AND Combustible loading in glovebox not controlled.	Potential ignition of combustibles in glovebox producing glovebox fire.	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Shift technical advisor sign off for material acceptability required by procedure. Combustible loading in glovebox is controlled by procedure.	F2

Table 9F.23.
S1* Hazardous Conditions

Item #	Acc Cat	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Freq Rank
A.2.01	**CRITICALITY**	Violation of criticality safety mass or spacing limit. Violation of dispersible inventory limit. (General glovebox hazard)	Failure to check or adhere to CPS or dispersible limit postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses. Release in seismic event above current accepted levels	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	F2
D.2.04	**UNCONTROLLED FIRE IN GB**	Fire in glovebox compromises glovebox HC-21C confinement.	Combustibles not controlled in glovebox come in contact with hot surface of furnace while it is operating. Combustible loading allows fire to spread. Port bag comes un-horsetailed and gets sucked in and contacts hot surface of furnace.	Potential burn through of gloves or port bags, softening or ignition of glovebox windows leading to spread of Pu from compromised glovebox confinement boundary.	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and prevents contamination spread unless several gloves or port bags are lost. Emergency exhaust valves on RMC line opens up on low glovebox vacuum. Fire brick insulates outer surfaces of furnace from the intense heat produced in the furnace. Only limited areas around the door of the furnace are hot enough to ignite combustibles. Room CAMs alert workers to presence of airborne contamination. E-3 ventilation system filters any release from Zone 3 area to the environment.	Operator training and procedures. Combustible loading in glovebox is minimized by procedure.	F2
H.3.01	**XTRN - Aircraft Crash**	Aircraft crashes into facility causing fire and loss of confinement. (General to all gloveboxes)	Pilot error or mechanical failure	Significant release of material		Controls preventing overflight of facility	F0
H.1.01	**XTRN - Facility Wide Loss of Power**	Facility wide loss of power with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in glovebox HC-21C.	Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Building structure.	Emergency procedures	F3
H.2.01	**XTRN- Range Fire**	Facility wide loss of power with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in glovebox HC-21C.	Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Building structure.	Emergency procedures Vegitation control programs	F3

APPENDIX 9G

Preliminary Hazards Analysis for Thermal Stabilization of Non-Product Quality Oxide Feed Materials

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PRELIMINARY HAZARDS ANALYSIS FOR THERMAL STABILIZATION OF NON-PRODUCT QUALITY OXIDE FEED MATERIAL

9G.1 STABILIZATION OF NON-PRODUCT QUALITY OXIDE FEED MATERIAL PHA

The hazards associated with thermally stabilizing non-product quality oxide feed materials in Glovebox HC-21C muffle furnaces were identified and evaluated using a Preliminary Hazards Analysis (PHA) approach. A detailed discussion of the PHA technique can be found in Guidelines for Hazard Evaluation Procedures (AIChE 1992). Non-product quality oxide feed materials are defined as:

* impure plutonium oxides
* mixed uranium and plutonium oxide
* floor sweepings
* plutonium oxalate
* Plutonium Reclamation Facility (PRF) sludges.

9G.2 PHA METHODLOGY

The PHA process is a systematic approach in which a system or process is broken down into basic elements and the hazards associated with operations in the system or process are identified, potential causes of those hazards are determined, potential consequences of the hazards are evaluated, and possible corrective and/or preventative measures are examined. The PHA was developed using a table to guide and record the results of a "brainstorming" process. Brainstorming was performed by individuals with detailed knowledge of the system or process being examined, and was supported by a multi-disciplinary team.

9G.2.1 PHA Data Description

The purpose and contents of each column in the PHA table, Table 9G-1, are described in detail in the following paragraphs.

Column 1, Item #: This column provides an alpha-numeric identifier for each hazard postulated in the table. The identifier is primarily used for cross referencing within the table and as an identifier for accident sequences discussed in Chapter 9 of the PFP FSAR.

Column 2, Process Step/Equipment: The step or steps and the important equipment involved in performing each set of operations is identified in this column. Listing each piece of equipment involved ensures that all relevant hardware failures are considered in the analysis and that the operational faults associated with use of each piece of equipment are considered.

Column 3, Failure/hazardous condition: The hardware failures or operational faults of concern are identified in this column. The hazards are identified first by postulating failures of the safety function(s) listed in the previous column. Simply postulating functional failure of hardware, however, is insufficient for identifying the wide range of things that can go wrong.

Additional hazards are identified by asking "what-if" type questions, such as, "what if the operation is not performed," "what if the operation is performed out of order," "what if the operation is performed too fast". Guideword deviations such as are used in HAZOP analysis (AIChE 1992) were also utilized to identify hazardous conditions. Guidewords are process parameters such as pressure, temperature, flow, concentration etc. Relevant deviations include "low/no," "high," "other than."

Column 4, Causes: This column identifies the causes for the failures/hazardous conditions postulated in Column 4. Identifying causes is important to identifying potential preventative controls for significant hazards. In many cases, multiple hardware or operational faults are required to produce a hazardous event. This column identifies the sequence of hardware and operational faults required to produce the postulated hazardous event.

Column 5, Consequences: This column describes the potential consequences that could result from the postulated hazards identified in Column 4. The focus of this column is to identify effects to the glovebox confinement system and to facility workers. None of the hazards associated with opening cans containing Pu metal and with processing the metal were found to be energetic enough to compromise building confinement or to pose a threat to onsite workers outside the plant or to the offsite public.

Column 6, Existing Engineered Features: This column identifies the engineered features (hardware items) intended or available to prevent or mitigate the consequences identified in Column 6. The engineered features in this column are candidates for designation as Safety Significant items for hazards that pose a significant threat to the health of facility workers.

Column 7, Existing Administrative Controls: This column identifies the administrative requirements that reduce the likelihood of the hazardous event identified in Column 4, or that help minimize the potential consequences of the hazardous event. The controls listed in this column are candidates for operational safety requirement (OSR) designation for hazardous events with the potential to significantly harm facility workers.

Column 8, Consequence Rank: This column is used to capture a code designator for the level of consequence associated with a hazardous event. The consequence ranking is a "first cut," qualitative estimate of the safety severity of the consequences. An alphanumeric system has been used at the PFP to designate the severity of hazardous events. The system has the following "S" rankings characterizing safety consequences:

S0 No effect outside the glovebox confinement systems; negligible safety concerns for the facility worker.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker. Such a hazard would be an operator injury where glovebox gloves are penetrated by the can punch causing worker injury and possible skin/wound contamination.

S1* Potential severe harm or potential death from industrial injury, radiological dose or chemical exposure to the facility worker. Hazards of this severity level warrant Safety Significant controls. Hazards at this severity level for the process examined in this analysis are typically those that result in significant

pressurization or damage to the glovebox structure causing release of radiological material from the glovebox. All events with enough energy to cause a significant release of radiological material from the glovebox are assigned an S1* consequence rank. This is conservative as such events will not necessarily cause severe harm to facility workers.

S2 Potential significant radiological dose consequences or chemical exposure to onsite workers located outside the facility. No hazards postulated for processing non-product quality oxide feed material were found to be energetic enough to compromise building confinement and lead to an S2 consequence.

S3 Potential significant radiological dose consequences or chemical exposure to the offsite population. No events were postulated with potential S3 consequences.

The engineered safety features and controls specific to the processing of non-product oxide feed material are not credited in assigning the above consequence rankings. This is to allow determination of whether the controls warrant Safety Significant designation.

The mitigative effects of features previously designated as Safety Significant or Safety Class in the PFP FSAR (WHC 1995) are credited in assigning the consequence rankings. For example, the glovebox structure E-4 ventilation system, and E-4 HEPA filters are credited with mitigating the effects of releases inside gloveboxes. This means that a spill of Pu oxide powder inside a glovebox (e.g., due to dumping the furnace boat after removal from the furnace) results in an S0 consequence ranking because the glovebox structure and E-4 ventilation system can be expected to prevent a significant exposure to facility workers. The effects of energetic events (such as flammable gas deflagration in a muffle furnace) on the glovebox structure, however, are assessed to determine if the hazardous event can compromise the Safety Significant confinement function provided by the glovebox structure and ventilation system. Similarly, the Safety Class Building 234-5Z structure and E-3 ventilation system are credited with protecting onsite workers and the offsite public outside the PFP from accidents that breach glovebox confinement.

Column 9, Frequency Ranking: The frequency ranking is a first cut, qualitative estimate of the likelihood of the hazardous event. The following ranking system is used.

F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is 1E-02/yr to 0.1/yr.

F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1E-04/yr to 1E-02/yr.

F1 Events not expected to occur during the lifetime of the facility, categorized as "extremely unlikely." The frequency range associated with this category is 1E-06/yr to 1E-04/yr.

F0 Events categorized as "beyond extremely unlikely," with a frequency less than 1E-06/yr. Events in this category (such as meteor strike) are so unlikely they generally do not require special controls.

The frequency estimate, like the consequence ranking, is assigned taking no credit for active engineered features. The frequency ranges shown above are based on the risk acceptance criteria for the onsite receptor from the PFP FSAR (WHC 1995).

Column 10, Comments: This column contains miscellaneous observations or clarifying comments for a given hazard. There are many hazards identified in the PHA that are adequately covered in the PFP FSAR (WHC 1995) or in other authorization basis documents (e.g., CSERs). The comments column is used to flag those hazards that are adequately addressed in other documentation.

9G.2.2 SCOPE OF THE PRELIMINARY HAZARDS ANALYSIS

The PHA covers the operations performed within the RMC line glove boxes, from seal-in of containers of non-product quality oxide feed material into Glovebox HC-21A to bag-out of the thermally stabilized product oxide from Glovebox HC-18M. Within the RMC Line glove boxes, the non-product quality oxide is handled, thermally stabilized, and placed in sealed containers. Storage of containers in vaults (before and after thermal stabilization) is not covered in this PHA, as the hazards associated with these operations are adequately covered in the PFP FSAR (WHC 1995). The specific activities evaluated within this PHA are identified in Section 9G.3.

9G.3 PHA ORGANIZATION

The PHA table used in this analysis is provided in Table 9G.1. The PHA table is structured to ensure a systematic and thorough review of potential hazards. The thermal stabilization of non-product oxide feed materials is broken down into logical sets of operations performed at specific locations. The breakdown of operational steps covered in the analysis were identified from verbal descriptions provided by the cognizant engineers, and other available information. The operational steps evaluated and documented in the PHA table (Table 9G.2) are identified with an alpha-numeric designator in rows that traverse the width of the table. The thermal stabilization of non-product quality oxide feed materials was broken down into the following basic process elements:

- general glovebox hazards
- transfer of feed materials from vault storage to Glovebox HC-21A
- transfer of feed materials from glovebox storage to Glovebox HC-21A
- charge preparation activities in Glovebox HC-21A (impure oxide and MOX feed materials from vault storage)
- charge preparation activities in Glovebox HC-21A (PRF sludge, floor sweeps, and oxalate feed materials from glovebox storage)

- transfer of prepared charge from Glovebox HC-21A to HC-21C
- thermal stabilization activities in Glovebox HC-21C
- interim storage in Glovebox HC-18BS
- sampling and packaging activities in Glovebox HC-18M.

In addition, the PHA evaluated the impact of severe natural phenomena (e.g., a seismic event) and external events (e.g., facility-wide loss of power) on thermal stabilization operations.

9G.4 HAZARDS EVALUATION RESULTS

The PHA results in Table 9G.2 identify 22 S0 items, 50 S1 items, 26 S1* items, and 1 S2 item. To facilitate further evaluation, the identified events were grouped into 18 categories based on similarities in phenomenology and consequence. These groupings are presented in Tables 9G.3 through 9G.20.

Events designated as S0 and S1 are evaluated as abnormal operations; and S1* and S2 events are evaluated as accidents. Categorizing hazardous events as either "abnormal operations" or "accidents" is consistent with the NRC Regulatory Guide 3.39 (NRC 1976) format of the PFP FSAR. In instances where a given group contains both S1 and S1* events, the group is collectively evaluated as an accident.

Three groupings of events; Occupational Hazards (Table 9G.14), Operational Upsets (Table 9G.15), and Radiation Protection (Table 9G.18), were not further evaluated as either abnormal operations or accidents. Occupational hazards and direct radiation exposure hazards are not unique to thermal stabilization operations and are adequately covered by existing PFP industrial safety and hygiene and radiation protection programs. The operational upsets identified are unique to thermal stabilization operations but do not pose hazards to facility workers or onsite or offsite individuals.

9G.4.1 Abnormal Operations

9G.4.1.1 Contaminated Wound

The potential for a contaminated wound (Table 9G.3) exists whenever operators work in gloveboxes. This event is not unique to thermal stabilization operations. Principal preventive controls including minimizing, to the extent practicable, sharp objects within gloveboxes and the use of protective gloves over glovebox gloves. Chapter 9, Section 9.1.9 of the PFP FSAR evaluates the penetration of a glovebox glove and an associated puncture wound.

9G.4.1.2 Dispersal of Plutonium Inside Glovebox

The hazards analysis identified numerous events resulting in a spill and dispersal of Pu inside gloveboxes (Table 9G.5). These events, which are not

unique to thermal stabilization operations, were assigned a consequence rank of S0, i.e., resulting in negligible safety concerns to facility workers.

9G.4.1.3 Dispersal of Plutonium Outside Glovebox

The potential for a release of plutonium during seal-out operations (Table 9G.6) exists at all PFP gloveboxes. The principal preventive and mitigative controls are operator training and procedures, a negative pressure differential between gloveboxes and the surrounding room, and the use of respirators during seal-out operations. This event is not a unique to thermal stabilization operations and is adequately covered by existing PFP controls. This event is considered a serious operational event, but it poses essentially no risk to onsite or offsite individuals. Chapter 9, Section 9.1.9 of the PFP FSAR discusses such events in greater detail.

9G.4.1.4 Dropped Container Outside Glovebox

The potential for dropping a container in an operating area (Table 9G.7) exists whenever containers are handled outside of gloveboxes. The principal mitigative controls are packaging and CAMs. This event is not unique to thermal stabilization operations and is adequately addressed by the analysis of a plutonium powder spill outside of a glovebox presented in Chapter 9, Section 9.1.3 of the PFP FSAR.

9G.4.1.5 Flammable Gas Deflagration in Glovebox

Flammable gases are potentially present in crimp-sealed containers due to the thermal and radiolytic decomposition of plastic contaminants and water. These gases could be released and burn when containers are opened in glovebox HC-21A (Table 9G.9). Chapter 9, Section 9.1.4 of the PFP FSAR evaluates the failure of a pressurized container as an abnormal operation but does not postulate ignition of flammable gases. Chapter 9, Section 9.1.9 of the PFP FSAR identifies an explosion or rapid release of gas pressure as a potential cause of a glovebox glove breach. Chapter 9, Section 9.1.11 of the PFP FSAR analyses?????, as an abnormal event, a release and burn of flammable gas upon opening a crimp sealed container. This event bounds S1 events identified in Table 9G.16, Pyrophoric Reaction in a Furnace, and Table 9G.17, Pyrophoric Reaction in Glovebox.

9G.4.1.6 Flammable Gas Deflagration in a Waste Drum

A flammable gas deflagration in a waste drum (Table 9G.10) due to the presence of radiolytically-generated hydrogen was postulated as a potential event resulting from various waste disposal activities associated with thermal stabilization operations. The activity of handling and disposing of plutonium contaminated material is not unique to thermal stabilization operations. This event is considered to be adequately addressed by the consideration of waste drum handling accidents in Chapter 9, Section 9.2.2D of the PFP FSAR.

9G.4.1.7 Loss of Glovebox Confinement Due to Mechanical Breach

Many causes of a loss of glovebox confinement due to mechanical breach (Table 9G.11) have been postulated. The principal mitigative controls are maintaining a negative pressure differential between the gloveboxes and surrounding room, and CAMs. This event is not unique to thermal stabilization operations and is considered to be adequately addressed by the analysis of a glovebox breach in Chapter 9, Section 9.1.9 of the PFP FSAR.

9G.4.1.8 Loss of Glovebox Confinement Due to Ventilation Failure

The E-4 ventilation maintains a negative pressure differential between gloveboxes and the surrounding operational areas. Either a loss of both supply and exhaust ventilation resulting in stagnant conditions, or a loss of only exhaust ventilation resulting in a pressurized glovebox, could result in a spread of contamination from the gloveboxes (Table 9G.12). This hazard is not unique to thermal stabilization operations and is considered to be adequately addressed by the analysis of a loss of ventilation in Chapter 9, Section 9.1.8, and the analysis of a glovebox breach in Chapter 9, Section 9.1.9 of the PFP FSAR.

In Glovebox HC-21C the ventilation system also serves to remove heat generated by furnace operation. Loss of the E-4 system could result in overheating of the glovebox leading to a breach of confinement. This hazard is also considered to be adequately addressed by Chapter 9, Sections 9.1.8 and 9.1.9 of the PFP FSAR.

9G.4.1.9 Rupture of Container in Storage Vault

The PHA identified numerous process upsets and failures that could result in inadequately stabilized product oxide. If this condition was not detected before the oxide was packaged, the container could rupture in storage due to internal pressurization (Table 9G.19). Should a container rupture while being handled in the 234-5Z Building, any airborne plutonium would be filtered by the E-3 ventilation exhaust system prior to release. In Building 2736-Z, many storage vault pedestals are instrumented to detect bulging cans. Those without this instrumentation are visually inspected monthly. A release from a ruptured can would be confined and filtered by the vault ventilation system.

Chapter 9, Section 9.1.4 of the PFP FSAR analyzes the rupture of a pressurized plutonium powder container outside of a glovebox. The impact of the thermal stabilization of non-product quality oxide feed materials on the prior FSAR analysis is presented in Chapter 9, Section 9.1.11**????** of the PFP FSAR. Note that the PFP FSAR categorized and evaluated the rupture of a pressurized container as an abnormal operation.

9G.4.2 Accidents

All S1* and S2 events warrant consideration for detailed accident analysis (the exception would be events with a corresponding frequency rank of F0).

9G.4.2.1 Criticality

Relatively large masses of plutonium will be handled during thermal stabilization operations. Placing too much of plutonium in a glovebox or having a sufficient amount of plutonium in a non-safe geometry could result in an accidental nuclear criticality (Table 9G.4). Controls to prevent criticality include administratively controlled mass and spacing limits, hardware that physically separates plutonium containers, limited quantities of water in the gloveboxes, controlled water addition by fire protection systems, and limits on the size and number of containers in gloveboxes. Criticality Safety Evaluations Reports are written establishing specific controls that provide double-contingency protection.

Chapter 9, Section 9.2.3 of the PFP FSAR quantitatively analyses the probability and consequences of a nuclear criticality. Plutonium handling operations associated with thermal stabilization operations do not differ from other PFP plutonium handling activities and do not warrant additional analysis as established controls have been determined to provide an adequate degree of protection.

9G.4.2.2 Uncontrolled Fire in Glovebox

The PHA identified numerous causes of a glovebox fire (Table 9G.20) including electrical shorts, the presence of pyrophoric materials in the feed, or combustible materials coming into contact with hot furnace surfaces. Controls to prevent or mitigate fires include controlling the quantity of combustible materials in gloveboxes, maintaining a safe separation between combustible materials and ignition sources, and fire suppression systems.

Chapter 9, Section 9.2.2A of the PFP FSAR analyses a fire in the RMC line as the bounding PFP fire hazard. The impact of the thermal stabilization of non-product quality oxide feed materials on the existing FSAR RMC line fire analysis is presented in Chapter 9, Section 9.2.10 of the PFP FSAR.

9G.4.2.3 Flammable Gas Deflagration/Energetic Chemical Reactions

The hazards analysis identified the potential for flammable gas deflagrations resulting from the thermal decomposition of TBP (and its degradation products) known to be present in PRF sludges or from the thermal decomposition of plastic or other organic materials potentially present in impure oxide, MOX, floor sweeps, and oxalates (Table 9G.9). Examples of controls for deflagrations include minimizing the quantity of TBP, plastics, and other organic contaminants present in the feeds, maintaining airflow and CO_2 flow through the furnaces, and slowly increasing the furnace temperature when processing PRF sludges

In addition to flammable gas deflagrations, the PHA identified the potential for energetic chemical reactions between incompatible chemicals potentially present as contaminants (Tables 9G.16 and 9G.17). This event was selected for detailed analysis in Chapter 9, Section 9.2.10 ????. Note that PFP processes are small in size relative to many chemical plants and that the processes generally employ low energy level chemistry.

9G.4.2.4 Natural Phenomena

The PHA identified three natural phenomena events: earthquake, high wind, and ashfall. The PHA identified four seismically induced events: an explosion, a fire, a loss of confinement, and a criticality (Table 9G.13).

Chapter 9, Section 9.2.4.1 of the PFP FSAR analyzes the response of PFP structures and gloveboxes, including those operated in support of thermal stabilization, to a seismic event, and calculates the consequences based on loss of confinement and criticality scenarios. The impact of the thermal stabilization of non-product quality oxide feed materials on the existing FSAR analyses is presented in Chapter 9, Section 9.2.10 of the PFP FSAR.

Chapter 9, Section 9.2.5 of the PFP FSAR analyzes the impact of a design basis wind. The 234-5Z Building is capable of withstanding both the wind forces and wind-generated missile associated with the design basis wind. Evaluation of this event with respect to thermal stabilization operations is not warranted.

Ash fall represents a roof loading concern and an abrasive concern for moving equipment. Evaluation of this event with respect to thermal stabilization operations is not warranted.

9G.4.3 External Events

The PHA identified facility-wide loss of power due to external events as an initiator to a flammable gas deflagration (Table 9G.8). The combination and sequencing of specific events is such that the probability is considered to be bounded by operator error or equipment failure initiators considered in Section 9G.4.2.3 above.

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Table 9G.1. PHA Data Table

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments

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Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A. General Glovebox Hazards – Applicable to all Feed Materials									
A.1.01	Electrical Equipment in glove box.	Fire in glove box caused by electrical short	Failure to properly inspect power cords or failure to identify frayed cords results in condition that leads to an electrical short that ignites combustibles in the glovebox Failure to control combustibles in glove box allows significant fire that damages glove box confinement.	Burn through of gloves seal out bags resulting in breach of containment Ignition of Polymethyl Methacrylate or Polycarbonate glove box panels and spread of fire to other gloveboxes Release of soot, hot embers, and water vapor to the E-3 and E-4 ventilation systems. Pluggage or failure of glovebox and E-4 filterbox HEPA filters. Potential pluggage of E-3 room prefilters or E-3 filterbox HEPA filters, with spread of contamination to clean portions of the plant. Worker uptake of airborne Pu	Halon fire suppression system in Gloveboxes HC-21A, HC-21C, HC-18M, HC-18BS, HC-2, and HC-3 Dry fire suppression system in Gloveboxes HA-23S, HC-28, and HC-4 Wet pipe fire suppression system in rooms 228C, 230A, B, C, and Room 235B Glovebox (E-4) ventilation system maintains negative glovebox pressure and confines release until several gloves or bag ports are burned out or window panels are breached, giving operators time to manually extinguish fire. Long length of E-3/E-4 ductwork between RMC line and filter room filters and dilution airflow from other E-3/E-4 areas of the plant are expected to cool offgasses from the fire enough to prevent heat damage to, or plugging of the E-3/E-4 filter-room HEPA filters. E-3/E-4 filter-room HEPA filters mitigate release to the environment CAMS alert workers to presence of airborne contamination.	MgO sand available in gloveboxes for extinguishing small fires Bayonet fire extinguisher is near glovebox for manually extinguishing fire. Housekeeping practices minimize combustible loading in glovebox. Senior supervisory watch OSHA inspections can identify frayed cords. Electrical safety program of cord inspection reduces the likelihood of the presence of frayed cords. Institutional occupational safety program of requirements and inspections reduces the likelihood of the presence of frayed cords. Hanford fire department located within a few miles of PFP	S1*	F3	Polymethyl Methacrylate panels are easier to ignite and spread flames more readily than Polycarbonate panels. Polymethyl Methacrylate panels have been replaced by Polycarbonate panels in Gloveboxes HC-21A and HC-21C. Several kg of burning plastic can generate enough radiant heat to ignite Polycarbonate panels. See RMC line fire accident analysis in Section 9.2.2 of the PFP FSAR.
A.1.02	Electrical Equipment in glovebox	Electrical shock to operator	Cord frayed in the glovebox Frayed cord contacts glovebox frame while operators body or leg is in contact with the glovebox frame.	Operator injury	None	Senior supervisory watch OSHA inspections can identify frayed cords. Electrical safety program of cord inspection reduces the likelihood of the presence of frayed cords. Institutional occupational safety program of requirements and inspections reduces the likelihood of the presence of frayed cords.	S1	F3	Commonly accepted industrial hazard. The likelihood of electrical shock injury is reduced by the presence of rubber mats that are placed on floor grating to protect shoe covers Hypalon glovebox gloves may provide some protection

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A.1.03	Glovebox Confinement Boundary	Hole in glovebox confinement boundary leads to spread of contamination from glovebox	Degradation of port bags, ice cream cartons used to seal sphincter port, or gloves due to aging, radiation, or heat.	Minor Spread of contamination from glovebox and potential uptake by workers.	E-4 ventilation system maintains negative pressure in glovebox and maintains confinement velocity across small holes	Gloves and bags have scheduled replacement dates which minimizes likelihood of degradation. Pre-job walkdown visual inspection of gloves, bags, and ice cream cartons. Air flow through leaks can cause a whistling sound which aids in detecting leaks in gloves, port bags, etc. during pre-job walkdown. Radiological control program: operators hands are surveyed every 15 minutes during glovebox operations and when changing glovebox locations to identify leaks. Alpha contamination survey on exit from radiological control area prevents spread of contamination to clean areas of the plant.	S1	F3	Ice cream cartons currently are replaced with each successive seal-in.
A.1.04	Glovebox Confinement Boundary	Breach in glovebox confinement boundary during waste bagout, port bag replacement, or glove change.	Sharp object punctures bag Bag not properly horse tailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers.	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers wear respirators during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	None

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
A.2.01	Glovebox CPS	Violation of criticality safety mass or spacing limit, loss of contingency	Failure to check or adhere to CPS postings on glovebox	Potential Criticality in glovebox with worker exposure to ionizing radiation and fission product gasses.	None	CSER controls on mass of Pu allowed in glovebox, spacing of containers in glovebox, etc. CPS posting on glovebox Operator training.	S1*	F2	Controls providing double contingency protection against criticalities are identified in separate CSER reports for each glovebox. S1* is consequence for a criticality, not a loss of contingency.
A.3.01	Glovebox (E-4) ventilation system	Stagnant glovebox or pressurized glovebox during operations causes spread of contamination from glovebox	Loss of E-4 ventilation flow or imbalance between E-4 supply and exhaust (caused by loss of power or equipment or control failures). Failure to detect HVAC upset during pre-job walkdown	Spread of contamination from glovebox during seal in or seal out of container, glove change, or change of port bag. Worker exposure to dispersible Pu. Overheating of Glovebox HC-21C during furnace operations (see item E.3.04).	E-4 HVAC controls Interlock shuts off supply fans if exhaust fans go down, which prevents glovebox pressurization. Pressure regulating valve on supply air regulates pressure in RMC line gloveboxes. Addition exhaust capacity provided via emergency exhaust valves in Room 228A should imbalance develop between supply and exhaust flow. Alarm activates in power control room on detection of low glovebox negative in control room. PAX announcement made if alarm activates. E-3 filter room filters mitigate release to environment if only E-4 ventilation is lost. Building shell mitigates release if glovebox and building goes stagnant. Backup power operates emergency exhaust fans that maintain negative pressure in gloveboxes if plant loses primary power. Room CAMs alert workers to airborne contamination.	Pre-job walkdown to verify proper glovebox ventilation flow and DP Operator training and procedures	S1 S1	F3 F2	S1/F3 for stagnant glovebox case. S1/F2 for pressurized glovebox case (pressurization is not large). Plant is evacuated if E-3/E-4 exhaust is lost, which minimizes potential worker inhalation doses.

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
B. Transfer Items from Vault Storage to Glovebox HC-21A									
B.1.01	Remove item from storage location and place on fixed array wagon	Breach of container	Operator drops container Pressurized container fails during handling	Spread of contamination, worker uptake	Multiple overpack containers Room CAMs alert workers to presence of airborne contamination Suspected pressurized containers (i.e., B, C, and D cans) placed in ITC HEPA filtered ventilation system	Training and procedures	S0	F3	None
B.1.02	Remove item from storage location and place on fixed array wagon	Violation of mass or spacing limits, loss of contingency	Operator placed too many items on wagon	Potential criticality with worker exposure to ionizing radiation and fission product gases	Fixed array wagon that limits the number of containers and establishes spacing	Training and procedures CPS limits	S1*	F2	Controls providing double contingency protection identified in applicable CSERs. S1* is consequence for a criticality, not a loss of contingency.
B.2.01	Transfer item to Glovebox HC-21A	Breach of container	Wagon tips over, container falls out and opens	Spread of contamination, worker uptake	Fixed array wagon holds cans in storage positions if tipped over Multiple overpack containers Room CAMs alert workers to presence of airborne contamination HEPA filtered ventilation system	Training and procedures	S0	F3	None
B.2.02	Transfer item to Glovebox HC-21A	Violation of spacing limits, loss of contingency	Wagon tips over, containers fall out	Potential criticality with worker exposure to ionizing radiation and fission product gases	Fixed array wagon holds can in storage positions if tipped over	Training and procedures	S1*	F2	Controls providing double contingency protection identified in applicable CSERs. S1* is consequence for a criticality, not a loss of contingency.
BB. Transfer Items from Glovebox Storage to Glovebox HC-21A									
BB.1.01	Transfer polyjar or slip-lid can from glovebox storage to HC-21A via glovebox conveyor system (transfer will primarily be from HA-23S via conveyors HA-28, HC-4, HC-3, airlock, HC-2)	Polyjar crumbles in worker hands during handling or is damaged in drop or by conveyor malfunction	Radiolytic/thermal degradation of polyjar	Spill of material to glovebox floor, entrainment of material into glovebox air Plastic contaminant in cleaned-up material potentially results in flammable gas burn during subsequent thermal stabilization (see E.3.04)	Glovebox confinement boundary and ventilation system confine release See E.3.04 for potential flammable gas hazard	Procedure requires sieving of material during transfer to furnace boat. Plastics and other contaminants visually detected by workers	S0 S1*	F3 F2	S0/F3 for spilling S1*/F2 for flammable gas burn See E.3.04

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
BB.1.02		Airlock between conveyors HC-2 and HC-3 left open, deminishes effectiveness of Halon system, loss of fire separation	Operator error results in airlock doors being left open	No consequence unless concurrent RMC line fire Reduced ability to Halon system to suppress fire	Operator training and procedures	Operator training and procedures	S2	F1	None
C. Activities in Glovebox HC-21A – PuO2 and MOX Feed Materials from Vault Storage (multiple overpack containers)									
C.1.01	Seal container into Glovebox HC-21A through bag in port or sphincter seal	Drop of Pu storage container outside glovebox during seal in.	Human error.	No significant release from Pu storage container expected.	Overpack containers protect inner container.	Operator training and procedures Inner containers have been drop tested and found not to leak.	S0	F3	Hazards associated with handling containers of Pu outside gloveboxes is adequately covered in the PFP FSAR.
C.1.02	Seal container into Glovebox HC-21A through bag in port or sphincter seal	High worker direct dose during handling of cans	Container containing PuF_4 handled instead of PuO_2 or MOX (PuF_4 much higher dose than oxide from alpha-n reactions). Cans handled for extended time period during handling/seal-in of cans.	Worker dose rate limit (Radiological work permit) potentially exceeded	Leaded gloves limit dose when handling cans inside the glovebox. Glovebox structure shields body of operator Inner can and first overpack are wrapped with leaded tape to minimize direct dose	ALARA principles applied to Pu storage container handling process. Periodic dose measurements taken on glovebox to establish acceptable worker exposure periods. Labeling of cans in vault (RAM tags) Cans surveyed for contact dose several times during movement and before loading into HC-21A. Blend plan identifies intended cans Institution radiological control program	S1	F3	None
C.1.03	Seal container into Glovebox HC-21A through bag in port or sphincter seal	Glovebox loss of confinement during seal in.	Sphincter seal failure Ice cream carton or can in sphincter seal inadvertently pushed into glovebox without can or carton behind it results in open sphincter seal. Seal in bag torn or pulled off port during seal in (also applies to change out of port bags) (see item A.1.04). Pressurized glovebox during seal in (see item A.3.01)	Minor release of contamination from the glovebox into the room. Potential worker uptake of Pu.	Glovebox ventilation system maintains negative pressure and confinement velocity across failed sphincter seal or port bag which minimizes the potential contamination spread. Backup glovebox (E-4) ventilation system maintains confinement on loss of primary ventilation. Room CAMs alert operators to presence of airborne contamination. PRV on supply restricts flow rate on low glovebox DP. Emergency	Operator training and procedures	S1	F3	S1 ranking assumes minor release of contamination from glovebox. Hazards associated with seal in of containers into gloveboxes is covered in the PFP FSAR. This accident is not unique to seal in of containers containing thermal stabilization feed materials. Room CAMs are designated safety significant in the PFP FSAR.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
					exhaust valves open on low glovebox negative. Sphincter seal design prevents release unless no can or carton in seal.				
C.2.01	Open outer cans and make empty cans into Non containers	Flammable gas (i.e. H_2) release and burn when overpack can opened.	Radiolysis of plastic bag around slip lid can and organic can seal during storage in vault. Ignition due to mechanical spark from can opener, static release from ejected powders, or electrical spark.	Potential deflagration involving H_2 released from can causing pressurization and potential failure of seal-in ports or sphincter ports with release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing potentially significant amounts of hydrogen are identified by visual detection of bulging.	S1	F2	Catastrophic failure of glovebox structure not expected due to limited quantity of H_2 possible in the can. Many pressurized cans have been opened at PFP without a resultant deflagration. Ignition of hydrogen released from the can by the can opener or static discharge is unlikely.
C.2.02	Open outer cans and make empty cans into Non containers	Operator injury and damage to glovebox glove compromising glovebox confinement integrity.	Operator punches through glove with can opener or cuts glove on sharp edges of the can or can lid	Operator injury with contamination of wound Small hole in glovebox confinement boundary Small contamination release from glovebox as hands withdrawn from glovebox gloves	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves are used over glovebox gloves when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Surgical excision of contaminated tissue. Leather gloves used when crushing or folding cans	S1	F3	None
C.2.03	Open outer cans and make empty cans into Non containers	Outer cans not properly made into non- container, loss of contingency	Can not crushed and folded, can with bottom removed set upright instead of on its side, can not turned upside down.	CPS infraction Margin of criticality safety reduced	None	Operator training and procedures Glovebox CPS posting (tells operator maximum open container volume to unit mass ratio)	S1*	F3	None S1* is consequence for a criticality, not a loss of contingency.

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
C.2.04	Open outer cans and make empty cans into □Non containers□	Operator injury and damage to glovebox glove compromising glovebox confinement integrity.	Operator suffers injury and ruptures glove while crushing empty can with hammer	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox.	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	S1	F3	None
C.3.01	Weigh storage container (inner and overpacks) and furnace boat (before and after filling) for Pu accountability and operational requirements	No safety hazard identified for this step.	--	--	--	--	--	--	Pu content of item is set by Accountability prior to placing container in vault. Scale can□t necessarily detect overbatch of Pu or potential criticality hazard since it only measures gross weight.
C.4.01	Open innermost can (can containing feed material)	Operator injury and damage to glovebox glove compromising glovebox confinement integrity.	Worker penetrates glove while opening sealed can with can opener, taped slip lid can with scissors, while handling can or lid.	Operator injury with contamination of wound Small hole in glovebox confinement boundary Small contamination release from glovebox	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves use when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	S1	F3	None
C.4.02	Open innermost can (can containing feed material)	Hydrogen gas release and burn when can opened	Radiolytic degradation of plastic contaminant, brush bristles, tool handle, bottle caps, etc. in oxide during storage generates hydrogen in can. Hydrogen ignited during release from can due to static or electrical discharge High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization	Potential deflagration involving H_2 released from can causing pressurization and potential failure of seal-in ports or sphincter ports with release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing potentially significant amounts of hydrogen are identified by visual detection of bulging.	S1	F2	Catastrophic failure of glovebox structure not expected due to limited quantity of H2 possible in the can. Many pressurized cans have been opened at PFP, all without a resultant deflagration. Ignition of hydrogen released from the can by the can opener or static discharge is unlikely.

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
			due to hydrogen buildup from reaction of the water with Pu and radiolysis of the water.						
C.4.03	Open innermost can (can containing feed material)	Pu particulate release from pressurized can when it is opened	Can temperature higher than when canned causes pressurized can Alpha decay causing pressure buildup (Helium usually diffuses out of can) High water content in oxide (above 1%) due to prior inadequate stabilization results in can pressurization due to hydrogen buildup from reaction of the water with Pu and radiolysis of the water.	Pu particulate release inside glovebox Increased dose rate to workers near glovebox from spilled Pu	E-4 ventilation system and glovebox confines release E-4 ventilation system HEPA filters mitigate release to the environment through the facility exhaust stack.	Housekeeping; spilled material is swept up and placed in cans and sealed out of glovebox. Institutional radiation protection program: Radiological control technicians set glovebox dose rates to limit operator direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures ventilation is operating correctly.	S0	F3	None
C.4.04	Open innermost can (can containing feed material)	Flammable gases (alkanes, H_2, etc) from organic in container released and ignited when can opened (can pressurized)	Container containing organic (e.g., sludge, floor sweeps) inadvertently sealed into glovebox and opened. Wrong container selected due to inaccurate labeling or human error. Flammable gases generated due to radiolytic decay of organic material (e.g., sludge) in the container. Ignition due to mechanical or electrical spark, or static discharge.	Pressurization of glovebox Potential damage to glovebox confinement boundary Pu release into room and worker inhalation uptake.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material.	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of flammable are easily identified due to bulging. Labeling of containers Operator training and procedures Shift technical advisor sign off for material acceptability required by procedure. Sludges which may contain organic are stored in vented polyjars which are easily distinguishable from multiple overpack cans containing PuO_2 and MOX	S1	F2	Recommend bulged containers not be opened in air. []Ruler test[] can be used to eliminate highly pressurized cans. Catastrophic failure of glovebox structure not expected due to limited quantity of flammable gas possible in the can. Many pressurized cans have been opened at PFP, all without a resultant deflagration. Ignition of flammable gas released from the can by the canopener or static discharge is unlikely.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
C.4.05	Open innermost can (can containing feed material)	Pyrophoric reaction and hydrogen burn when can opened	Pu metal, PuH_2 hydride contaminant in can Pu metal may be in can due to incomplete prior stabilization. PuH_2 forms from metal if plastic or organic contaminants are also present in can. Or if hydrogen from degradation of the plastic bag outside the can diffuses into the can. Can under vacuum due to catalyzed formation of oxides and nitrides in the container. When can is opened air is sucked in which reacts with the hydrided material. Hydride reactions releases heat and hydrogen gas which is ignited on exiting the can.	If sufficient hydride contamination present, slight pressurization of the glovebox could occur. Potential burn through of gloves and operator injury due to contact with hot embers. Embers burn through PVC ports Minor contamination spread from glovebox if gloves or port bags damaged. Potential ignition of combustibles in glovebox producing glovebox fire.	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Shift technical advisor sign off for material acceptability required by procedure. Combustible loading in glovebox is controlled by procedure.	S1 S1*	F3 F2	S1/F3 for sparking reaction and small hydrogen flash with maximum consequence being burn through of glove or port bag S1*/F2 for ignition of significant combustibles in the glovebox causing glovebox fire. Evaluate use of Pu net wt% to detect presence of Pu hydride in can before opening. Cans with relatively large quantities of hydride will be □panelled,□ making them easy to identify and not open in this campaign.
C.5.01	Transfer contents to furnace boat	Pyrophoric reaction as material poured through air	Pu metal, PuH_2, Uranium hydride; Pu_2O_3 contaminant in can Pu or U metal may be in can. PuH_2/ UH_3 forms from metal if plastic or organic contaminants are also present, or if hydrogen from degradation of the plastic bag outside the can diffuses into the can.	Sparks potentially initiating a glovebox fire. Hot embers entrained in air may burn hole in glovebox HEPA filters. Dispersal of Pu in glovebox Potential burn through of gloves and operator injury due to contact with hot embers. Burn through of PVC port bags. Minor contamination spread from glovebox if gloves or port bags damaged Potential ignition of combustibles in glovebox producing glovebox fire If sufficient hydride contamination present, slight pressurization of the glovebox could occur	Glovebox (E-4) ventilation system maintains confinement if damage limited to holes in gloves E-3 ventilation system filters release to environment if glovebox confinement lost Rooms CAMs alert worker to airborne contamination Glovebox dry fire suppression system for putting out glovebox fire Glovebox high temperature alarm	MgO sand for putting out small fire Bayonet fire extinguishers available near glovebox for putting out small fire Operator training and procedures Only material passing previous LOI test will be processed through the furnaces during this campaign. Blend plan identifies which containers are acceptable for processing. Container labeling and material processing records identify contents of containers. Cans with relatively large quantities of hydride will be □panelled□ and easily identified. Combustible loading in glovebox is controlled by procedure	S1 S1*	F3 F2	Evaluate use of Pu net wt% to detect presence of Pu or U metal in can before opening. S1/F3 for sparking reactions with maximum consequence being burn through of glove or port bag. S1*/F2 for ignition of significant combustibles in the glovebox.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
C.5.02	Transfer contents to furnace boat	Can/boat contents spilled to glovebox floor	Human error	Violation of criticality prevention specification limit regarding depth of powder allowed on glovebox floor Increased operator exposures during cleanup of spill	E-4 ventilation system and glovebox confinement release	Housekeeping Operator training and procedures	S0	F3	Operational upset only Significant dose to operator in cleaning up spill not expected.
C.5.03	Transfer contents to furnace boat	Material other than Pu oxide or MOX poured into furnace boat (e.g., metal button, sludge or glovebox floor sweeps) resulting in process upset.	Wrong can opened due to mislabeling or human error.	Process upset. Material would have to be canned up and bagged out of the glovebox for later processing. Potential adverse reaction in furnace in Glovebox HC-21C if wrong material not noticed by operator.	--	Labeling and paperwork associated with each container identify contents making it unlikely for wrong material to be processed. Operator training and procedures.	S0	F2	X-ray or Pu mass ratio information could be used to provide added assurance against processing materials other than Pu oxide. Sludges are stored in polyjars in Glovebox HA-23S, not in the vaults with the Pu oxide. Highly unlikely that container of sludge would get mixed up with container of oxide. Glovebox floor sweeps are stored in gloveboxes, not in the vaults with the Pu oxide, making selection of can with floor sweeps very unlikely. H/X ratio on sludges will indicate high organic loading. Hazards associated with inadvertently processing Pu fluoride are covered in this PHA since it may be difficult to visually tell the difference between fluoride and oxide through the yellowed glovebox windows (see items B.1.02 and D.3.10).

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
C.6.01	Identify and remove contaminants from oxide in furnace boat	Contaminants not identified or removed from oxide result in reaction hazards in Glovebox HC-21C furnaces. Contaminants can include unburned metal pieces from prior stabilization run, metal hydrides, and plastics including: tool handles, brush bristles, PVC or polyethylene bag fragments, polycarbonate pieces, etc.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Pyrophoric reaction in furnace in Glovebox HC-21C. See item E..3.05. Fires or deflagrations of flammables the furnaces in Glovebox HC-21C. See item E.3.04.	See items E.3.04 and E.3.05 for engineered features to mitigate reactions in the HC-21C furnaces.	Procedures with sign off by Shift Technical Advisor.	S1 S1*	F2 F2	S1/F2 for pyrophoric reactions in furnace. S1*/F2 for flammable gas deflagration in furnace resulting from excessive plastic contaminant in oxide feed to furnace.
C.7.01	Bag out waste (crushed cans, tape, plastic); replace port bag.	Breach in glovebox confinement boundary during waste bagout or glove change.	Sharp object punctures bag Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers on mask during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	None

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
C.7.02	Bag out waste (crushed cans, tape, plastic); replace port bag.	Spread of contamination from waste bag	Waste bag squeezed causing release of radiological material through taped vent Isolated transport container (ITC) dropped during handling causing bag to vent or rupture	Contamination of workers and potential uptake of radiological material	E-3 ventilation system filters release to environment. Room CAMs alert workers to airborne contamination.	Operator training and procedures Waste bags are put in isolated transport container (ITC) immediately after applying second bag. ITCs have lids to minimize spread of release from pail. Radiological control program. Survey of workers with alpha poppy probes to detect skin contamination. Worker decontamination by RCT if necessary.	S1	F3	None
C.7.03	Bag out waste (crushed cans, tape, plastic); replace port bag.	Hydrogen deflagration inside waste drum in satellite accumulation area.	Hydrogen generation from radiolysis in waste bags in waste drum. Ignition caused by spark generated while moving drum.	Pressurization of drum, drum damage and release of radiological material from waste drum in satellite accumulation area (Room 166) Potential worker injury	Waste drum is vented through a filter to prevent hydrogen accumulation Room CAMs alert workers of airborne contamination in Room 166 Room 166 ventilated by the E-3 system which confines and filters any release from waste drum.	Drum seal is verified. Periodic surveillance of rooms to detect bulging drums.	S1	F2	S1 ranking instead of S1* due to small quantity of Pu in drum. This hazard is not unique to the thermal stabilization process as it applies to drums containing bagged out waste from all gloveboxes. Hazards associated with drum storage are covered in the PFP FSAR. The Pu content of the bagged waste is so low that significant pressurization of a drum is not expected during its storage life at PFP even if vent plugs.
CC. Activities in Glovebox HC-21A – Sludges, Floor Sweeps, and Oxalates from Glovebox Storage (polyjars or slip-lid cans)									
CC.1.01	Weigh polyjar or slip-lid can and furnace boat (before and after filling) for Pu accountability and operational requirements	No safety hazard identified for this step	–	–	–	–	–	–	–

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
CC.1.02	Transfer container into Glovebox HC-21A via conveyor	High worker direct dose during handling of container	Container containing PuF4 instead of sludges, floor sweeps and oxalates	Worker dose rate limit (radiological work permit) potentially exceeded.	Leaded gloves limit dose when handling containers Glovebox structure shields body of operator	ALARA principles applied to Pu storage container handling process. Periodic dose measurements taken on glovebox to establish acceptable worker exposure periods. Labeling of cans in vault (RAM tags) Cans surveyed for contact dose several times during movement and before loading into HC-21A. Blend plan identifies intended cans Institution radiological control program	S1	F3	None
CC.2.01	Open polyjar or slip-lid can	Operator injury and damage to glovebox glove compromising glovebox confinement integrity	Polyjar crumbles, worker glove penetrated by shard. Worker glove penetrated by scissors while opening taped slip-lid can.	Operator injury with contamination of wound. Small hole in glovebox confinement boundary Small contamination release from glovebox	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across small holes preventing release of Pu to room.	Leather gloves use when opening cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury	S1	F3	None
CC.2.02	Open polyjar or slip-lid can	Hydrogen gas release when polyjar or slip-lid can opened	Radiolytic degradation of plastic contaminant, brush bristles, tool handle, bottle caps, etc. in oxide during storage generates hydrogen in can. Hydrogen ignited during release from can due to static or electrical discharge	Potential deflagration involving H_2 released from can causing pressurization and potential failure of seal-in ports or sphincter ports with release of Pu into the room air. Inhalation uptake of Pu by workers.	Glovebox and E-4 ventilation system confine release unless deflagration large enough to fail port bags or gloves. E-3 ventilation system filters mitigate release to the environment. Room CAMs alert workers to presence of airborne radiological material	Operators verify glovebox DP and filter DP before opening cans. Pressurized cans containing a dangerous amount of hydrogen are easily identified due to bulging.	S1	F2	Polyjars and slip-lid cans not likely to hold pressure. Catastrophic failure of glovebox structure not expected due to limited quantity of H2 possible in the can. Many pressurized cans have been opened at PFP, all without a resultant deflagration. Ignition of hydrogen released from the can by the can opener or static discharge is unlikely.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
CC.3.01	Sample sludge for organic content	Flammable gas above LFL	Operator fails to sample or collects non-representative sample	Potential flammable gas (butene) concentration greater than LFL. Possible fire or deflagration. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace. Furnace vacuum system sweeps air through the furnace that serves to dilute flammable gas concentration.	Operator training and procedures	S1*	F2	None
CC.3.02	Transfer contents to furnace boat	Polyjar or slip-lid can contents spilled to glovebox floor	Human error	Potential violation of criticality prevention specification limit regarding depths of powder allowed on glovebox floor. Increased operator exposure during cleanup of spill	E-4 ventilation system and glovebox serve to confine release	Housekeeping Operator training and procedures	S0	F3	Operational upset only. Significant dose to operator in cleanup of spill not expected/
CC.4.01	Identify and remove contaminants from feed in furnace boat	Contaminants not identified or removed from feed result in reaction hazards in Glovebox HC-21C furnaces. Contaminants can include plastics including: RTV, tool handles, brush bristles, PVC or polyethylene bag fragments, polycarbonate pieces, etc.	Human error; step not performed correctly Contaminants not readily identifiable due to color, size, etc. Poor visibility through glovebox windows.	Pyrophoric reaction in furnace in Glovebox HC-21C. See item E.3.05. Fires or deflagrations of flammables the furnaces in Glovebox HC-21C. See item E.3.04.	See items E.3.04 and E.3.05 for engineered features to mitigate reactions in the HC-21C furnaces.	Procedures with sign off by Shift Technical Advisor.	S1 S!*	F2 F2	S1/F2 for pyrophoric reaction in furnace. S1*/F2 for flammable gas deflagration in furnace resulting from excessive plastic contaminant in oxide feed to furnace.
CC.5.01	Make polyjar or slip-lid can into a noncontainer	Polyjar or slip-lid can not properly made into non-container, loss of contingency	Polyjar or slip-lid can not turned upside down or on side Polyjar or slip-lid can not cut or crushed	CPS infraction Margin of criticality safety reduced	None	Operator training and procedures Glovebox CPS posting (informs operator maximum open container volume to unit mass ratio)	S1*	F3	None S1* is consequence for a criticality, not a loss of contingency.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
CC.5.02	Make polyjar or slip-lid can into a noncontainer	Operator injury and damage to glovebox glove compromising glovebox confinement integrity	Operator injures self and ruptures glove while cutting or crushing polyjars or slip-lid cans	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox	Glovebox ventilation system maintains confinement velocity across hole in glove	Leather gloves use when cutting polyjars or crushing slip-lid cans Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury	S1	F3	None
CC.6.01	Bag out waste (cut polyjars, crushed cans); replace bagport.	See C.7.01 through C.7.03	See C.7.01 through C.7.03	See C.7.01 through C.7.03	See C.7.01 through C.7.03	See C.7.01 through C.7.03	See C.7.01 through C.7.03	See C.7.01 through C.7.03	See C.7.01 through C.7.03
D. Activities in Glovebox HC-2									
D.1.01	Transfer furnace boat down conveyor to Glovebox	Glove damaged during conveyor operation compromising glovebox confinement	Glovebox glove(s) pinched in conveyor during transfer.	Worker injury and contamination Potential spread of contamination from glovebox through hole in glove leading to potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and confinement velocity across ruptured gloves. CAMs alert workers to presence of airborne contamination.	Conveyor disabled when workers have hands in gloves - 3 key interlocks (in different rooms) must be enabled to operate conveyor. Gloves secured outside conveyor glovebox with bungee cords before conveyor is turned on. Operator training and certification.	S1	F3	None
D.1.02	Transfer furnace boat down conveyor to Glovebox	Spill/dispersal of Pu bearing material in glovebox	Furnace boat dumped off conveyor .	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred in a boat cover which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal	S0	F3	None

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
						should the boat tip over on the conveyor.			
E. Activities in Glovebox HC-21C									
E.1.01	Remove boat cover, adjust furnace hearth, and place boat in furnace	Spill/dispersal of Pu bearing material in glovebox	Furnace boat spilled while loading into furnace	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is collected, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. "Boat cover" limits the potential for Pu dispersal should the boat tip over on the conveyor.	S0	F3	None
E.2.01	Prepare for furnace operation, includes: - close furnace door	Operator injury/glove damage	Glove pinched in door when closed or glove punctured by sharp object.	Operator injury with contamination of wound Small hole in glovebox confinement boundary leading to contamination release from glovebox.	Glovebox ventilation system maintains confinement velocity across hole in glove	Operator training and procedures Operators are surveyed for contamination every 15 minutes while working in glovebox gloves. Self survey on exit from radiological area to detect skin contamination HPT deconning of skin or injury Leather gloves used when crushing or folding cans	S1	F3	None

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.2.02	Prepare for furnace operation: - adjust offgas (vacuum), flowrate typically 2-3 cfm	Buildup of flammable gas	Operator error in adjusting flow, valve failure	Potential flammable gas concentration greater than LFL. Possible fire or deflagration. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Flow meter on vacuum line	Operator training and procedures	S1*	F2	None
E.2.03	Prepare furnace for operation: - check ceramic filter DP	Buildup of flammable gases	Operator fails to check ceramic filter DP combined with buildup of solids on filter reduces air flow	Potential flammable gas concentration greater than LFL.. Possible fire or deflagration. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	None	Operator training and procedures	S1*	F3	None
E.2.04	Prepare furnace for operation: - Turn on and adjust CO_2 flowrate if processing sludge, flowrate typically 0.5 cfm.	No CO_2 purge during sludge processing	CO_2 not turned on Bottle runs empty CO_2 valved to wrong furnace	Potential flammable gas (butene) concentration greater than LFL.. Possible fire or deflagration. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Alarm on CO_2 tank switching Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace. Furnace vacuum system sweeps air through the furnace that serves to dilute flammable gas concentration.	Verification of CO_2 supply prior to conduct of furnace operations Quantity of organic in sludge limited to 10 g Ramp/dwell furnace operation controls rate at which flammable gases are generated.	S1*	F2	Ramp/dwell provides primary control, CO_2 provides defense in depth. Loss of CO_2 only not likely to result in flammable gas deflagration

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.2.05a	Prepare furnace for operation: - Remove combustibles (e.g. tools, cartons if present) from glovebox	Breach in glovebox confinement boundary during bagout of combustibles or while withdrawing gloves from glovebox.	Sharp object punctures port bag while bagging out combustibles or while changing bag. Bag not properly horsetailed or taped after removing combustibles from glovebox. Bag inadvertently pulled off port during bagout of combustibles. Glove tears while being pulled out of the glovebox to prevent contact with hot furnace.	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers wear respirators during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	None
E2.05b	Prepare furnace for operation: - Remove combustibles (e.g. tools, cartons if present) from glovebox	Fire in glovebox compromises glovebox confinement.	Combustibles not controlled in glovebox come in contact with hot surface of furnace while it is operating. Combustible loading allows fire to spread. Port bag comes un-horsetailed gets sucked in and contacts hot surface of furnace.	Potential burn through of gloves or port bags, softening or ignition of glovebox windows leading to spread of Pu from compromised glovebox confinement boundary.	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and prevents contamination spread unless several gloves or port bags are lost. Emergency exhaust valves on RMC line opens up on low glovebox vacuum. Fire brick insulates outer surfaces of furnace from the intense heat produced in the furnace. Only limited areas around the door of the furnace are hot enough to ignite combustibles. Room CAMs alert workers to presence of airborne contamination. E-3 ventilation system filters any release from Zone 3 area to the environment.	Operator training and procedures. Combustible loading in glovebox is minimized by procedure.	S1*	F2	None
E.2.06	Prepare furnace for operation: - Pull gloves out of glovebox an secure with bungee cords	Gloves melted by contact with furnace compromising glovebox confinement.	Gloves not withdrawn from glovebox before starting furnace; gloves contact hot surface of furnace and melts. Gloves not secured properly with bungee cords after being pulled out of the glovebox; negative pressure causes gloves to be pulled into glovebox contacting hot spot on furnace.	Burned out glove allows contamination to spread from glovebox; potential uptake by workers. Operator burned while trying to pull glove back from furnace.	Glovebox (E-4) ventilation system maintains negative pressure in glovebox and prevents contamination spread unless several gloves are lost. Emergency exhaust valves on RMC line opens up on low glovebox vacuum. Fire brick insulates outer surfaces of furnace from the intense heat	Operator training and procedures. Gloves are pulled out of glovebox and secured with bungee cords before operating furnaces.	S1	F3	Hypalon gloves are expected to melt not burn on contact with hot surface of furnace.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
			on furnace.		produced in the furnace. Only limited areas around the door of the furnace are hot enough to melt or burn gloves. Room CAMs alert workers to presence of airborne contamination. E-3 ventilation system filters any release from Zone 3 area to the environment.				
E.3.01a	PU OXIDE, MOX, FLOOR SWEEPINGS: (Temperature controller upsets) Select furnace program for Pu oxide/MOX/floor sweepings, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Temperature ramped up too fast (temperature controller fails high)	Controller failure. Programmer error. Relay contact fails closed.	Burn out of furnace coils leading to shutdown of process. No hazard found for heating Pu oxide, MOX, or floor sweepings too fast.	Furnace temperature controller and furnace thermocouples: Controller shuts off furnace if program temperature and furnace temperature differ by more than 200 °C. Controller limits maximum current to 17 amps which prevents coil burnout. Temperature alarm switch (TAS) shuts off power to furnace if temperature exceeds 1050 °C. Temperature deviation alarm provides indication of furnace temperature greater than 20 degrees from controller setpoint at any given time.	Operator training and procedures. Calibration of controller.	S0	F3	None
E.3.01b	PRF SLUDGES (Temperature controller upsets) Select furnace program for PRF sludges, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Temperature ramped up too fast, no dwell times	Temperature controller fails high, wrong controller program selected, programming error, relay contact fails closed.	Potential flammable gas (butene) concentration greater than LFL. Possible fire or deflagration. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace. Furnace vacuum system sweeps air through the furnace that serves to dilute flammable gas concentration.	Operator training and procedures 10 g TBP control limits the quantity of butene generated Controller operational test procedures Controller calibration	S1	F3	Oxycarbonate program ramp/dwell times and temperatures approximate those for sludge. Hazard remains relatively unchanged if oxycarbonate program selected instead of sludge
E.3.01c	PU OXALATES (Temperature controller upsets) Select furnace program for Pu oxalates, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C.	Temperature ramped up too fast, no dwell times	Temperature controller fails high, wrong controller program selected, programming error, relay contact fails closed.	Process material boils/foams over boat into furnace	No hazard	Operator training and procedures Controller operational test procedures Controller calibration	S0	F3	None

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.3.01d	ALL FEED MATERIALS (Temperature controller upsets) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Inadequate stabilization of material leads to rupture of container in storage vault.	Failure of furnace heating element. Loss of power during stabilization. Temperature controller failure (temperature not held high enough for required 2 h). Power shut off early by operator.	Rupture of container sometime after it is place in storage vault if furnace upset not detected and LOI test fails to determine high moisture content. PuO_2 reacts with water to form a binary oxide and hydrogen gas which overpressurizes the container. Potential worker inhalation hazard upon entering vault.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product. Temperature deviation alarm provides indication of furnace temperature greater than 20 degrees from controller setpoint at any given time.	Operator training and procedures. Radiological control program: Routine sampling of vault air. Furnace chart recorder readings are used to verify proper furnace operation and soak time. LOI testing is performed on representative sample of material after stabilization in the furnace. Material found to lose more than 0.5 wt% in LOI testing will be run back through the furnace.	S1*	F2	None
E.3.02a	PU OXIDE, MOX, PU OXALATES, FLOOR SWEEPIONGS (Furnace vacuum system upsets) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Reduced air flow or no air flow during stabilization of material in furnace.	Plugged ceramic filter. Vacuum system valved out or otherwise blocked. Failure of vacuum pump or loss of power to vacuum pump. Other loads placed on 26 in vacuum system reduce airflow through furnace. Airflow not set properly before operating furnace.	Hot air from furnace vents into glovebox while heating oxide. Furnace not cooled down in intended time period after stabilization oxide. Potential damage to glovebox gloves and operator burn when boat removed from furnace.	DP across ceramic filter allows identification of plugged filter. Flow meter on vacuum line. Glovebox (E-4) ventilation system adequately removes hot air vented from furnace preventing overheating of glovebox. Temperature recorder tells operator when furnace is cooled down. DP and orifice place in vacuum system indicate flowrate.	Flow through vacuum system is verified to be in proper range before each furnace use.	S1	F3	None

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.3.02b	PRF SLUDGE (Furnace vacuum system upsets) Select furnace program for PRF sludge, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Reduced air flow or no air flow during stabilization of material in furnace.	Plugged ceramic filter. Vacuum system valved out or otherwise blocked. Failure of vacuum pump or loss of power to vacuum pump. Other loads placed on 26 in vacuum system reduce airflow through furnace. Airflow not set properly before operating furnace.	Potential flammable gas (butene) concentration greater than LFL. Possible fire or deflagration. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	DP across ceramic filter allows identification of plugged filter. Flow meter on vacuum line. DP and orifice place in vacuum system indicate flowrate. Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace.	Flow through vacuum system is verified to be in proper range before each furnace use.	S1*	F3	None
E.3.02c	ALL FEED MATERIALS (Furnace vacuum system upsets) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Excessive airflow through vacuum system	Flow rate set too high by operator.	Entrainment of flighty Pu oxide powder in furnace. Elevated release of particulates to vacuum system. Potential pluggage of ceramic filter leading to loss of vacuum flow (see item D.3.03)	Baffle in furnace reduces airflow directly over furnace boat minimizing suspension of particulates. Ceramic offgas filter removes majority of particulates before they enter the vacuum system header. DP gauge across ceramic filter provides indication of plugging. Demister and HEPA filters in vacuum system remove residual particulates from vacuum system air before discharge to the environment. DP and orifice place in vacuum system indicate flowrate.	Operator verifies correct flowrate throughout the vacuum system via rotameter before operating furnace.	S0	F3	None
E.3.02d	ALL FEED MATERIALS (Furnace vacuum system upsets) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Unfiltered flow through/around ceramic filter.	Filter cracked due to thermal stress Filter cracked or not properly installed in canister during installation/replacement.	Pu release into vacuum system Potential plugging of vacuum line between furnace and vacuum header.	Ceramic filter designed for high heat environment. DP gauge across ceramic filter provides indication of plugging. DP and orifice place in vacuum system indicate flowrate to detect plugging of vacuum line. Demister and HEPA filters in vacuum system remove residual particulates from vacuum system air before discharge to the environment.	Maintenance procedure for proper replacement of ceramic filter Operator training and procedures	S0	F3	None

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.3.03	ALL FEED MATERIALS (E-4 ventilation upsets) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Overheating of glovebox	Loss of E-4 ventilation flow during operation of furnace due to equipment failures, damper closures, etc.	Overheating of glovebox leading to possible failure of port bags and gloves and inadvertent operation of the glovebox fire suppression system. Potential softening and sagging of glovebox windows. Release of contamination through failed gloves or bag ports (or failed windows). Potential Pu uptake by workers. Evacuation of Zone 3 process areas leading to unattended glovebox which could result in inability to control fire if combustibles ignited.	Insulating blankets protect glovebox panels from heat damage from nearby hot vacuum lines. Backup E-4 exhaust fans run by emergency generators or steam kicks on, on loss of normal exhaust flow protecting glovebox from overheating. Alarms if dP is lost Halon system designed to suppress fire by displacing a fraction of the air in the glovebox. It is designed not to discharge enough material to pressurize the glovebox. .	Alarms in power control room activate on loss of E-4 exhaust flow. Process areas are evacuated on loss of E-4 ventilation protecting workers from Pu potentially released from the glovebox. Work to restore ventilation flow on dampers or other equipment can occur as they are outside process areas. Operators are trained to hit "kill switch" shutting down furnaces before evacuating. Emergency plan	S1	F3	None
E.3.04	ALL FEED MATERIALS (Plastic/organic contaminants in feed materials) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Plastic/organic contaminants in feed result in fire/deflagration in furnace.	Plastic/organic contaminants not noticed in feed or not removed by operator (plastic/organic contaminants can include PVC, polyethylene, polycarbonate, polystyrene, polymethyl methacrylate, RTV sealant, hydraulic oil)	Fire or deflagration involving flammable gases (alkanes, alkenes, hydrogen, carbon monoxide) generated inside the furnace. Fire extending out from gaps around furnace door can ignite combustibles, burn through gloves or port bags. Deflagration can damage furnace, throw furnace door open and produce a jet of flames that can burn through gloves, or port bags.	Furnace door does not latch and thereby provides vent path to prevent catastrophic explosion of the furnace. Furnace vacuum system sweeps air through the furnace to dilute flammable gas concentration or to completely oxidize (burn) plastic contaminant in a controlled manner. Furnace controller program of sludges and Pu oxalate have ramp/dwell times. CO_2 purge gas when processing sludges	Plastic contaminants are looked for and removed when the oxide is poured and sieved into the furnace boat in Glovebox HC-21A.	S1*	F2	Combination of airflow rate and ramp up rate should be used to ensure complete and controlled oxidation of plastic in furnace, taking into account the maximum quantity of plastic likely to slip past detection in Glovebox HC-21A.
E.3.05	PU OXIDE (Pyrophoric metal contaminants in feed materials) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Metal contaminant in feed results in pyrophoric reactions in the furnace.	Metal turnings or pieces not noticed or removed from feed in Glovebox HC-21A.	Reaction of pyrophoric metal or hydrided metal contaminant in furnace, leading to hydrogen release and burn in the furnace. Potential furnace damage. Failure of glovebox not expected due to small quantity of hydrided metal expected in feed.	Glovebox ventilation system confines material dispersed from furnace.	Visual identification of "non oxides" in Glovebox HC-21A when material poured into furnace boat. Blend plan identifies previously stabilized oxide to restabilize in this campaign. Labeling of cans. Operator training and procedures.	S1	F3	Pyrophoric metals are not expected to be present in MOX, floor sweepings, or PRF sludges.

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Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.3.06	ALL FEED MATERIALS (Pu fluoride processed through furnace) Select furnace program for feed material, ramp up furnace temperature and stabilize material for 2 hours at 1,000 °C	Pu fluoride powder processed through furnace.	Wrong can selected for processing due to mislabeling or human error.	HF gas release due to reaction with water vapor in air run through furnace. Damage to furnace vacuum exhaust system. Increased direct dose to operators. Pu fluoride produces higher direct dose than oxide (due to alpha-n reactions). See item B.1.02.	None	Labeling and paperwork associated with each container identify contents making it unlikely for wrong material to be processed.	S0	F2	PuF_4 powders may be difficult to distinguish from PuO_2 through yellow glovebox windows.
E.4.01	Remove boat from furnace and let cool for one hour on boat stand.	Glove damage/operator burn	Boat removed from furnace too early or boat not allowed to cool on boat stand before handling.	Operator burns hole in glove and suffers injury while removing boat from furnace. Hole in glove compromises glovebox confinement.	Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Glovebox ventilation system removes enough heat to prevent overheating of glovebox air with furnace door open. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	By procedure, operators are not allowed to remove furnace boat until furnace is below 200 °C. Hot mill gloves used with boat handling tool to remove boat from furnace. By procedure, boat is left on boat stand to cool for one hour before being handled by glove.	S1	F3	None
E.4.02	Remove boat from furnace and let cool for one hour on boat stand.	Glovebox fire or radiant heat damage to glovebox confinement boundary	Door opened during heating cycle to remove boat	Radiant heat from coils melts gloves and burns operator, softens and potentially ignites glovebox panels Potential activation of glovebox dry fire suppression system (Halon system). Potential ignition of combustibles in glovebox. Release of Pu to room air and uptake by workers.	Furnace interior temp indication Glovebox (E-4) ventilation system maintains negative pressure and confinement velocity across hole in glove. Door/power interlock shuts off power to furnace coil when furnace door opened, minimizing radiant heat on gloves and glovebox panels. Furnace thermocouples and chart recorder indicate when it is safe to open furnace door.	Operators trained not to remove boat from furnace or to open furnace door until temperature has dropped below 200 °C. Combustible loading in glovebox is controlled.	S1* S1	F2 F2	Each furnace produces about 1800 W of heat. From the PFP FHA, a 34 kW/m^2 heat flux is sufficient to ignite a polycarbonate panel in 10 minutes. S1*/F2 for glovebox fire S1/F2 for softening of panels or failure of port bags.

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
E.5.01	Place cover on boat and transfer boat to Glovebox HC-18BS through Conveyor Glovebox	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped off conveyor Air supply to RMC line blows powder out of boat near Glovebox HC-18BS.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred with a "boat cover" which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	S0	F3	None
E.6.01	CO_2 supply system	Leak of CO_2 from liquid cylinder or transfer line	Handing accident, overpressurization, cylinder or line failure, PRV failure	Potential cryogenic burns to operators. Potential asphyxiation hazard	Cylinder restrained within storage cabinet. Ring at top of cylinder protects valve connections Cylinders vent approximately 2lb of CO_2 per days via PRV to reduce pressure build-up Room ventilation dilutes CO_2	Procedure governing transportation and storage of cylinders	S1	F2	None

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
F. Activities in Glovebox HC-18BS									
F.1.01	Transfer boats on surpentine conveyor to Glovebox HC-18M for LOI testing	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped off conveyor.	Added dose to workers in recovering from spill. Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack. Conveyor has special pedestals to hold furnace boats	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations. Boat is transferred with a □boat cover□ which limits the potential for Pu oxide dispersal from the RMC line supply air or dispersal should the boat tip over on the conveyor.	S0	F3	None
F.2.01	Temporarily store cans containing Pu oxide pending results of LOI tests in Glovebox HC-18M	Violation of criticality safety mass limit, loss of contingency	Too many containers stored too close together. Failure to adhere to glovebox postings. See item A.2.01.	see item A.2.01	see item A.2.01	see item A.2.01	□	□	--

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
G. Activities in Glovebox HC-18M									
G.1.01	Take cover off boat, weigh boat, and transfer material into sieve tray	Spill/dispersal of Pu oxide powder in glovebox	Furnace boat dumped or material spilled while transferring contents into sieve tray.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	S0	F3	No hazards identified for weighing step. Pu Accountability error only.
G.2.01	Place cover on sieve tray and turn on shaker	Dispersal of Pu oxide powder in glovebox .	Cover left off sieve tray while shaker on produces dust that spreads Pu throughout glovebox.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	S0	F3	None

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
G.3.01	Remove sieve tray(s) from shaker, remove pieces too large to fit through sieve (> 4 mesh) and grind using mortar and pestle for reprocessing through furnace, transfer contents that passed through sieve (< 4 mesh) to product can.	Spill/dispersal of Pu oxide powder in glovebox	Material spilled while transferring contents into product can.	Increased direct dose to workers working near glovebox due to increase in contamination level of glovebox.	Glovebox confinement boundary and E-4 ventilation system confine release. E-4 HEPA filters mitigate release to the environment through the 291-Z exhaust stack.	Housekeeping practices: spilled material is swept up, placed in cans, and sealed out of glovebox to minimize direct dose to workers. Institutional radiation protection program: radiological control technicians set glovebox dose rates to limit worker direct dose exposure. Operators verify glovebox DP and filter DP during pre-job walkdown which ensures the E-4 ventilation system is operating properly before initiating operations.	S0	F3	No hazards identified for weighing step. Pu Accountability error only.
G.3.02	Remove sieve tray(s) from shaker, remove pieces too large to fit through sieve (> 4 mesh) and grind using mortar and pestle for reprocessing through furnace, transfer contents that passed through sieve (< 4 mesh) to product can.	Pu metal added to product can causing rupture of container in storage vault.	Material not heated long enough or at high enough temperature in furnace to completely oxidize metal due to furnace failure or failure of furnace temperature controller. Sieve and size reduction step skipped due to human error results in metal pieces not being detected. Metal pieces not removed from oxide material before transferring material to product can.	Rupture of container in storage vault due to the formation of Pu oxide (assuming storage cans is not airtight). PuO_2 is less dense and takes up more volume than metal causing can rupture. Contamination of vault air. Potential uptake by workers on entry into vault. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verify proper furnace operation and soak time.	Operator training and procedures Radiological control program: Routine sampling of vault air. Oxide known be generated by button burning is recycled by procedure Shift technical advisor sign off required by procedure.	S1*	F2	None

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
G.3.03	Remove sieve tray(s) from shaker, remove pieces too large to fit through sieve (> 4 mesh) and grind using mortar and pestle for reprocessing through furnace, transfer contents that passed through sieve (< 4 mesh) to product can.	Non-representative sample taken from product can for LOI testing.	Material not heated long enough or at high enough temperature to be adequately stabilized due to furnace or temperature controller failure. Material not sieved or ground properly. Large (> 4 mesh) agglomerations of PuO_2 can give false high or false low LOI readings depending on furnace operation and how long the sample was exposed to humid air after removal from the furnace.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verify proper furnace operation and soak time	Operator training and procedures Radiological control program: routing sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	S1*	F2	None
G.4.01	Take 5 to 10 g sample for LOI test and perform LOI test	□Wet□ oxide transferred to product can and stored in vault, resulting in rupture of container in vault.	Material not stabilized long enough or at high enough temperature in furnace due to temperature controller or furnace failure. LOI test fails to detect inadequate stabilized material due to non-representative sample being taken (see above) or material canned without benefit of LOI testing due to human error. Or LOI test results or can labels mixed up resulting in wrong can being authorized for storage in vault.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Furnace chart recorder readings are used to verify proper furnace operation and soak time	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being recanned even if undetected furnace upset occurs.	S1*	F2	Oxidation of U can mask loss of water (due to U going to higher oxidation state) such that analysis may be indicate less than 5% LOI when it is actually greater.

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
G.5.01	If material found to contain greater than 0.5 wt% water by LOI test, reprocess material through furnace and repeat LOI testing.	"Wet" oxide transferred to product can and stored in vault, resulting in rupture of container in vault.	Inadequately stabilized material not run back through the furnace due to human error.	Rupture of container in storage vault due to presence of excess water in product can. PuO_2 reacts with water to form a binary oxide and hydrogen gas, which can overpressure the storage container. Contamination of vault air and potential inhalation uptake by workers entering vault.	Vault ventilation system and HEPA filters mitigate release to the environment. Pedestals in vault are instrumented to detect bulging cans. CAMs in vault alert workers to airborne contamination. Thermocouples monitor furnace temperature. Temperature is recorded as a function of time using a chart recorder. The chart recorder readings reveal furnace upsets that could result in moisture not being adequately driven off the oxide product.	Operator training and procedures. Radiological control program: Routine sampling of vault air. Blend plan identifies material processed in this campaign to be previously stabilized oxide material, minimizing likelihood of material containing excess moisture from being re-canned even if undetected furnace upset occurs. Furnace chart recorder readings are used to verity proper furnace operation and soak time	S1*	F2	None
G.6.01	Temporarily store Pu oxide material in product cans in Glovebox HC-18BS pending results of LOI testing.	Covered in items F.1.01 and F.2.01	Covered in items F.1.01 and F.2.01	Covered in items F.1.01 and F.2.01	Covered in items F.1.01 and F.2.01	Covered in items F.1.01 and F.2.01	–	–	Covered in items F.1.01 and F.2.01
G.7.01	Bag out of sample bottles from Glovebox HC-18M for transfer to the lab for LOI analysis Bag out of product cans from Glovebox HC-18MM or HC-1 in Room 228A for transfer to storage vault.	Breach in glovebox confinement boundary during waste bagout, bag change, or glove change.	Bag punctured by sharp object Bag not properly horsetailed or taped Bag inadvertently pulled off port Original or replacement bag glove tears Bungee chord used to hold replacement bag slips or fails while removing inner (original) bag Replacement glove inadvertently pull off lip of port Bag/glove pinched when tightening port ring Replacement bag/glove has undetected hole in it	Spread of contamination to room, external contamination of workers, and potential inhalation uptake by workers.	Glovebox (E-4) ventilation system maintains glovebox negative pressure and confinement velocity across small holes; minimizes potential spread of contamination from glovebox Glovebox port designed to minimize likelihood of loss of confinement during bag changes (notches, ridges to facilitate, 2 bags or gloves)	Workers wear respirators, during bag out of waste, bag/glove changes Room put on ARA status during bagouts, bag changes, glove changes. Operator certification.	S1	F3	By moving items down HC-1 conveyor to Room 228A for seal out, only Room 228A would be placed on mask such that primary thermal stabilization processing areas (Rooms 230A, B, and 228C) do not need to be put on mask.

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
G.7.02	Bag out of sample bottles from Glovebox HC-18M for transfer to the lab for LOI analysis Bag out of product cans from Glovebox HC-18M for transfer to storage vault.	Pu release from sample bottle or product can after bagout	Sample bottle or product can dropped after bagout causing bottle to break or slip lid to come off and bag to rupture.	Contamination of workers and potential uptake of radiological material	E-3 ventilation system filters mitigate release to environment should material be release to Zone 3 area. Room CAMs alert workers to airborne contamination.	Operator training and procedures Radiological control program. Alpha contamination survey to detect contamination spill. Worker decontamination by RCT if necessary. Bagged sample bottles are placed in ice cream carton and then in special wagon for transport to the analytical lab. Carton reduces chances of airborne release in a drop. Product cans are heat sealed in a polyethylene bag in the process of being sealed out of the glovebox. Taped slip lid can and double bag minimize the likelihood of a release should the container be dropped.	S1	F3	None
H. Natural Phenomena									
H.1.01	Plutonium feed material being thermally stabilized.	Seismic event causes fire or explosion and stagnant glovebox.	Seismic event results in loss of electrical power and potentially a loss of ventilation. Loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Seismic ventilation supply shutdown switch. Building structure.	Emergency procedures for evacuation.	S1*	F2	S1*/F2 based on seismic initiator frequency. F2 frequency assumed to be on the low side of the range.
H.1.02	Plutonium feed material in any unconfined state in gloveboxes	Seismic event causes dispersal of plutonium oxide powder in glovebox.	Seismic event results in dispersal of plutonium oxide powder into glovebox atmosphere.	Potential additional exposure to workers due to cleanup requirements.	Seismic ventilation supply shutdown switch. Building structure Glovebox structure	Emergency procedures	S1*	F2	S1*/F2 based on seismic initiator frequency. F2 frequency assumed to be on high side of range for events that do not fail glovebox.
H.1.03	Plutonium feed material in any unconfined state in gloveboxes	Seismic event causes criticality.	Seismic induced failure of Gloveboxes results in accumulation of a critical mass of Pu.	Worker exposure to ionizing radiation and fission product gasses	Glovebox HC-4 and HC-18BS seismically qualified.	CSER controls on mass of Pu in Gloveboxes. CPS Posting on Glovebox operator training.	S1*	F2	S1*/F2 based on seismic initiator frequency. F2 frequency assumed to be on the low side of the range.
H.2.01	Plutonium feed material being thermally stabilized.	NPH - Ash Fall	None	Ash Fall represents a roof loading concern, abrasive concern for	None	None	None	None	None

Table 9G.2. PHA – Thermal Stabilization of Non-Product Quality Oxide Feed Material

Item #	Process Step/ Equipment	Failure/ Hazardous Condition	Causes	Consequences	Existing Engineered Features	Existing Administrative Controls	Cons Rank	Freq Rank	Comments
	thermally stabilized.			moving equipment, and an electrical concern because of the conductivity of the ash.					
H.3.01	Plutonium feed material being thermally stabilized.	NPH - High Wind	None	High Wind represents a threat to the 234-5Z Building but not to an individual glovebox inside the building. Chapter 9.0 of the PFP FSAR considers the effect of a wind-driven plank striking the 234-5Z Building and concludes that no significant consequences result.	None	None	None	None	None
I External Events									
I.1.01	Plutonium feed material being thermally stabilized.	Facility wide external loss of power with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in Glovebox HC-21C.	External event causes facility wide loss of power resulting in loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Building structure. Backup ventilation system connected to emergency.	Emergency procedures	S1*	F1	F1 frequency considers negative specific sequencing of events.
I.2.01	Plutonium feed material being thermally stabilized.	Facility wide loss of power due to range fire with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in Glovebox HC-21C.	Range fire causes facility wide loss of power resulting in loss of airflow in muffle furnace combined with material in furnace boat that produces ethylene gas. Spark source assumed present.	Damage to glovebox confinement with release of plutonium oxide to facility. Potential contamination of workers and uptake of radiological material.	Building structure.	Emergency procedures Vegetation control programs	S1*	F1	This is not a threat to the 234-5Z building due to the large open areas that are kept clear of vegetation or combustible material buildup.
I.3.01	Plutonium feed material being thermally stabilized.	Aircraft crashes into facility causing fire and loss of confinement. (General to all gloveboxes)	Pilot error or mechanical failure	Significant release of material		Controls preventing overflight of facility	S1*	F0	This event is considered to be beyond extremely unlikely in the PFP FSAR and therefore is not being considered for further analysis.

Table 9G.3. Contaminated Wound

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.2.02	Operator injury in Glovebox HC-21A.	S1	F3
C.2.04	Operator injury in Glovebox HC-21A.	S1	F3
C.4.01	Operator injury in Glovebox HC-21A.	S1	F3
CC.2.0.1	Operator injury in Glovebox HC-21A.	S1	F3
CC.5.02	Operator injury in Glovebox HC-21A.	S1	F3
E.2.01	Operator injury in Glovebox HC-21C.	S1	F3

Table 9G.4. Criticality*

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
A.2.01	Violation of criticality safety mass or spacing limit results in loss of contingency.	S1*	F2
B.1.02	Violation of mass or spacing limits, loss of contingency.	S1*	F2
B.2.02	Violation of spacing limits, loss of contingency.	S1*	F2
C.2.03	Outer cans not properly made into non-container, loss of contingency.	S1*	F1
CC.5.01	Polyjar or slip-lid can not properly made into non-container, loss of contingency.	S1*	F1
F.2.01	Violation of criticality safety mass limit	S1*	F2
G.6.01	Violation of criticality safety mass limit	S1*	F2

Criticality Safety Evaluation Reports identify controls providing double contingency protection against accidental nuclear criticality. Loss of a single contingency does not result in a criticality, i.e., does not result in S1 consequences.

Table 9G.5. Dispersal of Pu Inside Glove Box

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
BB.1.01	Polyjar crumbles in worker hands during handling or is damaged in drop or by conveyor malfunction.	S0	F3
C.4.03	PuO_2 particulate release from pressurized can when it is opened in Glovebox HC-21A	S0	F3
C.5.02	Can/boat contents spilled to Glovebox HC-21A	S0	F3
CC.3.01	Polyjar or slip-lid can contents spilled to glovebox floor	S0	F3
D.1.02	Spill/dispersal of Pu in Glovebox HC-2	S0	F3
E.1.01	Spill/dispersal of Pu in Glovebox HC-21C	S0	F3
E.5.01	Spill/dispersal of Pu in Glovebox HC-21C	S0	F3
F.1.01	Spill/dispersal of Pu oxide powder in Glovebox 18-BS	S0	F3
G.1.01	Spill/dispersal of Pu oxide powder in Glovebox HC-18M	S0	F3
G.2.01	Dispersal of Pu oxide powder in Glovebox HC-18M.	S0	F3
G.3.01	Spill/dispersal of Pu oxide powder in Glovebox HC-18M	S0	F3
G.6.01	Spill/dispersal of Pu oxide powder in Glovebox HC-18M	S0	F3

Table 9G.6. Dispersal of Pu Outside Glove Box

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.7.02	Spread of contamination from waste bag during bagout of waste from Glovebox HC-21A	S1	F3
CC.6.01	Spread of contamination from waste bag during bagout of waste from Glovebox HC-21A	S1	F3
G.7.02	Pu release from sample bottle or product can after bagout from Glovebox HC-18M	S1	F3

Table 9G.7. Dropped Containers Outside Glove Box

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
B.1.01	Drop of Pu storage container during handling.	S0	F3
B.2.01	Breach of container	S0	F3
C.1.01	Drop of Pu storage container outside glovebox during seal in.	S0	F3

Table 9G.8. External Events

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
I.1.01	Facility wide loss of power with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in Glovebox HC-21C.	S1*	F1
I.2.01	Facility wide loss of power due to range fire with subsequent return of power causes flammable gas deflagration in or around stabilization furnace in Glovebox HC-21C.	S1*	F1
I.3.01	Aircraft crashes into facility causing fire and loss of confinement. (General to all gloveboxes)	S1*	F0

Table 9G.9. Flammable Gas Deflagration in Glove Box

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.2.01	Flammable gas (i.e. H_2) release and burn when overpack can opened in Glovebox HC-21A.	S1	F2
C.4.02	Hydrogen gas release and burn when can opened in Glovebox HC-21A.	S1	F2
C.4.04	Flammable gases (alkanes, H_2, etc) from organic in container released and ignited when can opened (can pressurized) in Glovebox HC-21A.	S1	F2
C.6.01	Flammable gas deflagration due to plastic contaminants not identified or removed from oxide that result in reaction hazards in Glovebox HC-21C furnaces. Contaminants can include tool handles, brush bristles, PVC or polyethylene bag fragments, polycarbonate pieces, etc.	S1*	F2

Table 9G.9. Flammable Gas Deflagration in Glove Box

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
CC.2.02	Hydrogen gas release when polyjar or slip-lid can opened	S1	F1
CC.3.01	Flammable gas above LEL	S1*	F2
CC.4.01	Contaminants not identified or removed from feed results in reaction hazard in Glovebox HC-21C furnaces.	S1*	F2
E.2.02	Buildup of flammable gasses	S1*	F2
E.2.03	Buildup of flammable gasses	S1*	F3
E.2.04	No CO_2 purge during sludge processing	S1*	F2
E.3.01.b	Temperature ramped up to fast, no dwell times.	S1*	F3
E.3.02.b	Reduced air flow or no air flow during stabilization of material in furnace.	S1*	F3
E.3.04	Plastic contaminants in Pu oxide feed result in fire/deflagration in stabilization furnace in Glovebox HC-21C.	S1*	F2

Table 9G.10. Flammable Gas Deflagration in Waste Drum

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.7.03	Hydrogen venting or deflagrating inside waste drum in 234-5Z satellite accumulation area.	S1	F2
CC.6.01	Hydrogen venting or deflagrating inside waste drum in 234-5Z satellite accumulation area.	S1	F2

Table 9G.11. Loss of Glovebox Confinement Due to Mechanical Breach

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
A.1.03	Hole in glovebox confinement boundary leads to spread of contamination from glovebox (general glovebox hazard).	S1	F3
A.1.04	Breach in glovebox confinement boundary during waste bagout, port bag replacement, or glove change (general glovebox hazard).	S1	F3
C.1.03	Glovebox HC-21A loss of confinement during seal in.	S1	F3
C.2.02	Damage to glovebox glove compromising Glovebox HC-21A confinement integrity.	S1	F3

Table 9G.11. Loss of Glovebox Confinement Due to Mechanical Breach

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.2.04	Damage to glovebox glove compromising Glovebox HC-21A confinement integrity.	S1	F3
C.4.01	Damage to glovebox glove compromising Glovebox HC-21A confinement integrity.	S1	F3
C.6.01	Breach in Glovebox HC-21A confinement boundary during waste bagout or glove change.	S1	F3
CC.2.01	Damage to glovebox glove compromising Glovebox HC-21A confinement.	S1	F3
CC.6.01	Breach in Glovebox HC-21A confinement boundary during waste bagout or glove change.	S1	F3
D.1.01	Glove damaged during conveyor operation compromising Glovebox HC-2 confinement	S1	F3
E.2.01	Glove damage during load in/ load out of the stabilization furnaces in Glovebox HC-21C.	S1	F3
E.2.05.a	Breach in Glovebox HC-21C confinement boundary during bagout of combustibles or while withdrawing gloves from glovebox.	S1	F3
E.2.06	Gloves melted by contact with furnace compromising Glovebox HC-21C confinement.	S1	F3
E.3.02.a	Reduced air flow or no air flow during stabilization of material in furnace in Glovebox HC-21C.	S1	F3
E.4.01	Glove damage/operator burn in Glovebox HC-21C	S1	F3
E.4.02	Glovebox fire or radiant heat damage to Glovebox HC-21C confinement boundary.	S1	F2
G.7.01	Breach in Glovebox HC-18M confinement boundary during waste bagout, bag change, or glove change.	S1	F3

Table 9G.12. Loss of Glovebox Confinement Due to Ventilation Failure

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
E.3.03	Overheating of Glovebox HC-21C.	S1	F3
A.3.01	Pressurized glovebox during operations causes spread of contamination from glovebox (general glovebox hazard)	S1	F2
A.3.01	Stagnant glovebox during operations causes spread of contamination from glovebox (general glovebox hazard).	S1	F3

Table 9G.13. Natural Phenomena

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
H.1.01	Seismic event causes criticality, explosion or fire and stagnant glovebox. (General to all gloveboxes)	S1*	F2
H.1.02	Seismic event causes dispersal of plutonium oxide powder in glovebox. (General to all gloveboxes)	S1*	F2
H.1.03	Seismic event causes criticality	S1*	F2
H.2.01	Natural Phenomena - Ash Fall	None	None
H.3.01	Natural Phenomena - High Wind	None	None

Table 9G.14. Occupational Hazards

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
A.1.02	Electrical shock to operator while working in Glovebox HC-21A	S1	F3
E.6.01	Leak of CO_2 from liquid cylinder or transfer line	S1	F2

Table 9G.15. Operational Upset

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
E.3.01.a	Stabilization furnace temperature ramped up too fast (temperature controller fails high) resulting in furnace failure in Glovebox HC-21C and process upset.	S0	F3
E.3.01c	Temperature ramped up too fast, no dwell times	S0	F3
E.3.02c	Excessive airflow through furnace in Glovebox HC-21C resulting in elevated particulate release to vacuum system causes process upset.	S0	F3
E.3.02d	Unfiltered flow through/around ceramic filter in Glovebox HC-21C results in operational upset.	S0	F3
C.5.03	Material other than Pu oxide poured into furnace boat in Glovebox HC-21A (e.g., metal button, sludge or glovebox floor sweeps) resulting in process upset.	S0	F2
E.3.06	Pu fluoride powder processed through furnace causes corrosion damage to furnace in Glovebox HC-21C results in operational upset..	S0	F2

Table 9G.16. Pyrophoric Reaction in Furnace

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
E.3.05	Metal contaminant in feed results in pyrophoric reactions in the furnace in Glovebox HC-21C.	S1	F3
C.6.01	Contaminants not identified or removed from oxide result in reaction hazards in Glovebox HC-21C furnaces.	S1	F2
CC.4.01	Contamination not identified and removed from feed results in reaction hazards in Glovebox HC-21C furnaces.	S1	F2

Table 9G.17. Pyrophoric Reaction in Glovebox

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.5.01	Pyrophoric reaction as material poured through air in Glovebox HC-21A.	S1	F2
C.4.05	Pyrophoric reaction and hydrogen burn when can opened in Glovebox HC-21A.	S1	F3

Table 9G.18. Radiation Protection

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
C.1.02	High worker direct dose during handling of cans in Glovebox HC-21A.	S1	F3
CC1.02	High worker direct dose during handling of cans in Glovebox HC-21A.	S1	F3

Table 9G.19. Rupture of Container In Storage Vault

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
E.3.01.d	Inadequate stabilization of material in Glovebox HC-21C furnace leads to rupture of container in storage vault.	S1	F2
G.3.03	Non-representative sample taken from product can for LOI testing in Glovebox HC-18M.	S1	F2
G.4.01	"Wet" oxide transferred to product can in Glovebox HC-18M and stored in vault, resulting in rupture of container in vault.	S1	F2
G.5.01	"Wet" oxide transferred to product can in Glovebox HC-18M and stored in vault, resulting in rupture of container in vault.	S1	F2
G.3.02	Pu metal added to product can in Glovebox HC-18M causing rupture of container in storage vault.	S1	F2

Table 9G.20. Uncontrolled Fire in Glovebox

Item #	Failure/ Hazardous Condition	Cons Rank	Freq Rank
A.1.01	Fire in glove box HC-21A caused by electrical short.	S1*	F3
BB.1.02	Airlock between conveyors HC-2 and HC-3 left open, diminishes effectiveness of Halon system, loss of fire separation.	S2	F1
C.4.05	Pyrophoric reaction and hydrogen burn when can opened which ignites combustibles in Glovebox HC-21A.	S1*	F2
E.2.05.b	Fire in glovebox compromises Glovebox HC-21C confinement.	S1*	F2
E.4.02	Glovebox fire or radiant heat damage to Glovebox HC-21C confinement boundary.	S1*	F2
C.5.01	Pyrophoric reaction as material poured through air in Glovebox HC-21A.	S1*	F3

APPENDIX 9H

Hazards Evaluation of Plutonium Metal Opening and Stabilization

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HAZARDS EVALUATION OF PLUTONIUM METAL OPENING AND STABILIZATION

9H.1 INTRODUCTION

A Hazards Evaluation (HE) was done for the opening of containers of Pu metal, conversion of the metal and corrosion products to plutonium oxide product, and sampling, testing and packaging the product. Hazards evaluation is the analysis of the significance of hazardous situations associated with an activity or process. The HE used the qualitative techniques of Hazard and Operability (HazOp) analysis and What-If analysis to identify those elements of handling and thermal stabilization processing that could lead to accidents

9H.2 METAL OPENING AND STABILIZATION ACTIVITY ANALYZED

9H.2.1 Operations in Glovebox 636

The following is a sequential listing of the metal opening operations that will normally be done in the 636 Glovebox. These steps were identified during the HE team meetings and are the substance of the activity rather than the final procedural form and format. These are the steps that are identified in the HE worksheets with an "OM" identifier in the "Node ID" column.

1. Segregate, remove or minimize all combustibles to far end of glovebox.

2. Inspect outermost can to determine if it's a suspect (bulged, paneled, weight gained) can.

3. If suspect, punch can and wait until no further obvious reactions ongoing.

4. Open can with can opener.

5. If lid falls in can, remove lid from can with dulled screwdriver or tweezers.

6. Inspect material within can.

7. If contents are another can, go to step 2.

8. If contents are burning product, place slip-lid on top of product can. (may curtail operations until burning stops) -Seal it into a slip-lid can, bag it out, can it, and transfer it directly to Glovebox HC-21A to be thermally stabilized.

9. If contents appear to be normal product, pour contents into open container (tray, boat, can).

10. Separate corrosion products from metal:

    a. brush whole, stable button with bristle brush

b. move clean stable button to a new can.

11. If contents are not a whole, stable button (per STA/Operator decision); re-can for transfer to Glovebox HC-21A.

12. When a maximum of 200 g of brushings have accumulated, can and transfer to Glovebox HC-21A.

Note: differences in operation in this GB636 & Glovebox HC-21A - 636 handles it more, no canning in Glovebox HC-21A, when opened in Glovebox HC-21A, it's poured into a boat, then conveyed to Glovebox HC-21C & thermally stabilized, and conveyed to and finally canned in GB18M.

9H.2.2 Subsequent stabilization operations in Gloveboxes HC-21A, HC-21C, and HC-18M

The following is a sequential listing of the metal opening operations that will normally be done in the Glovebox HC-21A. These steps were identified during the HE team meetings and are the substance of the activity rather than the final procedural form and format. These are the steps that are identified in the HE worksheets with an "TS" identifier in the "Node ID" column.

1. Seal-in Pu container into Glovebox HC-21A, weigh Pu container, and furnace boat for Pu material accountability purposes.

2. Punch suspect (bulged or paneled) outer containers to relieve pressure or vacuum (typically performed in GB636).

3. Open Pu containers (includes punching and opening, if necessary, of overpack containers and inner container of Pu metal).

4. Remove materials (maybe corrosion products, metal or any combination of both) from containers and place in furnace boat.

5. Transfer furnace boat with boatcover to HC-2. Bag-out empty cans, plastic bags and tape as needed.

6. Transfer furnace boat with cover from Glovebox HC-21A to Glovebox HC-21C via conveyor or passed by hand via conveyor glovebox.

7. Remove the boatcover from the furnace boat, place boat in the furnace and operate the furnace.

8. At the end of the cool down cycle, open furnace and remove boat. After further cooling, inspect for degree of stabilization and reprocess as necessary.

9. Upon completion of stabilization and cool down, transfer furnace boat to HC-18M via HC-2 for sieve/grinding, place in can and sample.

10. Transfer can to Glovebox HC-18BS for interim storage pending sampling results.

11. If the sample passes LOI, transfer to HC-18M, bag-out and can. If the sample does not pass LOI, return material to Glovebox HC-21A for reprocessing.

In addition to the above operations, the relevant utilities associated with the plutonium metal stabilization process were examined. The specific utilities evaluated were the glovebox fire suppression system, the E-4 ventilation system that exhausts the gloveboxes, the power supply to the RMC Line equipment, and the 26-inch-Hg vacuum system that exhausts the muffle furnaces in Glovebox HC-21C.

9H.3 HAZARD EVALUATION METHODLOGY

The HE process is one that employs a systematic approach in the identification of hazards associated with a system, or process. The process is one in which the system or process is broken down into its basic elements and the hazards associated with each element are identified. Potential causes of those hazards are determined, potential consequences estimated and evaluated and possible corrective and/or preventative measures are considered. The HE was developed using a table to guide and record the results of a What-If brainstorming process. The What-If technique was combined with Hazard and Operability analysis system of using guidewords in conjunction with process parameters or procedure activities to arrive at an unintended deviation. By this method, structure was given to the otherwise unstructured What-If analysis technique. This guided What-If brainstorming was performed by individuals with detailed knowledge of the system or processes being examined, and was supported by a multi-disciplinary team familiar with the operation. A detailed discussion of the HE techniques of HazOp analysis and What-If analysis can be found in *Guidelines for Hazard Evaluation Procedures* (AIChE 1992).

The purpose and contents of each column in the HE sample table, Table B-1, are described in detail in the following paragraphs.

Column 1, Node ID: This column provides an alpha-numeric identifier for each hazard postulated in the table. The identifier is primarily used for cross-referencing within the table and as an identifier for accident sequences.

Column 2, Step #: The step or steps involved in performing each set of operations is identified in this column

Column 3, "What-If" question: The deviation from the intended action put in the form of a "what if" question. The questions being generated using a set of deviation guide words. The deviation guides are the same as those used in a HazOp analysis.

Column 4, Consequence: Both the immediate and ultimate consequence of the activity/operational "What-If" deviation that could result are recorded in this column

Column 5, Causes: This column identifies the causes for both the What-If and the ultimate accident sequence conclusion.

Column 6, Engineered Safety Feature(s) for "What-If" and Accident: This column identifies the engineered features (hardware items) intended or available to prevent or mitigate the consequences identified in Column 4.

Column 7, Administrative Safety Feature(s) for "What-If" and Accident: This column identifies the administrative requirements that reduce the likelihood of both the What-If event (if applicable) and the Accident event consequences identified in Column 4, or that help minimize the potential consequences of the Accident event

Column 8, Consequence Category: This column is used to capture a code designator for the level of consequence associated with a hazardous event. The consequence ranking is the initial, qualitative estimate of the safety severity of the consequences. An alpha-numeric system has been used at the PFP to designate the severity of hazardous events. The system has the following "S" rankings characterizing safety consequences:

S0 No effect outside the glovebox confinement systems; negligible safety concerns for the facility worker.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker

S1* Potential severe harm or potential death from industrial injury, radiological dose or chemical exposure to the facility worker

S2 Potential significant radiological dose consequences or chemical exposure to onsite workers located outside the facility

S3 Potential significant radiological dose consequences or chemical exposure to the offsite population

Column 9, Frequency Ranking: This column shows the estimated frequency of occurrence. The frequency ranking is a first cut, qualitative estimate of the likelihood of the hazardous event. The following ranking system is used.

F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is 1E-02/yr to 0.1/yr.

F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1E-04/yr to 1E-02/yr.

F1 Events not expected to occur during the lifetime of the facility categorized as "extremely unlikely." The frequency range associated with this category is 1E-06/yr to 1E-04/yr.

F0 Events categorized as "beyond extremely unlikely," with a frequency less than 1E-06/yr. Events in this category (such as meteor strike) are so unlikely they generally do not require special controls.

The frequency estimate, like the consequence ranking, is assigned taking no credit for active engineered features.

Column 10, Remarks: This column contains miscellaneous observations or clarifying comments for a given hazard.

9H.4 HAZARDS EVALUATION WORKSHEET ORGANIZATION

The HE table structure used in this analysis is provided in Table 9H-T-1. The HE table is structured to ensure a systematic and thorough review of potential hazards. The thermal stabilization of metal and metal corrosion products is broken down into logical sets of operations performed at specific locations. The operational steps covered in the analysis were identified from verbal descriptions provided by the cognizant engineers and other available information and were identified in section 9H.2.

9H.5 REFERENCES

AICHE, 1992, *Guidelines for Hazard Evaluation Procedures*, American Institute of Chemical Engineers, New York, New York.

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Table 9H.1. Hazards Evaluation Worksheet Form

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq. Cat	Remarks

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Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Hazards Evaluation Team: R.B. Gelman, E.P. Bonadie, T.D. Cooper, E.E. Wallace, E.L. Kauer, H.R. Risenmay, C.A. Carro, R.M. Marusich, D.A. Clapp, Leader, D.M. Carson Scribe
Date Hazards Evaluation Conducted: 9 June 1999

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else

Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-1a	1	What if combustibles not segregated or removed before operations begin?	Increased severity of fire due to higher combustible loading. Accident: fire initiated by sparks from opened can.	Poor housekeeping.	WI: None. A: Bayonet-equipped fire extinguishers; in-glovebox fire extinguisher with quick-disconnect (636); MgO sand; Halon (21A);.	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F3 A: F2	Credit taken for SC ventilation HEPA filters. Frequencies are given with controls in place.
OM-1b	1	What if combustibles generated during operations not segregated or removed?	Increased severity of fire due to higher combustible loading. Accident: fire initiated by sparks from opened can.	Poor housekeeping.	WI: None. A: Bayonet-equipped fire extinguishers; in-glovebox fire extinguisher with quick-disconnect (636); MgO sand; Halon (21A);.	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F3 A: F2	
OM-1c	1	What if combustibles segregated but never removed before operations begin?	Increased severity of fire due to higher combustible loading. Accident: fire initiated by sparks from opened can.	Poor housekeeping.	WI: None. A: Bayonet-equipped fire extinguishers; in-glovebox fire extinguisher with quick-disconnect (636); MgO sand; Halon (21A);.	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F2 A: F1	
OM-1d	1	What if unused gloves are not pulled out from glovebox before operations begin?	Breach of glove with subsequent spread of contamination. A: fire initiated by sparks from opened can.	Human Error	WI: none. A: gloves are self-extinguishing; Room CAMs; Halon system sends fire Alarm (21A); room fire suppression	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F3 A: F2	Check for 636 fire detection/Alarms.
OM-2	2	What if we did not inspect a can?	See Remarks	See Remarks	See Remarks	See Remarks			Consequences determined by step 3.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else

Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-3a	3	What if we just opened a bulged suspect can without punching it first?	Release of Hydrogen from can A: Ignition of Hydrogen released from can.	See Remarks	See Remarks	See Remarks	WI: S A: S	WI: F A: F	Release and ignition of Hydrogen from a can is covered in Thermal Stabilization Addendum and in Rev. 1 to the PFP FSAR. Not a unique hazard to this operation.
OM-3b	3	What if we just opened a paneled suspect can without punching it first?	Increased reaction rate of contents (hydrides) A: "Sparky": (1) provides ignition source for combustibles in glovebox; (2) pressurization of glovebox; (3) provides increased particulate into glovebox.	Human error.	WI: none. A: (1) same as fire (2) ventilation system (3) glovebox containment	WI: Procedure compliance; training. A: (1) same as fire (2) none (3) none	WI: S0 A: 1)S1 2)S0 3)S0	WI: F3 A: 1)F3 2)F3 3)F3	Hydride bounds. To cause a fire, combustibles must be present. Calculations show that pressurization and particulate events are inconsequential.
OM-3c	3	What if we just opened a "weight-gain" suspect can without punching it first?	Bounded by OM-3b. A:	See Remarks	See Remarks	See Remarks	WI: S A: S	WI: F A: F	Normally, a leak of air into a can will result in formation of PuO2; however, if the leak is very, very small, reactive materials could still be present. Reactivity of materials is bounded by Pu hydride case, above.
OM-4a	4	What if typically-seen very fine dust coming from opened can is Pu hydride?	Powder will rapidly react in air – "Sparky". A: See OM-3b.	See OM-3b.	See OM-3b.	See OM-3b.	WI: S0 A: 1)S0 2)S0 3)S0	WI: F3 A: 1)F3 2)F3 3)F3	Essentially the same as OM-3b.
OM-4b	4	What if typically-seen very fine dust coming from opened can is non-reactive Pu compounds? (e.g., oxide)	Increased holdup in glovebox; higher dose rate.	See Remarks	See Remarks	See Remarks	S0	F3	Judged to be inconsequential.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else

Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-4c	4	What if the inmost can is turned upside-down, agitated, dropped, turned sideways, etc., before being opened?	Suspension of more particulate, which may escape and react – "Sparky". A: See OM-3b.	See OM-3b.	See OM-3b.	See OM-3b.	WI: S0 A: 1)S0 2)S0 3)S0	WI: F3 A: 1)F3 2)F3 3)F3	Calculations show ~ 0.75 g could be released from a pressurized can; this amount will likely be less than that.
OM-5	5								Inconsequential
OM-6a	6	What if the contents are not inspected before being dumped, and the material is burning?	Larger surface area available for reaction, greater exposure to oxygen. A: Fire in glovebox, assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	Single container will not contain more than 200 g of Pu hydride, and this quantity of hydride reacting anywhere in the glovebox is not enough to pressurize glovebox. This can be proven scientifically within a can, and by ~50 years of processing experience for outside the can, in the glovebox. (See Thurman for details). This is the highest likelihood for a fire in the glovebox – lots of glowing, burning, sparking material spread around.
OM-6b	6	What if foreign (e.g., aluminum foil) material is in the can?	WI: none A: foreign material trapping corrosion products and igniting while it is mixed with combustibles and causing a glovebox fire	WI: foreign material originally packaged with Pu metal	WI: none A: See OM-1a.	WI: none A: See OM-1a.	See OM-1a.	See OM-1a.	It is not anticipated that foreign materials will be present.
OM-7	7								Nothing to evaluate.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else

Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-8a	8	What if we do not place a slip-lid on top of a can full of burning material?	Continues to burn; source of ignition for combustibles. A: Fire in glovebox, assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	We don't expect to see fast-burning, high-temperature buttons, as we don't have enough hydride to do that. Calculations exist to verify that.
OM-8b	8	What if an Alarm sounds and the room is evacuated with burning material still sitting exposed in the glovebox?	Continues to burn; source of ignition for combustibles. A: Fire in glovebox, assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	
OM-9a	9	What if normal-appearing product begins to burn when it's poured into tray?	Same as 8.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	Three things that could be done: 1) Let it burn. 2) Cover burning material with slip-lid can. 3) Cover it with MgO sand.
OM-9b	9	What if the material was poured on the floor of the glovebox rather than in the tray?	Same as 8.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	This would likely pose a lower hazard because of a higher heat transfer through the floor of the glovebox.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else

Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-9c	9	What if the material does not come out of the can?	WI: can't process material and requires further evaluation to get it out. A1: puncher of glove with tool during forced extraction A2: reactive piece ejected and lands on combustible material causing a glovebox fire.	Panneled can or hardened corrosion products	WI: none A1: none A2: See OM-1a.	WI: none A1: training, treatment of contaminated wound A2: See OM-1a.	WI: S0 A1: S1 A2: See OM-1a.	WI: F3 A1: F3 A2: See OM-1a.	
OM-10a	10a	What if a stable-looking button crumbles when you pick it up for brushing?	Possibility of generating dust: increased holdup in glovebox; higher dose rate.	See Remark	See Remark	See Remark	S0	F3	Amount of generated dust judged not to have a significant impact.
OM-10b	10a	What if brushing is over-vigorous, leading to large amounts of suspended powder?	Material suspended in glovebox atmosphere.	See Remark	See Remark	See Remark	S0	F0	Years of button brushing have shown that this is not a concern.
OM-11	11								Activity covered by AB.
OM-12a	12	What if the accumulation of reactive brushed material in the glovebox exceeds our experience base? (200g of brushed material from multiple containers).	Potential for pressurization of glovebox A: Loss of glovebox containment and contamination spread to room.	Lack of inventory control.	WI: none. A: CAMs and glovebox differential pressure and HEPA filtered exhaust	WI: Accountability/ Inventory control system for brushed material. A: none.	WI: S0 A: S1	WI: F2 A: F2	Propose: hotplate in 636 to heat brushed material to 350 °C to passivate the material OR send brushed material over to 21A in single-batch amounts or single-brushing amounts.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	**Step #**	**"What If" question**	**Consequence**	**Cause(s) of "What If"**	**Engineered Safety Feature(s) for "What If" and Accident**	**Administrative Safety Feature(s) for "What If" and Accident**	**Cons Cat**	**Freq Cat**	**Remarks**
OM-12b	12	What if the brushed reactive material appears to burn when poured into a new can?	Source of ignition for combustibles. A: Fire in glovebox, assuming contact with sufficient combustibles	Intentional action. A: See OM-1a	See OM-1a	See OM-1a	WI: S0 A: S1	WI: F3 A: F2	Reactive materials close to combustibles. You would expect to see reactions when pouring this 200 g of highly-reactive, non-passivated brushed material through the air to a new can, or sweeping it from the tray to a can.
PFP Opening Metal Items and Thermal Stabilization in GB HC-21A "What If" Hazards Evaluation Work Sheets Hazards Evaluation Team: R.B. Gelman, E.P. Bonadie, E.L. Kauer, C.A. Carro, D.A. Clapp, Leader, A.B. Rau, Scribe Date Hazards Evaluation Conducted: 15 June 1999									
TS-1	1								Hazards associated with these activities are addressed in the Thermal Stabilization Addendum to WHC-SD-CP-SAR-021.
TS-2	2								Covered in OM-3 (a, b, and c) see above.
TS-3	3								Covered in OM-4 (a, b, and c) see above
TS-4a	4	What if hydride is present and reacts	WI: material continues to react to completion; source of ignition for combustibles A: fire in glovebox assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else

Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
TS-4b	4	What if metal is present and begins to burn?	WI: material continues to react to completion; source of ignition for combustibles A: fire in glovebox assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.
TS-4c	4	What if we spill it on the glovebox floor?	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.
TS-5	5								No safety impacts.
TS-6a	6	What if corrosion products react or metal ignites on conveyor?	WI: provides a heat/ignition source A: loss of glovebox containment and contamination spread to room	none	WI: none A: See OM-12a.	WI: none A: procedures and training	WI:S0 A: S1	WI: F2 A: F2	There is a very short residence time (e.g., less than a minute) on the conveyor.
TS-6b	6	What if furnace boat contents spill on conveyor?	WI: possibility of creating dust and increased holdup in glovebox A: higher dose rates to operators	Furnace boat becomes entangled with glovebox glove or operator drops furnace boat.	Furnace boat cover	Procedures and trainng and glovebox gloves are withdrawn and bungeed	S0	F3	
TS-6c	6	What if boat cover left off and boat inadvertently transferred to HC-18BS and reactive corrosion products disperse and ignite?	WI: exposed powder A: potential pressurization of glovebox if more than 200 grams of hydride	WI: human errors	Glovebox differential pressure, CAMs and HEPA filter exhaust	Procedures and training, 200 gram hydride restriction	S1	F1	Frequency judged to be at lower end of range (i.e., approaching 10^{-6} per year.
TS-7a	7	What if material not heated to >300 °C?	Residual hydride and potential exothermic reactions during subsequent processes	Equipment failure and failure to detect	Controller programmed to raise temperature to 1000 °C Setpoint temperature deviation alarms	Logbook entry and check chart recorders per procedure	S1	F1	This event could result in a glovebox fire. Glovebox fires have been previously identified in this Hazards Analysis with a probability of >F1.

Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB
"What If" Hazards Evaluation Work Sheets

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	**Step #**	**"What If" question**	**Consequence**	**Cause(s) of "What If"**	**Engineered Safety Feature(s) for "What If" and Accident**	**Administrative Safety Feature(s) for "What If" and Accident**	**Cons Cat**	**Freq Cat**	**Remarks**
TS-7b	7	What if there is no vacuum and hydrides are present?	Potentially flammable concentration of hydrogen within furnace and potential deflagration	Human error or equipment failure	Glovebox differential pressure, CAMs, HEPA filter exhaust	Procedures and training	WI:S0 A: S1	**WI: F3** A: F2	

HAZARD EVALUATION RESULTS

Table 3. Accidents With Potential Significant Worker Consequences (S1). (2 sheets)

ID#	Accident	Cause	Cons. Cat.	Freq. Cat.
OM-1a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-1b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-1c	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F1
OM-1d	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-2	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F3
OM-3a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2?
OM-3b(1)	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F3
OM-3c	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2?
OM-6a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-6b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-8a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-8b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-9a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-9b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-9c(1)	Hand puncture wound with Pu injection	Difficult extraction of solids from "paneled" - inadequate extraction tools	S1	F3
OM-9c(2)	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
OM-12a	Loss of 636 or HC-21A glovebox containment	Accumulation and subsequent reaction of more than 200g of the most reactive corrosion products - reaction produces enough energy to pressurize glovebox to the point of breach of containment	S1	F2

Table 3. Accidents With Potential Significant Worker Consequences (S1). (2 sheets)

ID#	Accident	Cause	Cons. Cat.	Freq. Cat.
OM-12b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
TS-2	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F3
TS-4a	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F3
TS-4b	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
TS-4c	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F2
TS-6a	Loss of HC-21A glovebox containment	Spontaneous reaction of corrosion products while traveling conveyor - ignites and/or melts glove that may be left in box causing leak path from glovebox	S1	F2
TS-6c	Loss of HC-21A glovebox containment	More than 200 grams of hydride being conveyed - reaction produces enough energy to pressurize glovebox to the point of breach of containment	S1	F1
TS-7a	Fire in glovebox HC-21A	Material not heated to stabilization temperature leaving residual reactive material which may react while not controlled in subsequent processing/handling activities Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can	S1	F1
TS-7b	(1)Fire in glovebox HC-21A (2)Loss of glovebox containment (HC-???)	Simultaneous loss of furnace vacuum and presence of hydrides causing flammable concentrations of hydrogen with ignition.	S1	F2

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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 10.0

CONDUCT OF OPERATIONS

FEBRUARY 2001

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PREFACE

Revision 2 of Chapter 10.0 of the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) incorporates the following:

- Significant revision in the Organizational Structure to reflect recent changes in Fluor Hanford's responsibilities
- Significant revision in the PFP's management and operations structure
- Revision of the emergency preparedness description including the BED
- Additional discussion regarding conduct of operations

Other minor changes include editorial changes and additional clarifications.

The significant areas of change in Revision 2 are indicated by vertical bars in the margin of each page.

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10.0 CONDUCT OF OPERATIONS

This chapter outlines the Plutonium Finishing Plant (PFP) administrative and operating elements, and activities that ensure continued and safe plant operations. The specific elements and activities presented are the organizational structure, operating startup plans, the PFP training program, standard plant operations, emergency preparedness, and plant decommissioning.

The following paragraphs identify the responsibilities and standards of operation required in the performance of all work at the PFP. The PFP Transition Project organization manages PFP in a safe, efficient, and environmentally sound manner and ensures that all activities at PFP are conducted in compliance with applicable DOE Directives and federal, state, and local regulations. The Nuclear Material Stabilization organization is composed of organizations that report directly to the PFP Transition Project Director and line organizations that are administered by the PFP Plant Manager. The organization structure at PFP is provided in FSP-PFP-5-8, *Plutonium Finishing Plant Administration*, Volume 1, Section A, *Organizational Charts*.

For each management position at PFP there is a set of functional responsibilities. The incumbent manager and the key functions for that position are listed in FSP-PFP-5-8, Volume 1, Section B, *Nuclear Material Stabilization - Key Functions*. Managers are held accountable to carry out their responsibilities in completing their assigned tasks. Every manager and employee has a prime responsibility to carry out their assigned tasks in a manner that ensures personnel safety, environmental compliance, criticality safety, protection of plutonium material, and responsibility is the need to perform all activities with good Conduct of Operations principles. Line management is responsible for assuring the quality and safety of work performed. PFP personnel are responsible for doing it right the first time. Managers have the responsibility to ensure that all operations are accomplished by qualified personnel in accordance with company/plant policies and procedures. When there is a concern or question with a procedure, work must be stopped to establish a safe condition.

Plant and area status is monitored and understood by personnel assigned responsibility for the area control. Understanding of plant conditions is paramount for effective and proper response to abnormal plant conditions. All activities that occur at PFP are under the control of the shift manager. The shift manager must be aware of, in control of, and accountable for all activities, including operations, maintenance, testing, and other work. Plant conditions and configurations are the responsibility of the shift manager and their permission is required prior to making any changes in the plant status. PFP personnel are accountable for their performance and for the implementation of the plant standards. All personnel are responsible for maintaining cleanliness in their spaces and work areas. PFP will take positive action to address all known employee concerns, procedural deficiencies, and facility deficiencies (e.g., leaks, broken equipment).

A single Building Emergency Director (BED) is designated for all buildings and facilities within the PFP. The BED is assigned to emergency response duties on the basis of the similarity of their normal daily responsibilities to the emergency response duties, and their demonstrated

ability to properly analyze data, assess situations, and make decisions under high stress conditions. In the event of an emergency, the BED assumes control over all facility occupants. As specified in FSP-PFP-5-8, Volume 1, Section B, the on-duty PFP Surveillance Shift Team Leader is the PFP BED. Consequently, the position of BED is staffed 24 hours per day, seven days per week. The BED is responsible for assessing and categorizing an event, and if the event is categorized as an emergency, classifying the event and initiating appropriate protective actions for the welfare and safety of facility occupants and affected areas. The BED communicates with emergency staff and directs subsequent actions at the event site. The specific authority and responsibilities of the BED are defined in FSP-PFP-0821, *PFP Conduct of Operations*, Chapter 1, "Operations Organization."

10.1 ORGANIZATIONAL STRUCTURE

The following sections outline the PFP Nuclear Materials Stabilization Project organizational structure, and those functions and responsibilities which relate to maintenance of the facility Authorization Basis. The Plutonium Finishing Plant Director and the Nuclear Material Stabilization Deputy Manager report directly to the Vice President for the Nuclear Material Stabilization Project as shown in FSP-PFP-5-8, Volume 1, Section A. The key functions for the Vice President and Director offices are specified in FSP-PFP-5-8, Volume 1, Section B. Some of the specific responsibilities include: Coaches/mentoring supervision, startup team management/ coordination, ISMS program management, ESH&QA policies, hazard communication program direction, corrective action management program monitoring, and oversight of other safety program elements.

10.1.1 PFP Business Management

The Manager of PFP Business Management reports directly to the Vice President for the Nuclear Material Stabilization Project as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Business Management organization includes the following functional organizations: Financial Integration and Administration Team, Project Scheduling Team, and Project Management Support Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.2 PFP Environmental, Safety, Health, and Quality Assurance (ESH&QA)

The Manager of PFP Environmental, Safety, Health, and Quality Assurance (ESH&QA) reports directly to the Vice President for the Nuclear Material Stabilization Project as shown in FSP-PFP-5-8, Volume 1, Section A. The ESH&Q organization includes the following functional organizations: Health and Safety Team, Quality Team, Environmental Team, and Safeguards and Security Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.3 PFP Thermal Stabilization and Polycubes Project

The Manager of PFP Thermal Stabilization and Polycubes Project reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The Thermal Stabilization and Polycubes Project organization includes the following functional organizations: Thermal Stabilization Support Team, P Shift Team, and Q Shift Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.4 PFP Vaults

The Manager of PFP Vaults reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Vaults organization includes the following functional organizations: Solid Waste Operations Team, Vault Operations Team, and Stabilization and Packaging Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.5 PFP Surveillance

The Manager of PFP Surveillance reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Surveillance organization includes the following functional organizations: A Shift Team, B Shift Team, C Shift Team, D Shift Team, Operations Support Team, Special Tasks Team, and Plastic Shop/Storeroom Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.6 PFP Infrastructure Services

The Manager of PFP Infrastructure Services reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Infrastructure Services organization includes the following functional organizations: Water, Air, Vacuum and Steam (WAVS) Team, HVAC Control Team, HEPA Filters Team, Safety Systems Team, Electrical Team, and Infrastructure Support Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.7 PFP Project Management

The Manager of PFP Project Management reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Project Management organization provides programmatic guidance/support and project management support for the PFP. The functional responsibilities are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.8 PFP Contracts and Procurement

The Manager of PFP Contracts and Procurement reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Contracts and Procurement organization facilitates procurement of good and services, and administers contracts and subcontracts in support of the Nuclear Material Stabilization Project. The functional responsibilities are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.9 PFP Solutions/Residues Stabilization Project

The Manager of PFP Solutions/Residues Stabilization Project reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Solutions/Residues Stabilization Project organization includes the following functional organizations: Solutions Handling Team and Solutions Project Management Team The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.10 PFP Radiological Control

The Manager of PFP Radiological Control reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Radiological Control organization includes the following functional organizations: Radiological Control Technician Team and Radiological Engineering Team. The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.11 PFP Near Term Planning Team

The Manager of PFP Near Term Planning Team reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The functional responsibilities for this team are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.12 PFP Analytical Laboratory

The Manager of PFP Analytical Laboratory reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Analytical Laboratory organization includes the following functional organizations: Analytical Services Team, XYZ Shift Team, and Waste Packaging and NDA Team The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.13 PFP Pu Process Support Labs

The Manager of PFP Pu Support Labs reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Pu Support Labs performs chemical process development and bench scale

testing, and operates and maintains the PPSL. Each of the functional responsibilities is specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.14 PFP Technical Support

The Manager of PFP Technical Support reports directly to the Plutonium Finishing Plant Director as shown in FSP-PFP-5-8, Volume 1, Section A. The PFP Technical Support organization includes the following functional organizations: Authorization Basis Team, Engineering Team, Materials Planning and Disposition Team, Technical Services Team, and Training Team The functional responsibilities for each of the individual teams are specified in FSP-PFP-5-8, Volume 1, Section B.

10.1.15 Standing Plant Committees

The following standing plant committees serve as integral parts of the PFP organization that aid in establishing the PFP ALARA program in accordance with *Occupational Radiation Protection*, Title 10, *Code of Federal Regulations*, Part 835 (DOE 1993) and *Hanford Site Radiological Control Manual*, HSRCM-1 (DOE-RL 1994).

The Enhanced ALARA Review Committee reviews and provides approval of work documents for jobs or activities involving estimated individual or collective doses >1 person-rem, infrequent or first time activities for recurring process operations, and results of ALARA design reviews for new designs and major modifications.

The PFP ALARA Committee addresses personnel awareness and concerns. The PFP ALARA Committee also assists radiological work planners to complete an ALARA Management Worksheet (AMW) or equivalent ALARA review. They also review high-risk radiological work.

The Nuclear Material Stabilization Plant Review Committees (PRC) at PFP serves as the Safety Review Board (SRB). The purpose is to provide a global over view, an independent review, and, if necessary, provide additional subject matter experts (FSP-PFP-5-8, Vol 1, Section 2.43 "Plant Review Committee).

10.1.16 Support Interfaces

The PFP operating contractor interfaces with many organizations. Fluor Hanford, Inc. (FH) is the Hanford Site integrating contractor as described in section 10.1.17.1 along with its project organizations and major Hanford subcontractors. Besides the integrating contractor, project organizations and major subcontractors, several separate Enterprise Companies support Hanford programs and projects as described in Section 10.1.17.2. Finally, there are three other organizations that contract directly with DOE-RL for specific services as described in section 10.1.17.3.

10.1.16.1 Integrating Contractor and Major Subcontractors. Fluor Hanford, Inc. (FH) is the integrating contractor for the Project Hanford Management Contract (PHMC). FH is responsible for planning, integrating, managing, and

executing the Hanford programs, projects, operations, and other activities at the Hanford Site. FH also operates several major cleanup projects and provides quality assurance services. The FH project team includes FH project organizations and major subcontractors, which are briefly described below.

The FH Nuclear Material Stabilization (NMS) organization is responsible for the Facility Stabilization Project. In this role, it examines all highly contaminated structures and makes the appropriate recommendations as to the best remediation action. Nuclear Material Stabilization is responsible for the Plutonium Finishing Plant.

The FH Spent Nuclear Fuel (SNF) organization work at Hanford involves managing the SNF Project. The scope of the SNF Project includes removing spent nuclear fuel from the present deficient storage conditions (basins), conditioning (drying and sealing in containers) the fuel, transferring the fuel to an interim storage, removing the sludge and debris from the basins, and treating the basin water.

The FH Waste Management (WM) organization is responsible for 200 Area liquids disposal (low level), solid waste storage and disposal, and Waste Retrieval and Packaging (WRAP) facilities.

DynCorp Tri-Cities Services (DYN) provides all essential infrastructure service in support of the Hanford Site. These services include Facility Maintenance and Site Services, Real Estate and Property Management, Landlord Program Management and Emergency Preparedness and Emergency Response Services.

Three Johnson Controls Package boilers that are sited north of PFP and west of 231-Z (Figure 1-1) provide the steam supply for the Plutonium Finishing Plant. These oil-fired boilers have a capacity to supply up to 100 psi steam. The 100 psi steam system can be used to operate the steam driven turbine exhaust fans in the 234-5Z building. The steam system delivers to the turbines approximately 85 psi steam which tests have demonstrated is sufficient for the steam turbines to meet or exceed minimum exhaust plenum pressure differentials. These local individual boilers have a thermal efficiency of approximately 75% and replace the central steam boiler in 200 West area which had an efficiency of about 33%. Additional information about the Johnson Controls Package boilers can be found in Section 1.5.1.1.

CH2M Hill Hanford Group, Inc. (CHG) is the Hanford Prime Contractor in charge of the River Protection Project (RPP), including 177 underground high-level waste tanks. CHG ascertains the contents and determines what is necessary for continued safe management of the tank waste. CHG pre-processes waste for disposition through DOE's privatization contracts and stores the stabilized waste on an interim basis until permanent facilities are available.

The Numatec Hanford Corporation (NHC) mission is to provide best-in-class engineering and project management services and technical expertise to Fluor Hanford, Inc. and its other major subcontractors, and to implement relevant technologies to accelerate cleanup at the Hanford Site.

Protection Technology Hanford (PTH) provides facility and/or system design and installation, security assessments, security program development and implementation to government and industrial markets. PTH will provide, manage, operate and integrate all safeguards and security services of the

Hanford Site, except Pacific Northwest National Laboratory, including function design, testing and upgrade of safeguards and security systems.

Waste Management Federal Services of Hanford, Inc. (WMH) is responsible for the Waste Management Project. The company uses existing and new technology to accelerate treatment and disposal of waste, reduce need for waste storage and minimize waste through partnerships with waste generators.

10.1.16.2 Enterprise Companies. Fluor Hanford and its major subcontractors established several new companies in the local area. These enterprise companies are described below and are separate businesses with the flexibility to pursue and perform Hanford and non-Hanford work.

COGEMA Engineering Corporation (COGEMA) will develop and design waste sampling characterization and retrieval equipment, specialized analytical methods and techniques development. The company will design environmental monitoring equipment and develop and design vitrification technology and processes. COGEMA Engineering will apply its expertise in field screening and sampling at the Hanford Site, as well as its special welding technique development and application.

Fluor Federal Services (FFS) is part of Fluor Daniel, Inc., the core engineering and construction business of Fluor Corporation. FFS provides engineering, procurement, construction, project management, project controls, and environmental, safety, health, and quality (ESH&Q) services. FFS's initial client base consists of the PHMC subcontractors listed in section 1.4.2

Lockheed Martin Services, Inc. (LMSI) provides telecommunications and network engineering, Internet technology integration, software modernization, maintenance and support, engineering computational resources, data center management, imaging and document management and multimedia services.

Waste Management Technical Services, Inc. (WMTS) role includes privatization of a select group of premier capabilities that were developed for use at Hanford but also have applications throughout the DOE complex or in the private sector. They include: transportation logistics; waste management engineering; environmental monitoring and investigations; well services; sampling and mobile laboratories; and integrated pest management.

10.1.16.3 Other Department of Energy Contractors. Three additional onsite contractors provide services to DOE-RL as described below.

Bechtel Hanford, Inc. (BHI), a division of Bechtel National, Inc., is the environmental restoration contractor at Hanford. BHI plans, manages, executes, and integrates a full range of activities for the cleanup of groundwater, contaminated soils, and inactive nuclear facilities under DOE's Environmental Restoration Program.

Hanford Environmental Health Foundation (HEHF) provides personnel health and occupational medical services to DOE and the site contractors. The HEHF provides on-call emergency medical support and operates the Emergency Decontamination Facility.

Pacific Northwest National Laboratory (PNNL), a division of Battelle Memorial Institute, is a research and development facility that provides contract work. PNNL also provides the Hanford Site-wide radiological and environmental surveillance programs, portable radiation detection instrument maintenance and the calibration laboratory.

10.1.17 Plutonium Finishing Plant Staffing Requirements

Staffing requirements for safe and efficient operation of the PFP are a function of the specific mission requested by the DOE-RL. The current mission is as follows:

- Addition of stabilization operations to permit safe storage of reactive Plutonium materials
- Long-term storage of plutonium material
- Laboratory facility support of Hanford Site programs
- Facility cleanup to minimize levels of contamination and quantities of hazardous chemicals
- Shutdown of plutonium recovery and conversion operations
- Other miscellaneous changes related to facilities and operations.

The number of personnel required by plant operations and by technical support is established through preparation of resource-loaded schedules that satisfy the requirements and commitments as determined by DOE and agreed to by Contractor management. See *Administrative Controls*, WHC-SD-CP-OSR-010, for the minimum staffing requirements.

The resource-loaded schedules are reviewed and approved by the Plant Manager and by the managers of the respective organizations providing support for the specific mission. These managers are responsible for ensuring that their staffs are of adequate size and have the required training and experience to operate the facility safely.

Staffing needs for shipping and receiving activities vary, depending on the plutonium material handling/inventory requirements of the DOE complex. Staffing needs for remediation and construction activities are also driven by the plutonium material handling/inventory requirements of the DOE complex and the need to upgrade or modify the plant and equipment. Consequently, the required plant operations and technical support staff varies according to the operating schedule. Evolving operations, safety, security, ALARA, training and environmental orders, directives, and requirements also affect the staffing requirements needed to satisfy a particular mission.

The determination of staffing requirements for specific unit operations and tasks considers job/task requirements, plutonium material security, industrial safety, radiation protection, management and quality oversight requirements, and other considerations. Technical Training performs detailed job analyses and identifies staffing requirements for PFP operational activities. The job/task analysis, the identification of job skills/crafts

needed to perform the task/operation, and administrative and regulatory requirements are used by management to establish staffing requirements for safe operations and tasks in specific units.

Confirmation that staffing levels are sufficient for safe operation is verified by an operational readiness review (ORR) conducted in accordance with *Startup and Restart of Facilities*, HNF-PRO-055. The types and numbers of personnel needed to perform a given activity are often specified by plant procedures (e.g., operating, maintenance, and administrative).

For short periods of time (i.e., less than one shift) and during facility weekend shutdown, the facility can be maintained in a safe configuration and can support limited operation with a minimum level of operating staff. This minimum staffing level maintains the essential building support systems and allows operations in a reduced mode for short periods of time.

10.1.18 Personnel Qualification and Responsibilities

Qualification requirements for key management personnel assigned to the PFP are based on the responsibilities of the position and organization. Individuals deemed qualified to assume and discharge the responsibilities of the position must complete plant-specific training as noted in Section 10.3. Personnel qualification and training programs are under continuous review and modification to reflect DOE-RL guidance and added responsibilities arising from the changing regulatory/industrial environment.

DOE Order 5480.20A, *Personnel Selection, Qualification and Training Requirements*, Chapter IV specifies education and experience requirements for nonreactor nuclear facility personnel.

10.2 PREOPERATIONAL TESTING AND OPERATION

At the PFP, preoperational testing is the second phase of testing that supports the plant readiness process. The readiness process includes all the steps necessary to ensure that those systems that already have been operated, and those systems/operations that represent a new technology not previously applied in the plant, can be operated safely and reliability. The depth and content of the readiness process is based upon a graded approach that considers the facility hazard category, system complexity, and facility life cycle stage. The extent of testing and/or review is determined by the type of operation, the technology used, the potential risk associated with the operation, the degree and complexity of control required, facility or process modifications, the knowledge and skill of the personnel, and the length of time since the operation was last active.

At the PFP, the Readiness Process consists of four general phases.

The first phase is acceptance testing, which demonstrates that fabrication, assembly, installation, and construction requirements have been met as defined in the procurement specifications. The acceptance test procedures (ATPs) are prepared and/or performed by the vendor/supplier to assure the facility custodian that the equipment, materials, etc. meet the procurement specifications.

Preoperational testing is the second phase, and is performed on the equipment and the process systems in preparation for operational testing. The operability test procedures (OTPs) assure the facility custodian that the system operates in the context of the actual process under real or simulated conditions.

Operational testing is the third phase, and is prepared and conducted by facility operators against the final in-service process/facility configuration. This testing is a cold run.

The Readiness Assessment (RA) or Operational Readiness Review (ORR) is the final phase; which verifies that all elements (plant, procedures, and personnel) are in conformance with process specifications. A graded approach determines the depth and breadth of the review, as delineated in FSP-PFP-5-8.

The purpose, scope, definitions, responsibilities, and procedures associated with the assessment of facility readiness are delineated in HNF-PRO-055. The readiness program relies on acceptance, preoperational, and operational testing as the primary source of information for determining operational readiness.

The purpose, scope, definitions, responsibilities, requirements, and procedures to a broad range of testing activities, including acceptance, preoperational and operational testing, are found in *Testing Requirements*, HNF-PRO-446. Acceptance, preoperational, and operational testing are used to determine the readiness of process systems before production operation.

Acceptance testing is the first step of testing used when new fabrication, assembly, or construction is associated with the process or system startup. Acceptance testing demonstrates that parts, equipment, and systems have met procurement, fabrication, and/or construction specifications. The supplier or vendor prepares and performs acceptance testing of parts and equipment; onsite acceptance testing is conducted for parts and equipment from Contractor sources to ensure that fabrication, assembly, and construction specifications have been met.

Preoperational testing is performed in preparation for operational testing. Operational testing is to ensure that equipment, systems, or processing lines function in compliance with specifications, procedures, and plant standards. During preoperational testing, components, subsystems, and systems are operated at reduced parameters to ensure that they are ready for full operational testing. When the components, subsystems, and systems have been tested sufficiently at the reduced parameters to indicate that the normal operating parameters can be achieved, they are tested at designated higher parameters. At the completion of preoperational testing, the test results are evaluated, and a determination is made to move into operational testing.

Primary emphasis is placed on the safety class equipment during preoperational testing. (For information about what constitutes safety class equipment, see *Hazard and Accident Analysis Process*, HNF-PRO-704.) The specific requirements of operability of the following safety systems are found in WHC-SD-CP-OSR-010, *Plutonium Finishing Plant Operational Safety Requirements*.

- Criticality prevention, detection and alarm systems

- Facility confinement and ventilation systems
- Dispersible plutonium inventory.

Operational testing demonstrates operational readiness through extensive testing conducted before process operation. During the test, the operating configuration of all equipment is readied. In the liquid systems, process flows are tested using a dilute solution, and other chemical solutions as appropriate, to simulate the process. In the dry areas, mechanical equipment can be tested through simulated operations without process chemicals. Instruments and interlocks are functionally tested to verify proper response during operations and in problem situations.

Reviews of the acceptance, preoperational, and operational tests are conducted before, during, and after testing is conducted. These reviews confirm test requirements and proper test performance, and verify the results. The type and extent of test reviews conducted are determined by the scope, complexity, and technical risk associated with the testing program. Test reviews confirm that a test meets established requirements, which include OSRs in the case of preoperational tests. Test reviews are typically conducted by representatives from facility engineers, Safety, QA, and Operations. Nonconformances associated with ATPs and OTPs are tracked to ensure their correction.

The contractor performs ORRs before the initial startup or before restart following major modification, significant interruption, or activity scope change, of all activities that have the potential for environmental, health, safety, safeguards and security, or operational risk.

A Readiness Review Board is convened by the plant manager to conduct the ORR of the operation/process to be started up. Using the procedures and criteria established in FSP-PFP-5-8, a thorough review is conducted. The results of the ORR include documentation of operational readiness, a punch list of nonconforming items, and a recommendation to the plant manager on whether to start up.

10.3 TRAINING PROGRAMS

The training programs for PFP personnel are designed to provide the knowledge required to operate the plant in a safe, efficient manner. DOE Order 5480.20A, presents the training requirements. Specific training procedures (i.e., HNF-PRO series of procedures) provide the Hanford Site requirements which are applicable to PFP. For the PFP, FSP-PFP-1121, *Plutonium Finishing Plant Training Administration*, implements these requirements and has the following objectives:

- Define a process for selection of personnel based on the ability to meet job performance requirements
- Specify minimum job qualifications and/or certification requirements for all positions with duties that could affect safe operation of the PFP

- Specify management and supervisory training as appropriate to assigned responsibilities
- Establish a qualification program for operators, maintenance, and technical support positions
- Develop requalification/recertification and continuing training programs to ensure personnel meet job performance requirements
- Ensure that sufficient qualified facility and support staff are available to ensure safe operation
- Formally document qualification, certification, requalification, recertification, and continuing training programs
- Maintain auditable records of training programs and personnel qualifications and training.

10.4 NORMAL OPERATIONS

All operations for the PFP are defined, controlled, and conducted by written procedures that include administrative/implementing procedures, technical documents (operating, maintenance, etc.), and work instructions that are included in work packages. The ensuing discussion in this chapter will describe the development, review, verification and validation, and configuration management of each of these document types.

10.4.1 Administrative Procedures

Administrative procedures and the development, review, publication, and control of these procedures are outlined and contained in FSP-PFP-5-8. The need to develop a new procedure must first be justified to and approved by the PFP Director. The content typically includes purpose, scope, responsibilities, requirements, procedures, review organizations, and references, as appropriate. In addition to editorial review, the draft procedure is reviewed by the organization that is assigned a responsibility or task in the procedure, the organization accountable for requirements or processes established in the procedure, and appropriate quality, environmental, and safety oversight organizations. All draft administrative procedures are coordinated through the review, approval, and publication cycle by the Manual Administrator who forwards the approved procedure to Unclassified Document Control for printing and release. Each administrative procedure is assigned a title, unique identifier, revision number, and effective date. This information is shown in the header.

FSP-PFP-5-8 is a controlled manual and its configuration management is in accordance with *Document Control*, HNF-PRO-224 and *Distributing Copy - Controlled Unclassified Documents*, HNF-PRO-225. All changes are sent to the holder of the manual, who must sign and return each change notice indicating that the change has been entered into the controlled manual. Each change notice has an effective list of pages and is consecutively numbered. The current approved copy of FSP-PFP-5-8 and associated administrative procedures

can be accessed electronically (read-only) on a dedicated computer file server.

10.4.2 Technical Documents

Technical documents provide the procedural basis used to support the operation of the PFP, regardless of the specific document type (i.e., maintenance procedures, operating procedures, specific manuals, and operating specifications).

The methods for preparing, validating, and approving technical documents, and for the implementation of document changes, is outlined in FSP-PFP-5-8, Volume 2, Section 13.5, "Processing PFP Technical Documents." The procedures for control, release, and distribution of these technical documents is contained in FSP-PFP-5-8, Volume 2, Section 13.6, "Technical Document Control System." The cognizant engineer is responsible for providing the procedural basis, which furnishes the justification for significant safety and technical elements of a procedure. These include administrative, technical (FSAR and/or federal, state and local laws and regulations) and design bases. The procedural basis is recorded on the Document Approval Form, which is the QA record for documenting the review, validation, verification, and approval process.

The PFP follows the guidance of DOE-STD-1029-92, *DOE Writer's Guide for Technical Procedures* (DOE 1992), in developing technical documents.

Validation is performed by a team of individuals, one of which must be an individual who would normally perform the task. The intended user takes the document to the location where the task is to be performed and (without actually performing the operation) ensures that each step is correct and readily usable as written.

Approval is the process by which each document is reviewed, verified, and approved by personnel designated by the cognizant engineer. Depending upon the nature of the document and its contribution to the safe operation of the plant, the review organizations could include QA, Safety, and Environmental. The cognizant engineer and cognizant manager are normally the last individuals to review the document before it is sent to the approval authority, who is a designated individual qualified in the operation to be performed.

The process for both permanent and temporary changes to technical documents is also outlined in FSP-PFP-5-8, Volume 2, Sections 13.5 and 13.6. If the change is technical in nature, the process is similar to that of a new technical document.

PFP Facility Engineering is responsible for the generation of these technical documents, and initiates the review, verification, and approval cycle of a technical document. The cognizant engineers are responsible for providing technical guidance and specifically to review the technical document for technical accuracy as it applies to systems, structures, or components (SSCs) and/or processes. PFP Facility Engineering Administration is responsible for formatting, incorporating changes and ensuring approvals are properly obtained. The cognizant engineer is responsible for conducting the

unreviewed safety question (USQ) screening in accordance with FSP-PFP-5-8, Section 2.23, "Identification and Resolution of Unreviewed Safety Questions."

All properly approved technical documents are maintained by PFP Facility Engineering Administration on a central computer file server in password-protected, "read-only" files. In addition, hard copies stamped with "Official Release" are distributed to locations requested by the approval authority. Only "Controlled Copy" documents are authorized for use within the PFP; "Working Copy" or "Information Copy" technical documents are not authorized for use. Each technical document is uniquely identified by title, number, revision/modification, pagination, issue date, and review date.

Before a document is used in the field, the document user is required to verify through a computerized listing that the document in use is the current revision. It is the responsibility of the manager to inform their personnel of changes, and to turn over information concerning a temporary change to a procedure to the incoming manager.

A graded approach is used to schedule periodic review of technical documents, and depending upon the approval designator, the frequency may vary from annually to every five years. The verification method is the same as for a new procedure. PFP Facility Engineering Administration provides the user organization with a copy of the procedure and a validation checklist two months before the required review completion date.

10.4.2.1 Technical Procedures. According to FSP-PFP-5-8, compliance with technical procedures is mandatory within the PFP. The procedure use method depends on risk implications to the facility, risk to the individual performer, quality implications, training of the performer, complexity of the procedure, and frequency of use of the procedure. There are three types of procedure use methods at the PFP: (1) step by step, (2) general use, and (3) routine use, in order of lessening strictness in application.

10.4.2.1.1 Step by step. Step by step procedures requires a step by step approach in the execution of the procedure and requires those performing the task to read through the procedure as the task is being performed.

10.4.2.1.2 General use. The individuals performing the task(s) outlined in the procedure are required to have the procedure available and should have read through the procedure prior to performing the task.

10.4.2.1.3 Routine use. The individuals performing the task have been trained for the procedure and have frequently performed the procedure in the past.

10.4.3 Work Instructions

Management of work activities within the PFP is accomplished through formalized procedures under the auspices of the Job Control System (JCS). For the PFP, this effort is managed by the Maintenance Administration and Support organization and is implemented by FSP-PFP-5-8, Section 13.4, "Job Control System Process Description." The JCS provides a formal, disciplined approach to the control of work to ensure all work is performed using appropriate instructions to assure personnel safety, equipment protection, and facility

configuration control. The JCS uses a graded approach to originating, planning, verifying, preparing, reviewing, approving, scheduling, releasing, performing, retesting, completing, and recording work efforts within the plant. The JCS uses automatic data processing (ADP) to facilitate the development, approval, documentation, and close-out of work packages.

Work packages that modify the plant configuration require an engineering change notice (ECN) that is prepared in accordance with *Engineering Documents Change Control Requirements*, HNF-PRO-440. A USQ screening is also required. Written procedures for conducting the work are reviewed, verified, and approved in much the same manner as any technical document. As part of the pre-job review, the job is walked down to ensure the task can be accomplished as detailed in the work instructions. Approved work packages are scheduled in the Plan of the Day and the person in charge (PIC) of the work to be performed is notified. The work packages are provided to the shift manager, who ensures that all prerequisite conditions are established and authorizes the work packages to be released during the next 24-h period. Once the authorized work has been performed per the work instructions, the PIC or the Maintenance Manager reviews the work package to ensure all required work activities were performed, required information was recorded, all appropriate signatures were obtained, and acceptance criteria were met. As directed by the Shift Manager, the equipment and facility is restored and/or retested and the work package returned to Work Control for close-out and transcription of the record copy into the JCS ADP (see Section 10.4.5 below).

10.4.4 Plant Records

The establishment of a system for creating and preserving records is a fundamental management responsibility. A sitewide records management system was developed and is maintained as described in *Records Management Program*, HNF-PRO-210.

10.4.4.1 Records Maintenance and Retention. The Contractor Records Management Program has been established and is devised to comply with the contractual requirements of the DOE. The program outlines the requirements for the maintenance and disposal of "record" and "nonrecord" material. This procedure defines the responsibilities and procedures for records management, assignment of retention periods, transfer of records, records disposition, and approval and disposition of the Records Inventory and Disposition Schedule (RIDS).

Records that pertain to organizational functions, policies, decisions, procedures, operations, or other activities of the PFP are considered "record" material and are preserved in accordance with the RIDS.

The RIDS is a listing of the filing units and general files of an organization, setting forth their mandatory disposition in terms of retirement, disposal, or transfer to storage after specified retention periods. The schedule includes all file material, whether record, nonrecord, classified, or unclassified. It includes records designated for permanent retention as well as those scheduled for disposal.

Operations, maintenance, engineering, and radiological control records that may be designated for retention include the following:

- Operations
  - Daily log (shift-to-shift reports/turnovers)
  - Hazardous Waste Storage Area Inspection Checklist
  - Sample graphs and data sheets
  - Surveillance sheets (operator reports, weekend readings, OSR data sheets)
  - Security Alarm Functional Test Records (functional tests on door and room alarms)
  - Reportable Occurrence Logs
  - Emergency supply check sheets
  - Safety showers check sheets
  - Essential Materials Checklist
  - Valve verification sheets
  - Item Transfer Sheets (custodians)
  - OSRs surveillance sheets
  - Strip charts
  - Sample logs, letterbooks
- Maintenance
  - Daily logs (shift-to-shift reports/turnovers)
  - Work packages (for preventive maintenance and corrective maintenance, as well as facility equipment modification work records)
- Technical Support
  - Nonclassified informational records on the operation of the plant
  - Comment sheets and letters related to the operation of the facility and considered to be useful at a future date
  - Classified records related directly to the building processes
  - Classified working documents
  - Plant drawings
  - Process data

- Sample result sheets
- Campaign reports

- Radiological Control
  - Contamination surveys
  - Radiation surveys
  - Airborne radiological surveys
  - CAM surveys
  - Instrumentation calibration
  - Records of RWPs.

In addition, groups such as Safety, QA, and Nuclear Material Management maintain records of audits, appraisals, processes, and individual group activities. Copies of these records are obtained by contacting the appropriate manager.

10.4.4.2 Occurrence Reporting System. Occurrence reporting is in accordance with DOE Order 0232.1, *Occurrence Reporting and Processing of Operations Information.* These requirements are implemented by *Reporting Occurrences and Processing Operations Information*, HNF-PRO-060 and by the PFP in *Occurrence Reporting*, FSP-PFP-5-8, Section 1.4. An occurrence is any event or condition that could have an adverse effect on safety, health, QA, safeguards and security, operations, or the environment. Occurrences are broadly classified into three categories of decreasing significance: emergency, unusual, and off-normal. For the PFP, FSP-PFP-5-8, Section 1.4 provides guidance for occurrence classification.

For emergency occurrences, the procedures defined in *Emergency Preparedness Program*, HNF-PRO-424, are invoked and implemented for the PFP in HNF-IP-0263-PFP, *Building Emergency Plan for Plutonium Finishing Plant Complex (BEP-PFP)* and in Section 10.5 below.

The contractor has established an Occurrence Notification Center (ONC) to assist facilities in notification and to provide centralized infrastructure support to the Hanford Site occurrence reporting program. This support includes hardware and software maintenance, training, occurrence report tracking and distribution, and input of occurrence reports onto the national DOE Occurrence Reporting and Processing System (ORPS). The PFP Building Emergency Director (BED) assumes responsibilities for making necessary reports, taking necessary actions to stabilize the facility/operation to a safe condition, preserving conditions for subsequent investigation, and initiating an investigation of the event following notification. The BED is to be trained and knowledgeable of applicable procedures. The PFP Building Emergency Plan (BEP) also reflects these guidelines and provides checklists for the BED, including initial notification and reporting, sources for assistance, event stabilization and/or emergency response procedures, and preserving conditions to facilitate accident investigations. The Hanford

Patrol Operations Center (POC) is also a source of assistance to the BED in an emergency.

For occurrences that involve the release of hazardous materials in reportable quantities, the BED notifies the Contractor Environmental Reports representative, who makes notification to offsite regulators with the assistance of the ONC (see Section 10.4.4.3 for details).

Preparing and filing of the occurrence Notification Report, update reports, and final report is the responsibility of the occurrence investigator. The final report is submitted only when the significance, nature, and extent of the event have been analyzed, the causes of the event or condition (including root cause) have been assigned, corrective actions have been identified, and lessons learned have been identified.

10.4.4.3 Environmental Reporting System. Reports and records required by federal, state, and local regulations are delineated in *Environmental Notification and Reporting*, HNF-PRO-453. These reports are primarily made by the Contractor Environmental Reports organization based upon information provided by the PFP.

10.4.4.4 QA Records Systems. See Chapter 12.0 of this document for discussion of specific recordkeeping and control systems.

10.4.4.5 Authorization Basis. The authorization basis of the facility is defined as those aspects of the facility design basis and operational requirements relied upon by DOE to authorize operation. These aspects are considered to be important to the safety of facility operations. The authorization basis for the PFP is provided by HNF-SD-CP-SAR-021, *Plutonium Finishing Plant Safety Analysis Report*, and WHC-SD-CP-OSR-010, *Operational Safety Requirements* (see FSP-PFP-5-8, Section 2.23 Appendix A for details of the authorization basis). Other safety analyses [i.e., hazard classification documents, technical safety requirements (TSRs), DOE-issued safety evaluation reports (SERs), and facility specific commitments made in order to comply with DOE orders or policies] supplement these documents (DOE Order 5480.21). Details of the FSAR revision process are provided in FSP-PFP-5-8, Section 2.34, *Final Safety Analysis Report Revisions*.

10.4.4.5.1 PFP Plant Manager. The PFP Plant Manager is responsible for ensuring the currency, accuracy, and completeness of the PFP FSAR.

10.4.4.5.2 Plutonium Finishing Plant Technical Support Manager. The PFP Technical Support Manager is responsible for designating the PFP FSAR representative, providing design engineering services for plant modifications that will impact the FSAR, and ensuring that FSAR update schedules and resources are available.

10.4.4.5.3 PFP FSAR Representative. The primary functions of the PFP FSAR Representative is to conduct an annual update of the FSAR as provided by DOE, initiating and approving ECNs resulting from annual review of FSAR or from an USQ, and act as FSAR document coordinator.

10.4.4.5.4 Cognizant Engineer. The cognizant engineer is to ensure that a particular system is accurately and adequately described in the FSAR.

10.4.5. Chemical Management Programs

The following discusses the development and implementation of chemical management programs at the PFP. These programs are described as they apply to the Hanford Site (Section 10.4.5.1), Fluor Hanford projects (Section 10.4.5.2), and the specific programs implemented at PFP (Section 10.4.5.3).

10.4.5.1. Hanford Site Chemical Management Program. The DOE and the Site contractors developed a chemical management program and requirements document for implementation on the Hanford Site. The purpose of the *Chemical Management Program Requirements* (CMP) (CMPR 1999) document is to establish common requirements to control onsite chemical (excluding waste and radioactive materials) management activities within the applicable regulatory requirements. The goal of the program and requirements is to protect Site personnel, the public, and the environment from chemical hazards.

The Site contractors (e.g., BHI, FDH, HEHF, PNNL) concurred with the requirements contained in the CMP with respect to the acquisition, tracking, storage, use, transportation, and final disposition of chemicals. This includes, as a minimum, hazardous chemicals as defined within the OSHA Hazard Communication Standard (29 CFR 1910.1200 and their Appendices A and B).

10.4.5.2. Fluor Hanford Chemical Management Program. The Fluor Daniel Hanford chemical management program and requirements are contained in HNF-PRO-2258, *Chemical Management*. The objective of HNF-PRO-2258, is to establish a chemical management program (excluding waste and radioactive materials), as required by the Integrated Environment, Safety and Health Management System Plan (ISMS), for implementation by the Fluor Hanford projects. The requirements contained in HNF-PRO-2258 can be applied using a 'graded approach' based on the complexity of the chemical management operations and the nature and severity of the chemical hazards. The PFP Chemical Management Program (PFP CMP) is based on the requirements contained in HNF-PRO-2258, *Chemical Management*.

10.4.5.3. PFP Chemical Management Programs. The PFP primarily relies on the following hierarchy of controls to mitigate or minimize hazardous chemical releases or exposures:

- Engineered controls
- Administrative controls
- Personnel protective equipment

The programs currently implemented at the PFP include the PFP Chemical Management Program, a compilation of facility specific procedures which meet the requirements of HNF-PRO-2258, the Hazardous Material Management Plan, EPCRA 312 and 313, and the Chemical Hygiene Plan. These are described in the following subsections.

10.4.5.3.1. PFP Chemical Management Program. In accordance with HNF-PRO-2258, the PFP CMP applies to all chemical operations associated with the acquisition, storage, use, transportation, and final disposition of chemicals, including management of newly generated waste. The implementation of the PFP CMP will minimize the use of and personnel exposure to hazardous chemicals.

As required in HNF-PRO-2258, a single individual at the PFP has been identified to create plans and programs to ensure the PFP CMP requirements are adhered to, and commit to minimizing waste generation and releases to the environment. Additionally, the PFP CMP is to be incorporated into the PFP ES&H management system.

Based on the results of the chemical hazards analyses performed at the PFP, the following four items, within HNF-PRO-2258, were identified as critical program elements necessary to ensure safe use and storage of hazardous chemicals at the PFP (HNF-6492, *Summary of Chemical Hazards Assessments and Chemical Management Programs at the Plutonium Finishing Plant*, Ullah 2000).

Operations –

- Chemical management operations are within the authorization envelope.
- A documented process for the identification, evaluation, and control of chemicals whose characteristics might have changed over time.
- New MSDS shall be forwarded and readily available to support hazardous chemical management.
- Interfaces between facilities and organizations are defined and documented.
- Chemical information is available and incorporated in emergency response and environmental procedures.
- Appropriate training will be provided to personnel using or handling chemicals.
- The PFP will generate rules and guidelines regarding the safe management of hazardous chemicals.

Acquisition – Acquisition of chemicals will be documented and must address the following:

- Need for chemical
- Nonhazardous or less hazardous substitutes or alternatives
- Amount required
- Suitability for storage facilities
- Final disposition plans
- Stability/shelf life
- Required documentation (e.g., MSDS)
- Input of chemical information in CMS tracking system
- Use of available excess chemicals in lieu of new chemical purchases

Storage – Storage of hazardous chemicals should consider the following:

- Proper safe storage at the proper facilities (e.g., flammable cabinets, segregation of reactive/incompatible chemicals)
- Inventory of the chemical be maintained current and include location and quantity, use, custodian, and hazards associated with the chemical in the CMS tracking system
- Control and documentation of chemical use in the CMS tracking system
- Periodic physical confirmation of inventory
- Documented maintenance and inspection program to ensure storage facility integrity

Use – Prior to using chemicals the following should be performed:

- Hazards analysis
- Controls (i.e., engineered barriers, administrative controls and PPEs)
- Tracking of newly created hazardous chemicals, if not immediately used, in the CMS tracking system
- Ensure the use is covered by a procedure or MSDS as appropriate

10.4.5.3.2. PFP Hazardous Material Management Plan. Hazardous chemicals or materials are addressed in FSP-PFP-5-8, Volume 1, Section 7.1, "Hazardous Material Management Plan EPCRA 312 and 313". The PFP HMMP is applicable to all organizations within the PFP that maintain or use hazardous chemicals (newly acquired, stored, or "hold-up"). The purpose of the PFP HMMP is to require hazardous chemical physical inventories, provide guidance on proper storage and segregation requirements, identify "hold-up" chemical management requirements, and hazardous chemical management reviews and reporting requirements.

The PFP HMMP applies to new hazardous chemicals as well as "hold-up" chemicals. "Hold-up" chemicals have been referred to in previous studies as legacy chemicals. For the purposes of this report "hold-up" chemicals are defined as material presently identified, which may or may not be fully characterized, in tanks, pipes, cylinders, process equipment or other vessels which is in solid, liquid or gaseous form. These are typically residual materials from previous production runs. The PFP HMMP is used in conjunction with HNF-PRO-2258; therefore, the following discussion focuses primarily on the management of "hold-up" chemicals or legacy chemicals. Previous analyses have determined that these hazardous chemicals represent the greatest potential chemical hazard at the PFP.

The concern regarding hold-up chemicals is primarily related to chemical incompatibility issues. That is, although extensive efforts have been undertaken to locate, identify, and characterize these chemicals, the potential exists for adverse chemical reactions due to inadvertent mixing.

Based on the results of the chemical hazards analyses performed at the PFP, the following items, within the PFP HMMP, are critical to ensure safe handling and storage of hazardous chemicals at the PFP (Ullah 2000).

1. **Facility Chemical Inventories** –

   - All OSHA reportable chemicals/hazardous materials are identified in the computerized chemical inventory control system
   - Data from the PFP vessel inventory (chemicals/materials identified during the FVA and hazards analyses) are included in the inventory control system
   - The inventory control system is maintained current

2. **Controlled Storage Locations** –

   - Storage areas are clearly marked

- Storage cabinets are clearly identified with respect the types of chemicals permitted for storage in the cabinet (e.g., corrosives, flammable/combustible)
- Storage cabinets and storage locations are segregated to prevent inadvertent mixing or adverse chemical reactions
- Quantities of chemicals outside of designated storage locations are limited to a one-day supply

3. **Training** -

- All employees using, handling, or storing hazardous chemicals receive Generator Hazards training prior to performing any activity
- All employees receive facility and hazardous material emergency response training

4. **Identification, Evaluation and Control** -

- All containerized chemical products are identified and entered in the inventory control system including,
  - potentially reactive chemicals
  - hold-up chemicals
- All chemicals are evaluated at time of purchase to identify,
  - hazards
  - shelf life
  - storage requirements and location
  - potential for chemical substitutes and source reduction
- All chemicals identified during the FVA and subsequent hazards analyses are evaluated to determine,
  - remediation techniques and schedule remediation activities
- All containerized chemicals are controlled by,
  - chemicals are stored in designated storage areas
  - storage areas are inspected for proper labeling, housekeeping, container integrity, leaks, or discoloration, etc.
- Hold-up chemicals are controlled by a task team responsible for,
  - mitigation
  - sampling
  - draining, flushing, and removal of lines and vessels containing hold-up chemicals

10.4.5.3.3. PFP Chemical Hygiene Program. Three chemical laboratories operate at the PFP: the analytical laboratory, the standards laboratory and PPSL. The analytical laboratory and standards laboratory operate using plant operating procedures. PPSL develops and troubleshoots plant processes. This laboratory also conducts significant work for others. Significant test activities in the PPSL are controlled using test plans. Although, generally small scale chemical activities up to the pilot scale can be conducted in the PPSL.

The *PFP Chemical Hygiene Plan*, ZAP-000-010 is an administrative procedure that currently addresses laboratory operations. The Plan includes a discussion on hazard communication and general rules for laboratory activities, including procurement and storage of chemicals, housekeeping and

maintenance, laboratory inspections, signs and labels, and record keeping. The Plan identifies chemicals typically used in the laboratories based on health effects and physical hazards (e.g., flammability). The Plan addresses employee protection including medical consultation, exposure monitoring, PPEs, and training and reading materials. The Plan also describes accident and spill prevention and response actions should a spill or accident occur.

The purpose of the PFP Chemical Hygiene Program (CHP) is to ensure that laboratory workers are not exposed to chemical hazards exceeding regulatory requirements during laboratory operations. Furthermore, the PFP CHP ensures that laboratory activities are evaluated and are controlled such that confinement barriers will not be challenged and personnel exposures are minimized, i.e. skin contact is avoided, ventilation systems are provided, and if identified in the MSDS or during pre-task planning appropriate PPEs are available. Because all of the laboratories exist within the PFP confinement building (Building 234-5Z), the programs specified in Sections 10.4.5.3.1 and 10.4.5.3.2 are applicable.

Based on the results of the chemical hazards analyses performed at the PFP, the following items, within the PFPCHP, are critical to ensure safe handling, storage, and use of hazardous chemicals in the PFP laboratories (Ullah 2000).

1. **Informing laboratory employees of:**

    - The contents of 29 CFR 1910.1450, *Occupational Exposure To Hazardous Chemicals In Laboratories* (OSHA 1990)
    - The location and availability of the chemical hygiene plan
    - The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard
    - Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory
    - The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, Material Safety Data Sheets

2. **Training laboratory employees on:**

    - Methods and observations that may be used to detect the presence or release of a hazardous chemical
    - The physical and health hazards of chemicals in the work area
    - The measures employees can take to protect themselves from these hazards
    - The applicable requirements of the chemical hygiene plan

3. **Emergency Response Planning**

    - PFP emergency response planning incorporates the potential hazards associated with PFP's laboratory chemical inventory and potential adverse chemical reactions.

4. Test Plans

- Test plans are prepared when a laboratory activity is not subject to an approved plant operating procedure or is not a routine laboratory activity
- Test plans include a description of the specific activities evaluated; identify planned reactions, chemical reactants to be used, and their byproducts; describe potential hazards and consequences (including physical hazards) associated with the test including consideration of process upsets and equipment failures; describe the engineering barriers, and administrative controls and personal protective equipment that will be required
- Test plans are reviewed and approved by knowledgeable, independent chemical safety personnel

10.5 SCOPE OF EMERGENCY PREPAREDNESS

This section addresses the emergency planning for the Hanford Site as a whole, and the implications for the emergency preparedness program at the PFP. Two DOE documents that must be implemented are *Hanford Emergency Response Plan*, DOE-RL-94-02, and *Emergency Plan Implementing Procedures*, DOE-0223. Appendix 1-2.B of DOE-0223 is devoted to "Recognizing and Classifying Emergencies" at the Plutonium Finishing Plant. This appendix describes the initiating conditions, emergency action level, and event classification for identified PFP facility emergencies, natural emergencies, and security contingencies.

Three PFP specific procedures that are applicable are: *Building Emergency Plan for Plutonium Finishing Plant Complex*, HNF-IP-0263-PFP; *Authorization Listing of the Building Emergency Organization for PFP*, FSP-PFP-0760; and PFP Casualty Response Procedures (ZCRs). The details of the PFP emergency preparedness program are discussed in Section 10.6, Emergency Preparedness Planning.

10.5.1 Operational Emergency Classes

An accident is classified according to the severity of the emergency action level. Emergency action levels are observable criteria, such as instrument readings, equipment status indicators, analytical results, security events, natural events, and discernible events that are used to determine the extent of an operational emergency.

10.5.2 Operational Event Classes

The emergency classes covered in emergency planning for the PFP are alert, site-area emergency, and general emergency. Unusual occurrences and off-normal events are nonemergency incidents of less consequence, which may require assistance from the facility emergency response organization, as well as from organizations outside of the affected site. The emergency response procedures allow for escalation or termination when new data pertaining to the nature and magnitude of the incident are obtained.

These nonemergency categories and emergency classes are described in DOE-RL-94-02, *Hanford Emergency Response Plan*, in *Emergency Preparedness Program*, HNF-PRO-424, in addition to being posted in the emergency response centers. Definitions of the five event classifications are as follows:

1. Off-normal event--a nonemergency event that indicates degradation of, or adversely affects safety, security, environmental or health protection performance, or operation of a facility

2. Unusual occurrence--a nonemergency event that has significant impact, or potential for impact, on safety, environment, health, security, or operation of a facility

3. Alert--an event that is in progress or has already occurred, that involves a substantial reduction (actual or potential) in the level of facility safety

4. Site-area emergency--an event that is in progress or has already occurred, that involves a significant reduction (actual or likely) of facility safety, or failure of facility safety functions needed for protection of onsite personnel and the public

5. General emergency--an event that is in progress or has already occurred, that involves a catastrophic reduction (actual or imminent) of facility safety, or failure of safety functions with the potential for loss of containment or confinement integrity and/or releases exceeding protective action guideline exposure levels offsite.

10.5.3 Emergency Planning Zones

The PFP emergency planning includes identification of emergency planning zones, which are defined on the basis of the consequence analyses for the accident scenarios found in the hazard analyses for each facility. The following 200 Area zones are listed in DOE-RL-94-02:

- Plume exposure zone--the area within a 16-km (10-mi) radius for 200 Area facilities

- Ingestion exposure zone--the area within a 80-km (50-mi) radius of the Washington Nuclear Plant 2.

For an emergency limited to an onsite area, a graded approach is used to determine the required emergency response actions. For example, an event affecting only a few staff members would be handled primarily by building management and cognizant safety and medical personnel. The Emergency Operations Center (EOC) is activated when an emergency is declared. When an alert or higher classification of emergency is declared, all emergency centers are activated. Offsite emergency response activities are based on scenario-specific determinations made by responders to an emergency. Emergencies are classified in accordance with facility-specific recognition and classification procedures.

10.6 EMERGENCY PREPAREDNESS PLANNING

This section summarizes the PFP emergency preparedness planning, including activation of emergency organizations, assessment actions, notification processes, emergency facilities and equipment, protective actions, training and exercises, and recovery actions.

Emergency plans ensure that appropriate actions are taken to minimize the consequences of accidents. Emergency plans alleviate the consequences of an accident by using predetermined accident consequences in the planning, using facility conditions to determine emergency action levels, predesignating responsibilities and procedures that must be carried out in response to an emergency, and determining equipment and resources that must be available to respond to an emergency. These plans are already established for the 200 Area, and were used in planning the mitigation of the specific postulated accidents developed in Chapter 9.0.

Emergency response actions for building personnel are described in the BEP and Casualty Response Procedures for the PFP. The Hanford Site Emergency Preparedness organization, management responsibilities, and communication interfaces with the DOE-RL, EOC, and outside emergency response organizations (as well as the communication interfaces between the DOE-RL and outside agencies), are identified in the DOE-RL-94-02. This document applies to all Hanford employees and facilities. Emergency routes, access points, and assembly points for the PFP are also provided in the BEP.

As provided in HNF-IP-0263-PFP, the BED provides initial notification of an emergency to the Patrol Operations Center (POC) and the Occurrence Notification Center (ONC) on 911. The ONC then notifies DOE Headquarters and other offsite agencies. If the event is an emergency, the BED notifies the Hanford POC and ONC. The ONC provides offsite notifications and response recommendations to the offsite local, tribal, state, and federal agencies.

10.6.1 Emergency Response Organization

The Emergency Preparedness Program, including identification of the individual responsibilities within the PFP organization, is described in the BEP-PFP, HNF-IP-0263-PFP. The DOE Hanford Site Emergency Preparedness Program is described in DOE-RL-94-02. The Hanford Emergency Preparedness Program contains organizational elements necessary to ensure that the DOE fulfills its responsibilities for emergency planning, preparedness, and readiness assurance activities, and that the emergency response activities of the DOE onsite contractors are integrated with relevant local, tribal, state, and federal agency activities.

The objective of the Emergency Preparedness organization is to effectively respond to any event, whether it is an unusual occurrence affecting and requiring notification of onsite personnel only, or an emergency affecting and requiring offsite notification. The performance requirements for the Emergency Preparedness Program and its supporting plans emphasize that the program and plans be easy to understand and implement, so that they may be executed smoothly regardless of the timing (e.g., normal day shift, swing shift, back shift or holiday), experience of the emergency staff and workers

(i.e., personnel assigned as primary responders versus staff available at the time), and environmental conditions (e.g., snow, ice, high wind).

The DOE-RL manager has the overall responsibility and authority to establish, develop, and maintain an effective, integrated Emergency Preparedness Program consistent with the scope of operations, potential emergencies, and requirements in those facilities and operations under the jurisdiction of the DOE-RL. The Hanford Site management and operations contractor is assigned the responsibility for developing and implementing an Emergency Preparedness Program for the facilities it operates for the DOE, in accordance with DOE orders and DOE-RL-94-02.

The emergency preparedness plans for the PFP and the supporting DOE-RL plans follow the requirements of DOE Order 0151.1, *Comprehensive Emergency Management System*. The BEP-PFP is intended to meet all applicable requirements for BEPs, and the State of Washington requirements for hazardous and dangerous waste contingency plans.

10.6.1.1 Plutonium Finishing Plant Emergency Preparedness Organization. The PFP staff are assigned to emergency response duties on the basis of the similarity of their normal daily responsibilities to the emergency response duties, and their demonstrated ability to properly analyze data, assess situations, and make decisions under high stress conditions. The BED is responsible for assessing and categorizing an event, and if the event is categorized as an emergency, classifying the event and initiating appropriate protective actions for the welfare and safety of facility occupants and affected areas. The BED communicates with emergency staff and directs subsequent actions at the event site. Personnel are responsible for identifying health and safety issues, as well as recommending actions. Staff responsible for communication establish liaison with the DOE-RL EOC and others. Staff familiar with the facility and operations gather information directly related to the facility and event site necessary for public dissemination. A small cadre of staff assists in maintaining vital operations, planning for corrective actions (i.e., control or termination of the energy source, conditions, or situation that led to the event), and providing necessary logistical support to cope with the event (e.g., obtaining staff with specialized skills, additional protective equipment, heavy equipment). Additional specialized technical support is available by calling 911.

10.6.1.2 Incident Command Post. The Incident Command Post (ICP) provides a graduated response mechanism for unusual conditions and emergencies on the Hanford Site. An ICP shall be established when it is determined that an incident has occurred or is underway which requires a structured emergency response. The ICP shall be established in a safe location near the incident scene.

In its most basic form, the ICP may be staffed in its entirety by facility or process personnel as deemed necessary by the BED or Building Warden (BW). In these instances, the BED or BW coordinates emergency response efforts at the scene to include oversight of mitigation efforts, use of appropriate personal protective equipment, local protective actions, and relevant notifications. Examples of when ICP implementation may be carried out at this level are during small releases of known substances when

mitigation can be accomplished by trained on scene personnel, minor first aid cases, non-injury contaminations, and non-emergency plant responses.

Incidents that require the response of emergency personnel beyond the incident scene are reported to the POC via 911 and automated alarm system, where applicable. This level of response requires the designation of an Incident Commander (IC). The senior responding Hanford Fire Department officer for events involving fire, medical, hazardous materials, or rescue shall be the IC. The Hanford Patrol Shift Commander will act in the capacity of the IC during security incidents.

For events that require establishment of an ICP, organizations supporting the ICP co-locate with the IC and retain responsibility for managing their technical operations and personnel. The IC is responsible for the health and safety of all personnel at the event scene (i.e., the impacted area under his/her direct control) and for the overall management strategy associated with the incident to ensure that all functional areas are appropriately staffed and working cohesively towards mitigation of the incident.

10.6.1.3 Hanford Fire Department. The Hanford Fire Department Operations Division is the emergency response element of the department and is responsible for actions to confine and control the full range of potential fire emergencies to include radiological, structural, and wildland fire emergencies within the Hanford Site boundaries.

The Hanford Fire Department is the designated incident command agency for control of all hazardous materials incidents on the site and, as such, controls the fire, hazardous materials and/or personnel rescue response activities associated with an emergency.

The Hanford Fire Department also monitors facility fire alarm systems and coordinates and provides emergency medical services on the Hanford Site.

10.6.1.4 Hanford Patrol. The Hanford Patrol monitors alarm systems and provides security services including coordination of the movement of emergency personnel through security gates, evacuation assistance, and barricade establishment where needed. Additional law enforcement is available through agreements with local and Federal agencies at the request of RL. The Hanford Patrol is the designated incident command agency for security emergencies.

Additionally, the POC, a 24-hour operational facility, is responsible for emergency functions which include:

- acting as the single point-of-contact to initiate emergency response by
  - notifying the BED/BW (when not on the premises)
  - requesting response from the Hanford Fire Department
  - notifying appropriate on-call personnel
  - activating or requesting activation of appropriate alarm signals;

    NOTE: PNNL uses 375-2400 as the single point-of-contact

- activating the ONC conference call upon notification of a declared emergency and implementing onsite protective actions by activating warning sirens and crash alarm telephone systems; and

- receiving emergency response telephone calls during offsite shipments of RL-owned hazardous materials.

During a security event, the Hanford Patrol establishes a Tactical Operations Center (TOC), which serves as the ICP and directs response and control of the security event through direction from the RL-EOC. The TOC is established at a location that provides communications, protection of the team from event activities, and the capability to monitor the activities associated with the event.

Functions performed at the TOC include:

- directing Hanford Patrol forces at the event scene;
- coordinating Hanford Patrol resources;
- communicating with the RL-EOC for event status and direction; and
- hostage negotiation activities.

10.6.1.5 DOE-RL Emergency Operations Center. The DOE-RL Emergency Operations Center (RL-EOC) is an emergency response facility maintained by DOE-RL for the purpose of providing an area where personnel may convene during emergency conditions to provide essential response functions. These functions include public information, offsite protective action recommendations, field monitoring and sampling, hazard assessment, oversight of onsite mitigative activities, and oversight of onsite protective actions.

The RL-EOC shall be activated and operational within one hour upon declaration of an Alert level or higher emergency.

The RL-EOC may also be fully or partially activated in the following situations.

- As directed by the RL Manager, Deputy Manager, or Assistant Managers when events occur that are not classified as an Alert level or higher emergency but where action to provide monitoring or assistance to the event scene or other agencies, is requested. Such events may include:

  - Hanford Site emergency conditions that potentially involve significant onsite or offsite consequences

  - RL-declared security events (RL takes control of the emergency until relieved of law enforcement responsibilities by the Federal Bureau of Investigation)

  - natural disasters (i.e., earthquake, tornado) that could or does result in significant onsite or offsite public or environmental impact

  - requests from other government agencies for support of regional emergencies

  - threats or acts of terrorism, or when a national emergency is declared by the President of the United States or the United States Congress.

- As directed by the RAP team leader to support a RAP response.

- In response to non-DOE emergencies that affect the Hanford Site.

- In response to TEP events involving the offsite shipment of RL-owned hazardous materials.

The RL-EOC is made up of several organizations which are responsible for implementing defined emergency response tasks. These organizational areas are defined in the following subsections.

Detailed procedures for the activation, staffing, and operation of the RL-EOC are contained in DOE-0223, *U.S. Department of Energy, Richland Operations Office Emergency Plan Implementing Procedures* (DOE 1992a).

10.6.1.5.1 Policy Team. The primary functions of the Policy Team are the oversight of onsite activities, approval and communication of offsite protective action recommendations, approval of reclassification recommendations, approval and communication of RL requests for Federal assets, oversight of public information activities, and coordination with offsite agencies.

The Policy Team is staffed by the RL Emergency Manager, Public Information Director, Emergency Preparedness Advisor, Offsite Interface Coordinator, DOE-HQ Liaison, and the responding State and County representatives.

During RL-declared security events, RL is responsible for all decisions that address mitigation of the security event. This involves direction and control of Hanford Site security and patrol forces, and coordination of facility response. However, the Federal Bureau of Investigation (FBI) may exercise the option to take command of security events involving the violation of the Atomic Energy Act of 1954 or other Federal statutes. Associated response by site contractor personnel for personnel and operational safety rests with the IC and the BED.

The RL Manager is the RL Emergency Manager. In the absence of the RL Manager, the RL Deputy Manager acts as RL Emergency Manager. The RL Emergency Manager is responsible for oversight operations of the RL-EOC and for ensuring implementation of the responsibilities of RL as Lead Federal Agency (LFA). In consultation with the RL-EOC staff, the RL Emergency Manager approves emergency reclassification and termination, offsite PARs, and notifications.

Once operational, general functions of the Policy Team include:

- overviewing onsite response and mitigation actions, and providing assistance to the event contractor as needed;

- providing offsite notifications and PARs to state, local, and Federal agencies, and continuous updates to the state/counties about conditions;

- notifying the cognizant DOE-HQ Program Senior Official and the DOE-HQ Emergency Management Team if facility operations were shut down as a part of the protective action response;
- providing direction and control, as appropriate in an RL-declared security event (security declaration takes precedence in combined security/safety events);
- reclassifying or terminating the emergency;
- directing the activities of the Joint Information Center (JIC) in providing timely and accurate release of information to the public and media, including approval of all RL news releases;
- requesting additional Federal assets as needed;
- providing liaisons to offsite emergency centers and responding Federal assets;
- providing a representative to DOE-HQ as requested; and
- designating a recovery organization.

10.6.1.5.2 Joint Information Center. The primary function of the JIC is the dissemination of accurate and timely information to the public and employees about RL activities during declared emergencies. The JIC is staffed by RL, contractor, State, and County communication professionals responsible for coordinating the release of information to the public and media.

One or more Newswriter(s) reside next to the Policy Team area in order to obtain the most current information for the development of draft press releases. Once developed, the Newswriter(s) ensures that the releases are reviewed for technical accuracy and security sensitivities prior to approval by the RL Public Information Director. Upon approval, the press releases are sent to the JIC for dissemination.

The JIC provides a single location where RL and site contractors can coordinate the release of information with other Federal agencies, state, and local jurisdictions. The JIC operates under the direction of the RL Public Information Director and is managed and staffed by RL and site contractor personnel. Provisions shall be made at the JIC for representatives from the states of Washington and Oregon, plume EPZ counties, and other Federal agencies who may be involved in the emergency response.

The functions performed at the JIC include:

- preparing and coordinating information released to the public and media;
- answering questions of the public and media; and
- rumor control.

10.6.1.5.3 Site Management Team. The primary functions of the SMT are to provide support to the ICP by providing additional resources not easily obtained by the IC; tracking the status of onsite protective actions; developing and directing implementation of additional onsite protective

actions away from the event scene (i.e., the area not under the direct control of the IC) as required; and providing communications support. The SMT is also responsible for hazards assessment activities, developing additional offsite protective action recommendations, record keeping, and overall operation of the center. The SMT is made up of four support organizations that are responsible for implementing defined emergency response tasks. These organizations are defined below.

10.6.1.5.3.1 Executive Team and Support Staff. The Site Emergency Director is responsible for the coordination of all SMT activities. In this role, the Site Emergency Director is responsible for the activities of the Event Support Coordinator, EOC Operations Manager, and the Unified Dose Assessment Center (UDAC) Manager. Since RL has an operational function over Hanford security forces, the Security Director is responsible for the activities of the Security Operations Coordinator. The Security Director will receive information from and provide direction to the security forces. The Security Director will communicate planned actions of security forces to the Site Emergency Director and Safety Oversight Director to ensure all safety and security issues are addressed and coordinated. The Site Emergency Director, in conjunction with the Security Director and Safety Oversight Director, is responsible for periodically providing status information to the RL Emergency Manager on the Policy Team. The Contractor Representative and SMT Emergency Preparedness Advisor provide support to the Site Emergency Director.

10.6.1.5.3.2 Security and Event Support. As part of the SMT staff, the Security Operations Coordinator's primary functions are security operations, which include interface with local law enforcement agencies, coordination with the FBI, and oversight of onsite patrol activities. In this role, the Security Operation Coordinator reports directly to the Security Director.

The Event Support Coordinator is responsible for event support activities to include site support services, technical support, communications with the event scene, and coordination with the Emergency Decontamination Facility. In this role, the Event Support Coordinator reports directly to the Site Emergency Director.

10.6.1.5.3.3 Unified Dose Assessment Center. As part of the SMT, the primary UDAC functions are monitoring and evaluating existing emergency conditions in order to develop additional protective action recommendations. The UDAC is responsible for field team activities to include plume tracking, monitoring, and sampling.

Representatives from the states of Washington and Oregon participate in the development of recommendations and provide direction for offsite environmental monitoring. The UDAC is operated by site contractor personnel with knowledge in the technical areas of meteorology, toxicology, industrial hygiene, and health physics. The UDAC Manager is responsible for all UDAC activities. In this role, the UDAC Manager reports directly to the Site Emergency Director.

Specific UDAC responsibilities include:

- acquiring necessary data and measurements to evaluate personnel radiation doses and chemical exposures resulting from the event;

- assessing the potential for onsite and offsite consequences of a release of radioactive or nonradioactive materials based on meteorological conditions, source term, location and dispersal of the hazardous material;

- assisting the event contractor or other Hanford Site contractors in onsite hazard assessment or development of onsite protective actions;

- analyzing the consequences associated with evacuating versus remaining in a take cover situation for onsite personnel and recommending appropriate additional protective actions if necessary;

- developing offsite PARs in coordination with representatives from the states of Washington and Oregon; and

- coordinating and directing emergency environmental monitoring teams that are not assigned to the event facility. This may include state field teams performing offsite monitoring if requested by the states.

10.6.1.6 Outside Agencies. The DOE-RL and Contractor respond to all emergencies within the Hanford Site boundary (DOE Order 0151.1). The DOE-RL and its contractors have established agreements to coordinate responses to emergencies. The coordination agreements for the emergency responses of both onsite and offsite organizations are described in this section. The Hanford contractors' familiarity with Hanford facilities allows them to assist in emergency events with a minimum of direction.

10.6.1.6.1 Memorandums of Understanding. Notification and response for an event with a potential offsite impact or one that may require additional support from offsite agencies are prescribed by MOUs. Initial offsite notifications are made by the BED through the ONC. The EOC team has the responsibility for further offsite communications or requests.

Several MOUs are in place involving offsite agencies surrounding the Hanford Site. The DOE-RL, Benton County, Franklin County, Grant County, and the states of Washington and Oregon have MOUs that describe the planning, communication, and response to Hanford Site emergencies that may have offsite consequences. An MOU among the DOE-RL, the the Energy Northwest, Benton and Franklin counties, and the Thirteenth Coast Guard District is in place to ensure the safety of the Columbia River during an emergency at the Hanford Site and to provide guidelines for river evacuation. Another MOU between the DOE-RL and Energy Northwest provides for mutual assistance in the use of facilities and equipment for personnel decontamination, first aid, evacuation reassembly areas, respiratory protective equipment, protective clothing, vehicles (including the use of ambulances), radiological surveying equipment, resources for river evacuation, and radiological assistance. The DOE-RL also has an agreement with the Washington Area National Weather Service that defines the mutual responsibilities for providing meteorological information in an emergency situation. The Federal Aviation Administration (FAA) has agreed to establish flight restrictions surrounding the Hanford Site during emergencies, as requested by the DOE-RL.

MOUs are also in place between Hanford emergency and security personnel and surrounding site agencies. Mutual aid agreements for support of the HFD have been established with the Richland, Kennewick, and Pasco Fire Departments; Benton County Fire Districts 1, 2, and 4; Franklin County Fire District 3; and Walla Walla Fire District 5. The Hanford Patrol, the physical security agency for the Hanford Site, has several MOUs established with area law enforcement agencies to provide additional backup capabilities.

10.6.1.6.2 Medical Support. The HEHF provides professional medical support for the entire Hanford Site. Doctors and nurses who are trained to work with personnel contaminated with a radioactive source or exposed to a hazardous material are available for emergency assistance during normal duty hours. Hospital services are provided by Kadlec Medical Center in Richland, with backup service at Kennewick General Hospital and Our Lady of Lourdes Health Center in Pasco. Ambulance service with qualified emergency medical technicians and paramedics as attendants is provided 24 h/day by the HFD.

An exposure evaluator, also available 24 h/day for consultation and assessing radiation doses, is notified whenever there is an inhalation, ingestion, or injection of a radioactive or hazardous substance.

An RCT, with the appropriate radiation monitoring instruments, accompanies any patient contaminated with radioactivity to the hospital and provides continued monitoring for the patient and hospital premises as needed.

Severely contaminated injured patients are treated in the Emergency Decontamination Facility (EDF) (also referred to as the 748 Building), which provides for both isolation and decontamination. The EDF is located immediately north of Kadlec Medical Center in Richland. The only exception is if the injury is so severe that immediate medical attention in a hospital is necessary. The HEHF directs activation of the EDF and uses personnel from Kadlec Medical Center or other organizations as necessary. Additional details of the EDF are provided in Section 10.6.4.1.2.

10.6.2 Assessment Actions

The UDAC provides onsite and offsite dose consequence projections (see Section 10.6.1.5.3.3).

10.6.3 Notification

Notification of an emergency may be initiated by a staff person who becomes aware of a condition that may affect occupants or operations (see Section 10.4). When the automatic or manual actuation of a building alarm (such as fire) is the alerting mechanism, the alarm is automatically relayed to the POC. If an alarm is not the initiating action, a staff person calls PAX 222, 911 or 373-3800 and provides their name, and the nature and exact location of the emergency. Staff in the building, area, or on the Hanford Site in general are notified about the emergency by one or more of the following emergency warning systems.

- Building public address system. A public address system (referred to as the PAX system) is used for incidents that affect only the PFP complex.

- Hanford Site standard emergency alarm signals. These signals sound different alarms (gongs, sirens, bells, etc.) depending on the emergency situation. Specific emergency alarms for the PFP are listed in the BEP.

- Crash alarm telephone system. This telephone system is used to disseminate emergency messages and is normally activated by the POC, which has been notified by a BED that an emergency exists. Dialing a single number connects the initiator to a set of predetermined telephones across the site. The location of crash alarm telephones that serve the PFP are provided in the BEP. Persons receiving the crash alarm telephone messages notify the BED and forward instructions to other personnel in the area who do not have crash alarm telephones, by standard telephone, radios, or word-of-mouth.

10.6.3.1 Public Information. The public information plan provides instructions for the implementation, operation, and activities of the DOE JIC during emergency situations at the Hanford Site. The plan states that each event will be handled on a case-by-case basis to determine which provisions of the plan will be implemented. The JIC is always activated in the event of an alert or higher classification of emergency.

The DOE and Hanford contractors are directed to make prompt and accurate information available to the public by DOE-0223 (DOE-RL 1997). Audiences served by the JIC are the media; local community; onsite employees and emergency workers; elected federal, state, and local officials; DOE Headquarters; federal, state, and local agencies; and special interest groups.

10.6.3.2 Records. The record-keeping process for emergency preparedness includes taping telephone conversations with emergency response centers and collecting written records generated during the emergency. Much of the communication within and among emergency centers occurs via written emergency messages that can be stored for future reference.

10.6.4 Emergency Facilities and Equipment

The PFP is responsible for maintaining facility emergency equipment and ensuring that it is complete and in working order. All emergency kits are inventoried and/or calibrated, and all items removed for testing or maintenance are simultaneously replaced. Stored emergency kits are maintained in a complete and working condition. Contractor emergency management staff are responsible for maintaining the communications equipment in the DOE-RL EOC.

10.6.4.1 Emergency Facilities. The following emergency facilities and resources are available to the PFP.

10.6.4.1.1 Medical. As described in Section 10.6.1.4.2, professional medical help is available to provide emergency assistance for the entire Hanford Site at any time.

A Health Care Center staffed by trained medical personnel is located in the 200 West Area and is available for response to other areas. Injured or contaminated persons can be treated by the nurse during normal day shift hours Monday through Friday, and transported offsite to the hospital or emergency decontamination if necessary. Medical assistance is also available 24 h/day from the 200 E Health Care Center.

10.6.4.1.2 Radiation and Contamination Assessment. Two facilities, the EDF (748 Building) and the Invivo Radioassay and Research Facility (747A Building), are available for evaluating the radiation exposure of contaminated individuals. Both facilities are staffed by PNNL, HEHF, and Kadlec personnel and are located adjacent to the Kadlec Medical Center.

747A Building (Invivo Radioassay and Research Facility; Whole Body Counter). This facility is available for performing whole body and lung counts, as well as routine whole body counts. The PNNL Radiation Control staff assigned to the 747A Building can perform portable whole-body radiation counting near the event scene, or offsite if an event warrants such support. Special bioassay and external dose measurement can also be arranged for by the PNNL's Hanford exposure evaluator. Since this facility is part of the Federal Radiological Monitoring and Assessment Program, a substantial inventory of emergency supplies and equipment is stored in a mobile trailer near the whole-body counter. This equipment includes radiation detection/measurement instrumentation and protective clothing kits. The equipment is available for use in emergencies occurring on the Hanford Site.

748 Building (Emergency Decontamination Facility). This facility provides radiosurgery for highly contaminated individuals, as well as providing whole body counting and wound counting. The facility is equipped with emergency decontamination utilities (showers, etc.) and shielded bays to prevent contamination of staff personnel from contaminated patients.

10.6.4.1.3 Federal Emergency Response Assets. The DOE-RL EOC may also request activation of the appropriate DOE Federal Emergency Response Assets to assist in monitoring and assessment for radiological emergencies. These assets include the Aerial Measuring System, the Atmospheric Release Advisory Capability, the Federal Radiological Monitoring and Assessment Center, and the Radiological Emergency Assistance Center.

10.6.4.2 Emergency Equipment. Emergency equipment is used primarily to protect emergency response personnel and to mitigate an accident or incident consequences. The emergency equipment includes protective clothing, respiratory protection equipment, equipment for cleanup or control of hazardous chemical spills, first-aid kits, firefighting equipment, and emergency response team identifiers (e.g., hard hats, arm bands, vests). Lists of facility-specific equipment and its location, including fixed and portable emergency equipment, are provided in the BEP and emergency response guides (WHC-IP-1045-PFP). A portable whole-body counter located in the 200 East Area is also available for use, at the event site or offsite, as needed.

10.6.4.2.1 Hazardous Materials Response Vehicles. In addition to facility-specific equipment, the 200 Area Fire Department has a hazardous materials response vehicle and a crew of trained hazardous materials responders available at all times. The vehicle is equipped with the supplies

necessary to detect, contain, and mitigate or neutralize hazardous materials. The unit is able to respond to the following nine classes of hazardous materials: (1) explosives; (2) gases; (3) flammable liquids; (4) flammable solids, spontaneously combustible materials, and materials that are dangerous when wet; (5) oxidizers and organic peroxides; (6) poisonous and etiologic (infectious) materials; (7) radioactive mixed waste materials; (8) corrosives; and (9) miscellaneous hazardous materials.

10.6.4.2.3 Richland Operations Office Emergency Operations Center. The DOE-RL EOC is equipped with telephones, radios, telefax machines, emergency plans, maps, status boards, etc.

10.6.4.2.4 Other Emergency Control Equipment and Supplies. Several sources of equipment and supplies are available on the Hanford Site for use in controlling and mitigating the consequences of an emergency situation. A large variety of light and heavy equipment and supplies that could be diverted from routine to emergency use, if needed, are maintained at the Hanford Site.

Through a mutual-aid agreement, WPPSS has agreed to provide emergency facilities and equipment for personnel decontamination, first aid, evacuation reassembly, and respiratory protection, as well as protective clothing, vehicles, and survey instruments. The WPPSS has also agreed to provide information on radiological conditions, meteorological data, and other necessary environmental data.

Radiological monitoring teams can gain access to the east and north sides of the Columbia River with a boat made available by PNNL. Arrangements are in place for aerial surveillance and monitoring through the UDAC. The radiological monitoring teams, the Hanford Patrol, and the HFD have radio-equipped vehicles in use on a daily basis that may be used in the event of an emergency.

10.6.4.3 Communications Equipment. The telephone systems are the primary source of communication, with radios serving as backup. Telephone communication can take place via the commercial telephone system and dedicated telephone lines. Several radio systems and frequencies are available for emergency communication. The Safety Net is a dedicated radio frequency for communication between emergency centers and field teams.

10.6.4.3.1 Plutonium Finishing Plant. Emergency communication equipment consists of the following:

- Building public address system for events that affect only the PFP complex
- Hanford Site standard emergency alarm signals (described in DOE-RL-94-02)
- Crash alarm telephones to disseminate emergency messages (dialing a single number connects the initiator to a predetermined number of telephones)
- Two-way radios and cellular phones.

10.6.4.3.2 Not Used

10.6.4.3.3 Richland Operations Office Emergency Operations Center. The following is a list of the emergency communication routes available to the DOE-RL EOC:

- A telephone system installed with sufficient instruments to contact onsite and offsite groups, DOE headquarters, and federal agencies
- A conferencing bridge to provide communications between the incident command past and the DOE-RL EOC
- A base radio system located in the DOE-RL EOC Security Room, with frequencies for the Hanford Patrol, Hanford Tactical, Hanford Fire, Hanford Safety (the dedicated Safety Net emergency frequency), the Benton County EOC, Franklin County, Grant County, Benton County Law Enforcement Primary, the Law Enforcement Radio Network, WPPSS, and the Coast Guard
- A dedicated communication system for notifying and communicating with the WPPSS, Benton and Franklin counties, and the Washington State EOC (a facsimile transmission of the notification form is sent to verify verbal information concerning the event)
- A secure phone located in the DOE-RL EOC
- Cellular phones.

10.6.4.3.4 Miscellaneous Communication Information. The Hanford Site ONC, the POC, and DOE-RL EOC can communicate 24 h/day by radio, telephone, and telefax with emergency dispatch centers in Benton and Franklin counties, WPPSS, the sheriffs of Benton and Franklin counties, the Washington State Patrol, the state of Washington ECC, the management and duty officers of DOE-RL, and onsite support response organizations. The National Warning Service Circuit, located in the POC, can be used as a backup notification channel to the state and counties in the event that contact cannot be made by telephone. Descriptions of the communications capabilities for the state and local emergency centers are given in the state and local emergency plans.

10.6.5 Protective Actions

Protective actions are taken during an emergency to prevent or minimize actual or projected exposure to releases of hazardous radioactive or nonradioactive materials. Specific actions are typically sheltering or evacuation, or the use of time, distance, and, shielding to reduce exposure to hazardous materials by emergency workers and the public.

The BED uses facility emergency action levels to classify the event as an operational, security, or natural emergency. The event is classified by the BED according to the event recognition and classification procedure that is based on the emergency classification criteria discussed in Section 10.5.2. The BED either evacuates the facility or directs the facility to take cover, and contacts the POC for all additional protective actions that are kept on the POC checklists specific to each area.

Predetermined emergency planning zones are also used in response actions. Specific requirements regarding protective actions listed in DOE Order 0151.1 are addressed as follows:

- Offsite recommendations are made through the DOE-RL EOC to the appropriate state, tribal, and local authorities
- Workers evacuated from the site undergo radiological and hazardous material surveys and decontamination as necessary (see Section 10.6.1.4.2)
- Field teams equipped with instruments capable of detecting radiological or hazardous materials are deployed to determine the area actually affected by an operational emergency
- The emergency response team uses specific procedures to account for all facility personnel within 30 min; BEP describes procedures, assembly areas, transportation methods, and evacuation routes
- During response activities, control of emergency worker exposures to hazardous materials is guided by radiological and nonradiological criteria in DOE-RL Emergency Plan 4.0 of DOE-0223 (DOE-RL 1993); systems already in place for monitoring exposures and maintaining records are used
- Radiological and hazardous material decontamination of equipment evacuated from the site is performed as necessary.

10.6.6 Training and Exercises

10.6.6.1 Training. Emergency response training is conducted at all levels (i.e., the facility, area, DOE-RL EOC). Specialized individual training programs are provided for Hanford Site contractors, the DOE-RL staff, and non-DOE emergency personnel. Training includes initial training and retraining, as appropriate. In addition, personnel perform periodic exercises and drills. The PFP training program is contained in FSP-PFP-1121.

10.6.6.2 Drills and Exercises. HNF-PRO-424, *Emergency Preparedness Program*, requires all Hanford Site exercises to be developed and conducted in accordance with DOE orders. All exercise scenarios are reviewed by the Contractor exercise project officer, DOE-RL Emergency Preparedness, facility representatives, Contractor Safety, and Contractor Safeguards and Security. If appropriate, scenarios are also reviewed by the Contractor Environmental Program, Contractor Radiological Engineering, the Hanford Patrol, the HFD, HEHF Industrial Safety, an HEHF medical representative, appropriate site contractor representatives, and PNNL.

The extent, type and frequency of PFP drills are the responsibility of the plant manager, who is responsible for coordinating these drills with affected organizations, including nearby facilities, the HFD, Hanford Patrol, etc.

10.6.6.2.1 Drills. Drills are supervised instruction periods aimed at either training or testing skills in a particular function or operation.

Hanford Site emergency personnel participate in periodic subsystem drills and exercises in addition to an annual exercise. Drills are conducted at the PFP at least annually to maintain proficiency in emergency response for credible emergencies. These drills may include scenarios and response needs for fire, evacuation, sheltering, security, loss of utility, contamination spread, and hazardous material containment.

10.6.6.2.2 Hanford Sitewide Exercises. DOE orders establish guidelines for the planning and conduct of major sitewide emergency exercises. An exercise is conducted annually to test the integrated capabilities, as well as a major portion of the basic elements in the emergency plans and procedures for DOE-RL and the Hanford management and operations contractors. These exercises include offsite participation by counties and states.

10.6.6.2.3 Emergency Drill and Exercise Critiques and Follow-Up. Oral critiques, with all players at each location, are conducted immediately following the exercise. The evaluators of the event note all comments and consider them for input into the formal critique of the event. In addition, all evaluators provide immediate feedback to the participants relative to accomplishment of the exercise objectives.

Evaluators complete the evaluation forms provided in the exercise manual for their area of responsibility. The project officer compiles the evaluations into a final critique after review by the exercise director, exercise committee, evaluators, and action item responders. An exercise closeout meeting is held as needed to resolve any remaining issues pertaining to the final critique. The project officer forwards the final critique, with corrective action plans, to the DOE-RL within six weeks from the date the exercise was conducted. All corrective action items are incorporated into a tracking system.

10.6.7 Recovery and Reentry

Actions to be taken after an emergency situation has been stabilized are specified in DOE-0223, DOE-RL-94-02, and HNF-PRO-424. Actions generally fall into the categories of emergency event termination, reentry, and recovery.

10.6.7.1 Emergency Event Termination. The emergency can be officially terminated and closed out when the event has been stabilized and protective actions have been implemented. Termination and closeout is the responsibility of the highest activated agency, and occurs after all applicable criteria have been met and concurrence between the event contractor and the DOE-RL has been obtained. The applicable criteria for closeout are found on the closeout checklist and include the following:

- The event scene is in a controlled and stable condition
- Release of hazardous material is controlled to less than emergency action levels (i.e., radiation levels, airborne radioactivity, and hazardous materials concentrations are determined to be stable or decreasing, and below alert-level criteria)
- Fire, flooding, or similar emergency conditions are controlled or have ceased

- Damage to facilities and process-related systems and equipment are stabilized or corrected
- Contaminated and injured individuals have been properly treated, or transferred to a hospital or suitable treatment facility
- Security of the affected facilities is controlled.

All relevant onsite entities, as well as the DOE and relevant state, county, and offsite agencies, are notified of an event's termination.

10.6.7.2 Reentry. Reentry is the act of reentering an evacuated area to perform emergency activities, or to assess facility damage to determine if the emergency can be terminated and the recovery activities that are required. Reentry can be performed at any time before termination of the emergency and during recovery activities.

The DOE-RL EOC emergency manager approves reentry to an event area, except when time-urgent actions are required to save a life, minimize injuries, or prevent or minimize damage. When time-urgent actions are required, reentry may be authorized by the event commander or the Emergency Response organization.

Reentry investigations are performed by reentry teams. Objectives and specifications for members of the reentry teams (including at least one RCT or industrial hygienist, depending on the nature of the event) are established. The Site Emergency Director is responsible for ensuring that the event commander (or designee) provides a pre-entry briefing to the reentry teams. Work is conducted in accordance with the process described in Section 10.4.3. Hazardous material work is conducted in accordance with established industrial hygiene requirements. The reentry team is debriefed after exiting.

10.6.7.3 Recovery. A recovery organization is formed to plan and implement the activities necessary to return the affected facility and surrounding areas to normal upon termination of the emergency event. The recovery organization also supports the offsite recovery efforts of federal, state, and local agencies.

The recovery organization is composed of at least two teams; support and onsite recovery. The recovery support team provides oversight for the onsite recovery effort, and provides information and assistance to offsite agencies. The onsite recovery team is responsible for developing and implementing the onsite recovery plan. This team includes engineering, operations, support services, safety, and planning experts. For a nuclear facility emergency, members are assigned to the Washington State Fixed Nuclear Facility Reentry and Recovery Task Force, which is responsible for coordinating offsite recovery in its jurisdictional area.

Upon completion of the initial reentry team assessment and evaluation activities, the Site Emergency Director is responsible for implementing recovery actions in compliance with normal site requirements and procedures. This includes an investigation in accordance with DOE-RL Order 0225.1, *Accident Investigations*.

10.7 DECONTAMINATION AND DECOMMISSIONING

Activities required to accomplish decontamination and decommissioning (D&D) of facilities are described in Section 10.7.1. Previous experience with D&D activities is presented in Section 10.7.2.

10.7.1 Decontamination and Decommissioning Activities

DOE Order 6430.1A *General Design Criteria*, requires that facilities where radioactive materials are used to be designed to simplify ultimate facility decommissioning and disposal or reuse. The D&D activities are an integral part of the overall scope of the management of DOE-owned, contractor-operated facilities.

The disposition of a facility is conducted to meet all applicable laws, DOE orders, codes, and standards. The approach consists of five phases and encompasses all project activities, from post-operational characterization through project final reporting. The five phases include the following.

1. Post-Operational Characterization--thorough chemical, physical, and radiological characterization of the project facilities

2. Environmental Review Process--a series of planning, evaluation, public comment, and decision-making steps required by the National Environmental Policy Act (NEPA); the Resource Conservation and Recovery Act (RCRA); and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

3. Engineering--preparation of detailed technical, administrative, cost, and schedule information

4. Decommissioning Operations

5. Post-Decommissioning--conduct of final radiation and hazardous chemical surveys, and preparation of project completion records.

The D&D activities are responsive to CERCLA and other environmental requirements and involve the following activities: preliminary assessment, site investigation, remedial investigation, feasibility study, and site remediation.

With the conclusion of the operating mission at the PFP, the facility will be deactivated to meet regulatory requirements and turned over to the Hanford Site Environmental Remediation Contractor for surveillance and maintenance to maintain the facilities in a safe condition until D&D activities are initiated. Plans for both deactivation and D&D will be prepared before any activities are initiated.

10.7.2 Decommissioning Experience

The D&D activities involving both in-plant and onsite plutonium-contaminated facilities have been conducted at the Hanford Site for the past 25 yr.

Such activities have been conducted in the PFP on specific gloveboxes and other areas of the plant as facility missions have changed, and gloveboxes and equipment have been upgraded and/or replaced. In addition to TCO of miscellaneous gloveboxes, ducting, and piping, the 232 Building has undergone TCO and HVAC isolation. Project B-634, "Improved Plutonium Nitrate Handling Facility," involves the D&D of the 242-Z Building. Portions of unused piping and duct work are being removed to reduce radiation levels and to reduce overall risk. Such efforts are managed by Nuclear Material Stabilization Operations. Earlier in-plant experience includes the decommissioning of the rubber glove line, the Recuplex plutonium facility, the Division of Military Applications plutonium fabrication facilities, replacement of hoods 27 and HC-30, portions of the 232-Z Building, and portions of the Radioactive Acid Digestion Test Unit facility.

Onsite D&D experience is also rather extensive and includes the decommissioning of the P-11 plutonium-contaminated Critical Testing Facility, portions of the 231-Z Building, the 233-S Plutonium Concentration Facility, and the 201-C Strontium Semiworks.

10.8 PFP CONDUCT OF OPERATIONS IMPLEMENTATION

Criteria for the development of DOE compliant conduct of operations program at the PFP is provided by DOE Order 5480.19, *Conduct of Operations Requirements for DOE Facilities*. The conduct of operations program at PFP is developed and implemented primarily through the administrative procedures contained in FSP-PFP-0821, *PFP Conduct of Operations*. The program described in this manual meets the requirements of DOE Order 5480.19 and covers the following topics in detail:

- Operations Organization and Administration
- Shift Routines and Operating Practices
- Control Area Activities
- Communications
- Control of On-Shift Training
- Control of Equipment and System Status
- Lockouts and Tagouts
- Independent Verification
- Logkeeping
- Operations Turnover
- Operational Aspects of Facility Chemistry and Unique Processes
- Required Reading
- Timely Orders to Operators
- Operator Aid Postings
- Plutonium Operations Tickle File
- Control of Locked Equipment
- Housekeeping
- Keys, Locks and Combination Control

Specific chapters/sections of other PFP procedures/manuals further implement some of the requirements of DOE Order 5480.19, including the following:

- FSP-PFP-5-8, *Plutonium Finishing Plant Administration*
- FSP-PFP-0848, *PFP Facility Engineering Directives*

- FSP-PFP-0887, *PPSL Required Reading*
- FSP-PFP-1121, *Plutonium Finishing Plant Training Administration*

The specific procedure, chapter, and section that implements each part of the 18 chapters of the DOE Order are defined in the *Conduct of Operations Applicability Summary*, Memo 15000-98-026 dated August 24, 1998 (FDH 1998).

REFERENCES

Documents

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DOE, 1993, *Occupational Radiation Protection*, Title 10, Code of Federal Regulations, Part 835 (Part IV), U.S. Department of Energy, Washington, D.C.

DOE, 1995, *Plutonium Finishing Plant Safety Evaluation Report*, DOE/DP-0130, U.S. Department of Energy, Office of Defense Programs, Washington, D.C.

DOE-RL, 1994, *Hanford Site Radiological Control Manual*, HSRCM-1, Rev. 2, U.S. Department of Energy, Washington, D.C.

DOE-RL, 1997, *Emergency Plan Implementing Procedures*, DOE-0223, U.S. Department of Energy-Richland Operations Office, Richland, Washington.

DOE-RL-93-75, *Hanford Contingency Plan*, U.S. Department of Energy-Richland Operations Office, Richland, Washington.

DOE-RL-94-02, *Hanford Emergency Response Plan*, U.S. Department of Energy-Richland Operations Office, Richland, Washington.

FDH, 1998, *Contract No. DE-AC06-96RL13200 - Receipt of Plutonium Finishing Plant's Conduct of Operations Applicability Matrix*, (Letter L. J. Olguin, FDH, to R. D. Redekopp, BWHC, FDH-9857026, dated August 24), Fluor Daniel Hanford, Inc., Richland, Washington.

FSP-PFP-5-8, *Plutonium Finishing Plant Administration*, B&W Hanford Company, Richland, Washington.

FSP-PFP-0760, *Authorization Listing of The Building Emergency Organization for PFP*, B&W Hanford Company, Richland, Washington.

FSP-PFP-0821-PUO, *Plutonium Operations Administration*, B&W Hanford Company, Richland, Washington.

FSP-PFP-0840, *PFP Facility Engineering Directives*, B&W Hanford Company, Richland, Washington.

FSP-PFP-0887, *PFP Process Support Laboratories*, B&W Hanford Company, Richland, Washington.

FSP-PFP-1121, *Plutonium Finishing Plant Training Administration*, B&W Hanford Company, Richland, Washington.

HNF-IP-0263-PFP, *Building Emergency Plan for Plutonium Finishing Plant*, B&W Hanford Company, Richland, Washington.

HNF-IP-1054, *Plutonium Finishing Plant Emergency Response Guides*, B&W Hanford Company, Richland, Washington.

WHC-SD-CP-OSR-010, *Operational Safety Requirements for the Plutonium Finishing Plant*, B&W Hanford Company, Richland, Washington.

WHC-SD-CP-SAR-021, *Plutonium Finishing Plant Safety Analysis Report*, B&W Hanford Company, Richland, Washington.

Hanford Contractor Procedures

HNF-PRO-055, *Startup and Restart of Facilities*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-060, *Reporting Occurrences & Processing Operations Information*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-173, *Implementing Training*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-210, *Records Management Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-224, *Document Control*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-225, *Distributing Copy - Controlled Unclassified Documents*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-229, *Technical Procedure Standard*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-424, *Emergency Preparedness Program*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-440, *Engineering Document Change Control Requirements*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-446, *Testing Practices Requirements*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-453, *Environmental Notification and Reporting*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-696, *Conduct of Operations Policy*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-700, *Safety Analysis and Technical Safety Requirements*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-PRO-704, *Hazard and Accident Analysis Process*, Fluor Daniel Hanford, Inc., Richland, Washington.

WHC-CM-4-14, *Applied Radiological Controls*, Westinghouse Hanford Company, Richland, Washington.

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DOE Order 0151.1, *Comprehensive Emergency Management System*, U.S. Department of Energy, Washington, D.C.

DOE Order 0232.1, *Occurrence Reporting and Processing of Operations Information*, U.S. Department of Energy, Washington, D.C.

DOE Order 4700.1, *Project Management System*, U.S. Department of Energy, Washington, D.C.

DOE Order 5480.19, *Conduct of Operations Requirements for DOE Facilities*, U.S. Department of Energy, Washington, D.C.

DOE Order 5480.20A, *Personnel Selection, Qualification, and Training Requirements*, U.S. Department of Energy, Washington, D.C.

DOE Order 6430.1A, *General Design Criteria*, U.S. Department of Energy, Washington, D.C.

DOE-RL Order 0225.1, *Accident Investigations*, U.S. Department of Energy-Richland Operations Office, Richland, Washington.

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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 11.0

OPERATIONAL SAFETY REQUIREMENTS

FEBRUARY 2001

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PREFACE

In accordance with the letters of approval of the Operational Safety Requirements (OSRs) from DOE-HQ (see Note 1) and DOE-RL (see Note 2), the OSRs presented in WHC-SD-CP-OSR-010, are approved for implementation at the PFP. The requirements contained in WHC-SD-CP- OSR-010 are in compliance with and implemented in accordance with DOE 5480.22.

As with Technical Safety Requirements (TSRs), the OSRs are consistent with: (a) the current plant configuration and mission, and (b) the accident analyses presented in Chapter 9.0.

NOTE 1: DOE-HQ Memorandum, Donald F. Knuth, Acting Deputy Assisstant Secretary for Facility Transition and Technical Support to Manager Richland Operations Office, May 20, 1994. "Approval of Plutonium Finishing Plant Operational Safety Requirements"

Note 2: DOE-RL Letter 94-OPB-54, J. E. Mecca, Director Operations and Transition Division, to President, Westinghouse Hanford Company, May 23, 1994. "Approval of Operational Safety Requirements for the Plutonium Finishing Plant".

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PLUTONIUM FINISHING PLANT
FINAL SAFETY ANALYSIS REPORT

CHAPTER 12.0

QUALITY ASSURANCE

FEBRUARY 2001

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PREFACE

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12.0 QUALITY ASSURANCE

12.1 POLICY

B&W Hanford Company (BWHC) under a Project Hanford Management Contract (PHMC) operates the Plutonium Finishing Plant (PFP). BWHC's PFP Quality Assurance (QA) organization is committed to excellence in its work and delivering to the customer the highest quality products and services available. BWHC will continue to seek to comprehend and comply with the customer's requirements and expectations, while maintaining cost effective performance of services and activities.

Directors and Managers at PFP take full ownership of the PFP Quality Assurance Program, are responsible for its implementation, ensure quality objectives are established, measured and met, and ensure work is conducted in a disciplined and cost effective manner.

Employees are responsible to achieve quality through thorough analysis, detailed planning and adherence to procedures and work controls. Post-job feedback is used to achieve continuous improvement and high quality in work performance at PFP.

12.2 INTRODUCTION

BWHC subcontract #8023764-9-K002, Clause 55, with the PHMC Prime Contractor requires BWHC to implement the *Project Hanford Quality Assurance Program Description* (QAPD), HNF-MP-599. Nonreactor nuclear facilities such as PFP are subject to the requirements of Title 10, *Code of Federal Regulations*, Part 830.120, *Quality Assurance Requirements* (10CFR830.120). As required by 10CFR830.120, the PHMC prime contractor has an approved Quality Assurance Program Description (QAPD) and submitted to the U. S. Department of Energy (DOE) Richland Operations an implementation plan (IP), HNF-SP-1228 that is subject to enforcement under 10CFR820, *Procedural Rules for DOE Nuclear Activities*. BWHC has developed and promulgated the *Facility Stabilization Project Quality Assurance Program Plan* (QAPP), FSP-MP-004, to describe and implement Quality Assurance requirements for all facility stabilization and advanced reactor projects subject to BWHC control at Hanford. The quality assurance program for PFP satisfies the requirements identified in the *PFP Standard Requirements Identification Document*, HNF-SD-MP-SRID-003, HNF-MP-599, the IP approved for use at Hanford, 10CFR830.120, and the BWHC QAPP, FSP-MP-004. The QAPP for the PFP is tailored to the needs and activities of BWHC at PFP. Since this QAPP is an administrative tool, it is promulgated in the *PFP Administrative Manual*, FSP-PFP-5-8, Section 15.1.

12.3 PROGRAM

The PFP QAPP, FSP-PFP-5-8, Section 15.1, fully describes the responsibilities, functions, requirements, and structure needed to accomplish BWHC's tasks of maintaining a safe facility and stabilizing wastes at PFP. This plan references higher tier documents, such as HNF-MP-599, where needed, rather than restate requirements or information contained therein. In like fashion, this chapter of the PFP facility Final Safety Analysis Report

references the FSP-PFP-5-8, Section 15.1 procedure (QAPP) rather than restate the information contained or referenced therein.

REFERENCES

Documents

10CFR820, *Procedural Rules for DOE Nuclear Activities*, Code of Federal Regulations, as amended.

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HNF-MP-599, *Project Hanford Quality Assurance Program Description*, B&W Hanford Company, Richland, Washington.

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LABORATORY PROTOTYPE CALCINER

ADDENDUM TO PLUTONIUM FINISHING PLANT FINAL SAFETY ANALYSIS REPORT

NOT AUTHORIZED FOR OPERATION

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This addendum to the Plutonium Finishing Plant (PFP) Final Safety Analysis Report (FSAR) (FDH 1999) provides the basis for authorization for testing of the Laboratory Prototype Calciner. Testing of the calciner involves processing of plutonium-bearing solutions to produce a dry plutonium oxide product. This FSAR addendum is necessary to permit processing of reactive plutonium-bearing solutions in the calciner to a stable dry form. Solution processing for testing of the laboratory calciner is not specifically addressed in the current PFP FSAR.

The scope of this addendum includes the operations, equipment and controls necessary for safely converting plutonium-bearing solutions to a stable dry material for long term storage. The addendum covers operations involving loadout of solutions from Glovebox HC-227S, interim storage of solutions, transfer of solutions to Glovebox 188-1, processing of solutions in Glovebox 188-1, and transfer of calcined material from the product receiver vessel to ½ L slip-lid cans inside Glovebox 188-1. Although the addendum discusses sampling and packaging of the calcined product and transfer of the product to storage, these operations are included for completeness and are not specifically covered by this addendum. Information is provided in this addendum on the process chemistry, the equipment and operations used to process the solutions, the potential hazards involved in the operations and the appropriate controls to minimize the hazards. The addendum also defines the appropriate safety classification for the equipment used in the process. It is noted that operation of the calciner equipment occurs essentially as a batch process and, therefore, is of an intermittent nature. The accident analysis provided in this addendum does not consider the intermittent operation of the calciner when evaluating the annual likelihood of the postulated events.

This addendum complies with the requirements for activity based safety basis documents as defined in the criteria document for the 1999 FSAR update (BWHC 1999a).

1.2 BACKGROUND

The end of the "cold war" and resultant reductions in nuclear weapons production requirements left many U.S. Department of Energy (DOE) processing plants with large inventories of plutonium and uranium in various forms which are not suitable for long term storage. In 1995, the DOE issued its plan for dispositioning the excess inventories throughout the DOE complex. The plan included a requirement to stabilize the plutonium nitrate solutions stored at the PFP.

The excess inventory of plutonium at the PFP includes about 4,800 L of solutions from various sources. The solutions are corrosive and container leakage is a potential hazard over long periods of time. The compositions of these solutions vary in plutonium concentration, acid concentration and impurities depending on the source of the solution. These solutions need to be processed to convert the plutonium to a stable, dry form suitable for long-term storage and to

transfer the corrosive solutions resulting from the processing operations to waste tanks for disposal.

In anticipation of the requirements of the DOE plan for disposition of excess inventories, PFP initiated development of a vertical direct denitration calciner process to thermally stabilize the plutonium nitrate solutions at PFP by conversion to plutonium oxide powder. The conversion is accomplished by heating to (1) boil off the liquids, (2) decompose the nitrate anion, leaving only an oxide compound, and (3) improving the hygroscopic properties and particle size of the oxide crystals as they reach appropriately high temperatures. The calciner uses the direct denitration process to avoid introducing additional chemicals into the calciner. To determine the adequacy of the equipment and process design, a prototype calciner was installed in the Plutonium Process Support Laboratory (PPSL) at the PFP. The prototype was used to evaluate the calciner design for safe and reliable use for application to the design of the future production calciner. The prototype calciner unit and the process rates were full scale designs for direct transfer of the test results to the future calciner production process and equipment.

The Laboratory Prototype Calciner began testing with plutonium nitrate solutions in September, 1995. The basic testing performance of the calciner process equipment was generally favorable, resulting in relatively few equipment and process design modifications. The successful prototype calciner test program resulted in the design and initiation of construction of a production calciner. However, prior to initiation of operations using the new production calciner, solution stabilization operations using the Laboratory Prototype Calciner will continue for additional evaluation of the equipment and process design to validate the production calciner design and process parameters. Details of testing for the calciner are contained in the calciner test plan (BWHC 1999b). This addendum provides the authorization basis for testing of the Laboratory Prototype Calciner.

1.3 PLANNED OPERATIONS UNDER THIS FSAR ADDENDUM

This addendum covers plutonium-bearing solution stabilization operations using the Laboratory Prototype Calciner in the PPSL portion of Building 234-5Z at the PFP and related support operations. The principal operations involve load-out, transfer, interim storage, and processing of plutonium nitrate solutions. The operations also involve sampling, seal-out, packaging and transfer to storage of the plutonium oxide product which are included in this addendum for completeness but are not a part of the authorization basis provided by the addendum. A description of the feed solutions to be processed and the process chemistry for solution stabilization are provided in Sections 2.1 and 2.2, respectively. The equipment used in the stabilization operations and a description of the process are provided in Sections 2.3 and 2.4, respectively.

This FSAR addendum primarily covers the solution stabilization equipment and operations performed in Building 234-5Z of the PFP as follows:

- Load-out of plutonium-bearing solutions from Glovebox HC-227S in Room 227.

- Transferring solutions for processing in Glovebox 188-1 in Room 188 of the PPSL or for interim storage in appropriate locations.

- Processing the solutions through the prototype vertical denitration calciner and collecting the dry plutonium oxide product in the product receiver vessel.

- Transfer of material from the product receiver vessel to ½ L slip-lid cans in Glovebox 188-1.

The above activities support the test objectives identified in the calciner test plan (BWHC 1999b). The objectives are specified in the plan are:

- To demonstrate satisfactory direct denitration conversion of plutonium-bearing solutions to stable solids in a vertical calciner and ancillary systems.

- To demonstrate the adequacy of performance of the essential components of a vertical calciner and support systems for direct denitration processing of plutonium-bearing solutions and to determine deficiencies for possible remediation.

In addition, the addendum includes discussion of various activities associated with calciner operations for completeness. However, these activities are not included as a part of this addendum for purposes other than information. These activities include:

- Sampling, testing and bag-out of the product.

- Final canning of the product and transfer to storage.

- Transfer of spent scrub solutions to the waste storage tanks.

Additionally, some activities associated with the performance of solution stabilization operations (e.g., blending and sampling of solutions in Glovebox HC-227S and storage of the plutonium oxide product) are already addressed within the PFP FSAR (FDH 1999) and have been previously authorized. These activities are included, as appropriate, to provide for clarity and completeness.

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2.0 SYSTEM DESCRIPTION

The PFP currently contains a large quantity of residual plutonium-bearing solutions that remain from prior production operations at the PFP as well as from other Hanford facility operations, e.g., PUREX. These solutions are reactive and are not suitable for long term storage. Therefore, the solutions are to be stabilized by conversion to a dry product which facilitates safe, long-term storage until final disposition of the material is determined. The solution stabilization process using the Laboratory Prototype Calciner and related equipment is designed to safely load-out solutions, transfer solutions, provide interim storage of solutions, if needed, process the solutions to a stable, dry product form, and test, package and transfer the product to storage.

The following sections provide information on the feed materials to be stabilized, the process chemistry involved in the calciner operations, the equipment used in the stabilization process and a description of the process operations. The information in these sections is primarily based on various reports discussing the design and performance of the Laboratory Prototype Calciner (WHC 1996, BWHC 1997, and FDH 1998a).

2.1 PROCESS FEED MATERIALS

The feed material for the Laboratory Prototype Calciner is limited to plutonium nitrate solutions. Other solutions, e.g., concentrated filtrate solutions and flush solutions, are not currently allowed to be processed since they have not been evaluated for hazards or accident potential. The plutonium nitrate solutions are normally limited to 2.5 L in a single 3 L polybottle per transfer container and must have a nitric acid concentration greater than 4 M to limit the hydrogen production rate during transfers and interim storage of the solution prior to processing. This, along with other controls, e.g., vent clips on transfer containers, reduces the potential for a hydrogen deflagration during transfers or upon opening of transfer containers, polyethylene bag-out bags, or the solution polybottles.

The plutonium nitrate solution is limited to a concentration of 450 g-Pu/L of solution. This limit is established for criticality control purposes and to limit the hydrogen generation rate in transfer containers. The isotopic distribution of the plutonium in the feed solution is limited to $< 10\%$ ^{240}Pu content to limit the potential doses resulting from a seismic event. The feed solution is limited to 1% organic content with no visible, separable phase of organic material permitted in the feed solution. This limits the potential for a deflagration due to organic decomposition in the calciner. In addition, feed solution must not contain any significant amount of sodium, potassium, calcium or similar materials which could melt and form plugs of material inside the calciner bed and impact agitation and product removal through the product drop tube.

Solutions not meeting the above requirements are not permitted to be stabilized in the Laboratory Prototype Calciner.

2.2 PROCESS CHEMISTRY

The objective of the plutonium-bearing solution stabilization program using the Laboratory Prototype Calciner process is to convert the plutonium in plutonium nitrate solutions to plutonium oxide. The acidic offgases produced by the conversion process are treated in the scrubber prior to being released to the atmosphere. The process technology is described in the following sections. A flow diagram for the process is shown in Figure 1.

2.2.1 Plutonium Oxidation

The plutonium nitrate, $Pu(NO_3)_4$, in a solution of nitric acid, HNO_3, at a concentration of 4.0 M or greater, is decomposed to plutonium oxide when heated in excess oxygen/air in the calciner, which has been heated to a temperature of 1000 °C. A residence time of approximately 4 hours in the calciner assists in heating the product for a sufficient length of time to obtain the desired product which meets loss-on-ignition (LOI) requirements (BWHC 1998) and produces a product that meets the long-term storage criteria in DOE-STD-3013 (DOE 1996).

The decomposition of the plutonium nitrate to plutonium oxide follows a reaction similar to:

$$Pu(NO_3)_4 + \text{heat} \longrightarrow PuO_2\downarrow + 0.6NO\uparrow + 3.4NO_2\uparrow + 1.6O_2\uparrow$$

The nitric acid in the feed thermally decomposes to water, as steam, and oxides of nitrogen (NO_x). The offgases produced from the reaction are a mixture of the NO_x compounds with nitric acid vapor and steam.

2.2.2 Offgas Treatment

The NO_x compounds, nitric acid vapor and steam discharged from the vertical calciner are drawn through the offgas treatment scrubber using the 26-in.-Hg vacuum system. The offgas scrubber uses a fritted glass disk that disperses the gas into small bubbles in a sodium hydroxide solution. This dispersion increases the reaction area in the scrubber solution and reduces NO_x and nitric acid vapor emissions.

The neutralization of the NO_x compounds and nitric acid vapor follows reactions:

1) $2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$

2) $HNO_3 + NaOH \longrightarrow NaNO_3 + H_2O$

3) $HNO_2 + NaOH \longrightarrow NaNO_2 + H_2O$

4) $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$

5) $2NO + O_2 \longrightarrow 2NO_2$

The NO_x compounds and nitric acid vapor are converted to mostly sodium nitrate, per reaction 2, in the liquid phase. The reaction consumes a portion of the sodium hydroxide (NaOH) and lowers the pH, or sodium hydroxide concentration, as sodium salts of nitrate/nitrite and water are formed.

2.2.3 Offgas Scrubber pH

The reactions shown above consume sodium hydroxide which reduces the pH of the scrubber solution. The hydroxide ion is forced to form water to maintain a chemical balance in the system. Gases and accumulated liquid exit the scrubber and separate in the spent scrub solution tanks (also called phase disengaging tanks). The scrubber tank volume and pH is adjusted by continuously adding fresh 30% sodium hydroxide solution. The sodium hydroxide addition maintains the scrubber at a pH of approximately 14.1 at 1.0 – 1.5 M NaOH. Lower pH values (below 13.5) result in NO_x emissions to the vacuum system lines and, hence, the vacuum pump seal water which causes low pH discharges to the Low Level Waste Treatment Facility in Building 243-Z.

2.3 DESIGN DESCRIPTION

The process of stabilizing plutonium-bearing solutions in the Laboratory Prototype Calciner is accomplished using primarily the following equipment in Building 234-5Z of the PFP:

1. Glovebox HC-227S and solution transfer bottles --- solutions are blended and sampled in this glovebox, located in Room 227 of Building 234-5Z, and are loaded into transfer bottles (polybottles) for transfer to the calciner glovebox.

2. Transfer containers --- these containers are used to safely transport polybottles of solutions between Glovebox HC-227S and Glovebox 188-1 for processing in the calciner.

3. Glovebox 188-1 --- this glovebox, located in the Plutonium Process Support Laboratory (PPSL), contains the vertical denitration calciner and related support systems/equipment required for the stabilization process.

The following sections provide design details for this equipment and for related support systems/equipment. Where appropriate, reference is made to chapters or sections of the PFP FSAR (FDH 1999) where adequate descriptive information already exists rather than duplicating the information.

2.3.1 Glovebox HC-227S and Solution Transfer Bottles

This glovebox is located in Room 227 of Building 234-5Z, as shown in Figure 2, and is used to blend various solutions and to sample the resultant plutonium-bearing solutions to ensure they meet the requirements for stabilization operations in the Prototype Laboratory Calciner. Acceptable solutions are loaded into transfer bottles (polybottles) which are then placed in transfer containers (described in Section 2.3.2) for transport to Glovebox 188-1 in the PPSL.

Glovebox HC-227S is described in Chapter 5 of the PFP FSAR (FDH 1999). A front view of the glovebox is shown in Figure 3. Use of the glovebox for processing and downloading solutions for stabilization in the calciner has not required any change in the design or operation of the glovebox as described in the FSAR.

The solution transfer polybottles are fabricated from polyethylene and have a nominal capacity of 3 L. The fill volume of the bottles is normally limited to 2.5 L so that 2 bottles will fill the calciner feed tank without leaving any excess solution in the bottles. The polybottles have dimensions of approximately 4.6 in. in diameter by 17.75 in. in length. Polybottles are closed with a plastic screw cap having a small vent hole which prevents pressurization and limits the buildup of hydrogen within the bottle. The polybottles are bagged out of Glovebox HC-227S, placed in a second bag and then placed in transfer containers for transport to the PPSL for processing in the calciner. The bags are closed in a manner which prevents pressurization and limits hydrogen buildup.

2.3.2 Transfer Containers

Filled polybottles bagged out from Glovebox HC-227S are placed in either a Product Receiver (PR) can storage container or an Isolated Transport Container (ITC) for transfer to the PPSL. A PR can container is essentially a standard, DOT 17H, 55-gal. drum constructed of 16 gauge stainless steel. A schematic including the PR container (identified as "drum") is shown in Figure 4. A supporting framework, located in the bottom of the container, holds the solution transfer bottle in place during container transport. The container closure consists of a gasket and lid which are held in place by a locking ring. The locking ring is a split ring design which is closed by tightening of a bolt. A vent clip is placed between the lid and body of the PR Container to prevent pressurization and limit the buildup of hydrogen in the container due to radiolysis. The PR Container is mounted on an I-beam skid which is welded to the bottom of the container. The I-beam skid allows a pallet jack to be used to transport the container around the facility.

The second type of container used to transfer bottles of solution is the ITC. The ITC is constructed of plastic with a snap type closure lid which is not designed to seal tightly. This prevents container pressurization and limits the buildup of hydrogen in the container due to radiolysis. The ITC is approximately 12-in. in diameter at the bottom, 16-in. in diameter at the top and 20-in. in height. The ITC is transported around the facility by being hand carried.

2.3.3 Glovebox 188-1 and Process Equipment and Support Systems

This glovebox is located in Room 188 of Building 234-5Z as shown in Figure 5. Also shown on Figure 5 are other rooms related to stabilization operations in Room 188. Room 188 and Glovebox 188-1 contain most of the equipment and systems necessary to support plutonium-bearing solution stabilization operations using the vertical calciner process. Section 2.3.3.1 provides a description of the glovebox and Section 2.3.3.2 provides a description of the process equipment and support systems.

2.3.3.1 Glovebox 188-1

A schematic of Glovebox 188-1 is shown in Figure 6. The glovebox is constructed of stainless steel with numerous viewing windows, glove ports, bag-out ports and sphincter seal ports. The viewing windows are generally wire-reinforced glass except for the large rectangular window in front of the calciner equipment which is a fire-resistant plastic. The glovebox measures approximately 8 ft. in length, 3 ft-8 in. in depth and 6 ft-11 in. in height and rests on a structural framework which provides a base to elevate the glovebox approximately 2 ft off the floor. The glovebox structure and supports are seismically qualified to withstand a 0.2-g seismic event to ensure that it will not topple from the seismic motion. However, the equipment inside the glovebox is not seismically qualified.

The glovebox is divided into an upper and lower section by an intermediate floor approximately 2 ft above the floor of the glovebox. The lower section is termed "the basement" with the intermediate level being "the main floor."

At one end of the glovebox, there are two extensions. The upper extension is open to the main part of the glovebox and is approximately 3 ft wide by 3 ft deep by 2 ft-9 in. high. The floor of the upper extension extends about 3 ft into the main part of the glovebox to provide a partial third level which is identified as "the attic." The lower glovebox extension, identified as "the basement annex", measures approximately 3 ft wide by 3 ft deep by 3 ft high. The intermediate level floor ends at the lower extension section and is open to the extension. The floor level of the main part of the glovebox extends into the lower extension to provide the floor for the extension. A criticality drain is provided in the "basement" of the glovebox to limit the potential for accumulation of water and resultant criticality.

The glovebox is designated as a safety significant item (see Table 6), as are all operational gloveboxes, because of its personnel protection function. The PFP safety equipment list (FDH 1998b) provides the definition of the glovebox safety boundary.

2.3.3.2 Process Equipment and Support Systems

A process flow diagram for the Laboratory Prototype Calciner and a simplified piping and instrumentation diagram are shown in Figures 1 and 7, respectively. The principal items of equipment required for the calciner process are:

- Feed Tank and Feed Pump

- Calciner
- Caustic Scrubber
- Spent Scrub Solution Tanks
- Vacuum Trap.

Systems required to support operation of the calciner equipment consist of the following:

- Process air system
- 26-in.-Hg vacuum system
- Caustic supply system
- Chilled water system
- Fire protection system
- Electrical power
- Emergency shutdown systems
- Ventilation systems
- Radiation protection.

The equipment and systems listed above are described in the following sections. Instrumentation and controls required for operation of the calciner process equipment and support systems are discussed together with the related equipment or system.

2.3.3.2.1 Feed Tank and Feed Pump. The feed tank provides a reservoir for the plutonium-bearing solutions to be processed through the calciner. Feed solution is poured from polybottles into the top of the tank after removal of the tank closure lid. The feed tank is constructed of glass and is approximately 6-in. in diameter by 12-in. in length. The tank volume is 5.2 L with an operating capacity of 5 L. The tank is supported by metal legs attached to the bottom flange of the tank and bolted to the glovebox intermediate level floor. The feed line from the tank is ¼-in. Teflon™ tubing and contains an isolation valve to provide positive feed shutoff.

The feed pump draws solution from the feed tank and pumps it through ¼-in Teflon™ tubing to the liquid feed injector on the calciner. The feed pump is a diaphragm-operated metering pump that injects feed to the calciner in discrete pulses. There are two control knobs on the pump for controlling both frequency and volume of the pulses. The maximum flowrate for the pump is approximately 15 L/hr with the normal flowrate set at about 4 L/hr. The maximum pressure is about 100 psi with the normal operating pressure about 60 psi.

2.3.3.2.2 Calciner. The calciner receives plutonium nitrate feed solution and converts it to plutonium oxide through the application of heat. A cross-sectional view of the calciner showing the major components is contained in Figure 8. The main components of the calciner are constructed of 310 stainless steel. The body of the calciner is schedule 10 pipe and consists of two sections: the lower section is the calciner chamber; the upper section is the filter chamber. The overall calciner is approximately 6-in. in diameter by 21-in. in length. The calciner chamber is approximately 9-in. long and the filter chamber is about 12-in. in length. The calciner is supported by steel legs which are connected to the ½-in. thick lower flange assembly and bolted to the glovebox intermediate floor.

The calciner chamber is constructed with a dome extending into the chamber from the base into which a heater is inserted. Thermowell assemblies are provided in the baseplate and dome to monitor and control calciner temperatures. A schematic of the dome and baseplate assembly is shown in Figure 9. Feed solution is injected along with process air from the bottom into a bed of plutonium oxide which is maintained in the annulus formed between the dome and outer wall of the calciner chamber. A motor-driven agitator continually stirs the material bed in the annulus and, as the bed increases in height due to addition of feed solution, plutonium oxide powder from the top of the bed falls through the product drop tube into a collection vessel. The product drop tube fits into a cutout formed in the dome. The outside of the calciner chamber is heated by a series of tubular heaters mounted to the inside of thermal insulation. The insulation/heater assembly is supported by the lower ½ in. thick flange base assembly of the calciner chamber.

The filter chamber contains three filters which prevent the plutonium oxide powder in the calciner chamber from being carried along with the off-gases to the scrubber tank. The filter chamber is not heated but is insulated. The agitator shaft enters the calciner through the top plate of the filter chamber which also contains the connections for the off-gas vacuum lines, back-pulse air for cleaning the filters, and a vacuum sensor. The top plate also contains the calciner pressure relief device.

The main components of the calciner are as follows:

- Liquid feed injector
- Product drop tube and receiver vessel
- Agitator
- Off-gas filters
- Heaters
- Insulation

Liquid Feed Injector – The liquid feed injector is fabricated from 310 stainless steel and consists of a ¼-in. liquid feed tube concentrically housed inside a ½-in. air supply line. A schematic of the injector is shown in Figure 10. The feed solution and air are injected at the bottom of the calciner into a hot bed of approximately 4 kg (approximately 1 L) of plutonium oxide powder. The plutonium nitrate feed solution is converted into plutonium oxide and gradually dries and rises to the top of the bed before being expelled out of the product drop tube. This ensures that the plutonium oxide has sufficient residence time in the calciner to pass the loss-on-ignition test performed on the product. The agitator continually stirs the plutonium oxide bed over the injection port to ensure that the incoming solution reacts with hot material and that a hole does not develop in the bed which would allow the solution to flush directly into the calciner. This would result in inadequate residence time in the calciner since the plutonium oxide product would then end up on top of the bed and be quickly swept out of the product tube. The combination of pressurized feed solution injection, air injection and agitator rotation, all occurring through the plutonium oxide bed in the base of the calciner, results in generation of a significant amount of plutonium oxide dust in the calciner airspace.

The air supply around the feed tube serves to insulate the liquid feed from the hot baseplate as well as to provide some cooling. This prevents the feed solution from boiling inside the feed tube which could lead to excessive corrosion or possibly precipitative blockage of the feed tube. The feed line system is fitted with an air nozzle at the calciner baseplate surface. The injection nozzle is engineered so that air delivery rates above 1 cfm will produce supersonic air velocity at the plate surface. This breaks the feed liquid into a fine mist, which is carried by the air up into the material bed. This atomization prevents the feed solution from pooling and potentially corroding the baseplate. The feed tube has been designed to be replaceable. However, the air injector nozzle is not readily replaceable.

Air is normally supplied at a rate of 40 scfh at approximately 65 psi and the liquid feed is supplied at a rate of 1 ml/sec at a pressure of 60 psi. Upon loss of air pressure, there is a potential for liquid to be forced by the feed pump back up the air line and into the process air system. Therefore, an interlock is installed to shut down the feed pump and to prevent startup of the pump when the air pressure is below about 60 psi. In addition, a check valve in the air supply line prevents solution from backing up into the air line should the feed port in the calciner base become plugged.

The feed port location is such that the agitator blades wipe directly across the orifice roughly 4 times per second. This is designed to continually bring new material in contact with the feed solution. It also helps prevent tube blockage, scale buildup, and pooling of solution.

During normal operation, positive liquid feed flow prevents powder from the material bed from being packed down the tube by the action of the agitator. A cleanout rod has been provided should the feed tube become plugged. It is designed to fit flush with the top of the calciner baseplate to prevent powder from being packed down the tube by action of the agitator when the feed pump is not running.

Compression fittings are used throughout the system to connect the feed tube, feed supply line, cleanout rod and air supply line.

Product Drop Tube and Receiver Vessel – The overflow collection port is a slot cut out of one side of the dome in the bottom of the calciner chamber. The slot contains a chamber which holds a 1-in. stainless steel product drop tube that is inset into the dome to permit excess bed material to drop into a collection vessel. The tube is calibrated and is adjusted vertically through a compression fitting with a Teflon ferrule to set the depth of the plutonium oxide bed in the calciner chamber. The drop tube extends well below the base of the calciner and is adjusted externally during calciner operation. The base of the drop tube is connected to a ball valve mounted on the top plate of the product receiver vessel. This valve allows material collection to be suspended while the receiver vessel is replaced. The receiver vessel is constructed of heat-resistant glass which allows visual observation that product is falling from the calciner and of the level of product within the vessel. The receiver vessel has a nominal operating volume of 500 ml with a maximum capacity of 850 ml. The vessel is approximately 6 in. in height by 3.5 in. in diameter with a wall thickness of about 3/16 in. and a rounded bottom. A tray is located beneath the receiver vessel to collect any material that may spill from the tube or vessel.

The receiver vessel is periodically removed from the drop tube assembly and emptied into a 1 lb, stainless steel, lead-lined, slip-lid can for bag-out from the glovebox. The slip-lid can has a nominal capacity of 0.5 L and a maximum capacity of 0.55 L. There is a limit of approximately 1000 g of plutonium oxide in the slip-lid can due to a 3 W heat loading limit for the PVC plastic bags used for bag-out.

Agitator – The agitator is designed to provide continual mixing of the bed material in the calciner and to drive processed plutonium oxide powder to the product drop tube. A schematic of the agitator is shown in Figure 11. The rotation of the agitator continuously moves hot bed material over the feed injection port to vaporize the incoming feed. The rate of rotation can be varied between 0 and 120 rpm and is set at a nominal rate of 60 rpm. Adjustment of the rotation rate is accomplished using a stop watch and varying the speed of the drive motor.

The agitator assembly consists of a drive motor, drive shaft, pipe cap and four agitator blades. The drive motor is a ¼ hp, variable speed, dc electric motor which is torque-limited to 50 in.-lb to prevent damage to the agitator or vessel should the assembly jam. The drive motor transfers power to the agitator through a chain and sprocket assembly with a one-to-one gear ratio. The drive gear is linked to the agitator shaft with a slide coupling. The assembly is enclosed in a guard housing. The chain drive prevents heat from being conducted from the agitator shaft to the motor and permits the motor to be located away from the area of high convective heat flow from the calciner. A thermocouple is used to monitor the temperature of the motor.

The agitator shaft is constructed of 1-in.-diameter 310 stainless steel. A 5-in.-diameter pipe cap is welded to the lower end of the shaft with a conical cap welded on top of the pipe cap to reinforce the shaft-to-pipe-cap connection. The agitator blades consist of ¼-in. plate welded to the pipe cap. The agitator blades continuously rotate through the bed material.

The top plate of the calciner is a 1-in. thick, stainless steel plate which contains various fittings for operation of the calciner and a sleeve to hold the graphite shaft alignment bushing for the agitator. The primary function of the bushing and sleeve is to align and center the agitator shaft. It also supports the weight of the agitator assembly, serves as a gas seal to preserve the vacuum in the calciner and acts as a thrust bearing. A second graphite shaft bearing is located in the lower portion of the filter plate which is below the calciner top plate. This bearing distributes the forces exerted by the agitator over a wider area.

Off-gas Filters – There are three off-gas filters in the filter chamber of the calciner which are supported by a 2-in. thick stainless steel filter plate near the top of the calciner. The filter plate has been machined to mate with the filter seals. The 1-in. thick top plate of the calciner maintains compression on a flexitallic gasket on top of the filters and provides the connections for the vacuum lines to draw off the gases from calciner operation. The top plate also contains the filter blow-back assembly which periodically cleans the filters.

The off-gases from the calciner process must be removed without allowing plutonium oxide powder to escape. To accomplish this, calciner offgases are drawn off under vacuum through a set of 1 micron, high-temperature, sintered, silicon carbide particle filters. These

filters ensure a high efficiency of radionuclide separation from the waste gases, while minimizing contamination of the gaseous and liquid effluents.

The filter chamber section of the calciner is designed principally to house the offgas filters. The height of the filter section was determined by the length of filters required to handle full flow with 25 % additional capacity. The three ceramic filters together have a capacity of about 20 cfm. The filter chamber is equipped with a pressure relief weight designed to lift at a pressure of approximately 2 psi. Should the filters become plugged and a positive pressure buildup in the calciner, the pressure relief weight would lift and allow the off-gases to escape into the glovebox. The gases would then be swept out with the glovebox E-4 ventilation system flow. Breakage of a filter would allow plutonium oxide particulate to be carried out of the calciner and to the scrubber. This would be noticeable by a dramatic change of color in the solution in the scrubber. Either of these conditions, plugged or broken filters, would be noticed by a change in the differential pressure gauge between the calciner and the filter vacuum line or by a change in the vacuum gauge on the calciner. Similarly, should the liquid feed rate overwhelm the filter/vacuum system, the gauges would indicate a change in the operating conditions.

With the high gas flow, moist air, and large amounts of lofted powder, it is crucial to provide a means of clearing the filters while the calciner is in operation. Compressed air is blown back through the filter elements to remove accumulated plutonium oxide powder on the element surface. The filter blowback system sends a pulse of compressed air sequentially to each filter. The pulse is directed through a venturi port, causing a small shock wave to dislodge any accumulated material from the filter surface. The blowbacks are controlled by a 2-stage electronic timing system in the instrument panel. The blowbacks are not uniformly timed and are not always in the same pattern but occur approximately once every 1-2 minutes in each filter.

Heaters – Heat is supplied to the calciner from two heater units, each with its own power supply. The first is a single 1100 W canister heater located inside the dome of the calciner chamber. The second is a 6000 W set of 14 separate tubular heater elements around the outside of the calciner chamber. All heaters are internal resistance heaters that radiate heat to the calciner walls. The outside elements are mounted through the two half sections of insulation surrounding the chamber. One element may be non-functional in each half section of insulation. However, replacement is required when either half has two or more non-functional elements.

Power for the heater units is supplied from phase-angle controlled, silicon-controlled rectifier (SCR) current sources. The power supplies are operated from a programmable temperature controller. The temperature controller monitors the temperature on the outside of the calciner at a point near the center of the jacket heating elements. At full temperature, the heating elements are designed to operate about 250 °C above the temperature of the vessel wall; this is the temperature drop across the air space between the furnace and the vessel.

During startup, the temperature controller varies the amount of current the power sources supply to the furnaces to maintain a set ramp-up rate, typically between 5 °C and 10 °C per minute, to prevent excessive thermal stress on the calciner. Once at full operating temperature, the controller modulates the power to maintain its setpoint temperature. The controller also

provides a programmable interlock to the solution feed pump to prevent the feed pump from operating whenever the calciner vessel temperature is below 700 °C. This prevents flooding of the calciner with liquid feed and subsequent paste formation in the powder bed due to the introduction of liquid at low temperatures.

To preclude excessively high calciner temperatures, an interlock is provided by a programmable temperature alarm relay which receives input from a thermocouple probe. This probe senses temperature on the calciner vessel wall and automatically shuts off power to the heaters and provides a local over-temperature alarm should the vessel temperature exceed 1100 °C.

Insulation – The calciner assembly and offgas tubing are thoroughly insulated to ensure efficient operation of the calcination process and to prevent overheating of the glovebox. The calciner chamber is insulated with a 4-in. thick layer of high-efficiency sintered glass fibers. The insulation is made in two blocks that are banded together at assembly. This insulation restricts heat flow very well, but is very absorbent and must be kept dry for criticality prevention. The calciner chamber heaters are attached to the inside of each half of insulation with the individual heater ends protruding through the insulation. The filter chamber is insulated by a multi-layered stainless steel foil "mirror" insulation jacket. The jacket is a series of 17 reflective concentric sheets of metal each separated by 1/8 inch of air. The chambers formed by the concentric sheets are not sealed but have openings small enough at the top and large enough at the bottom to prevent liquid accumulation inside. The filter chamber insulation is made in two halves that hinge together.

2.3.3.2.3 Caustic Scrubber. A schematic of the caustic scrubber is shown in Figure 12. The scrubber receives off-gases from the calciner, cools and condenses the vapors, neutralizes the acidic offgases, and reacts NO_x vapors to form soluble salts. Sodium hydroxide solution is used to neutralize the acids and react the NO_x vapors.

The primary components of the scrubber are fabricated from heat-resistant glass and stainless steel. The glass scrubber tank is approximately 6-in. in diameter by 44-in. in height. The total capacity of the scrubber is approximately 21 L with an operational volume of about 16 L of caustic solution. The scrubber tank is provided with stainless steel top and bottom flanges and a stainless steel service ring with connections for filler and caustic solution. The scrubber is supported on legs mounted on the lower flange and bolted to the glovebox intermediate floor.

The offgas from the calciner is brought to the scrubber under vacuum through an insulated ¾-in. stainless-steel pipe. The offgas is brought into the scrubber through a 1-in. glass inlet tube which extends from the top of the scrubber to the base of the internal cooling coil where the gases enter a quartz gas dispersion chamber. At the top of the gas dispersion chamber is a fritted glass diffuser disk designed to disperse the offgas into small bubbles. This facilitates efficient conduction of the heat from the offgas and neutralization of the acids.

The hot offgas from the calciner heats the caustic solution in the scrubber. To efficiently cool, condense, and react the offgas, the caustic solution in the scrubber is cooled by an internal

heat exchanger that consists of a cooling coil made of ½-in. stainless steel tubing. The cooling coil is suspended down the center of the scrubber and the coils are closely spaced to form a long cylinder within the scrubber. Cooling water in the coil recirculates through a chiller located in Room 187 to provide the necessary cooling for the scrubber. The offgas inlet tube runs down the center of the cooling coil. The tightly stacked cooling coils provide a chimney effect where the incoming gas bubbles rise to create a current that circulates around the coils in the caustic solution. Once the bubbles reach the top, the gas, along with any excess liquid is drawn down the exhaust tube.

The proper concentration of the caustic solution is maintained by continuous pumping of caustic solution from the caustic supply drum located external to the process glovebox. The makeup caustic solution has a concentration of approximately 30% NaOH.

2.3.3.2.4 Spent Scrub Solution Tanks. There are two identical spent scrub solution tanks (also termed phase disengaging tanks) in the calciner process which receive the offgas and excess liquid from the caustic scrubber. A schematic of a spent scrub solution tank is shown in Figure 13. The units separate the calciner offgas from liquids which are comprised of condensed vapor and the caustic makeup solution injected into the scrubber. Only one of the two tanks is used at a time.

The spent scrub solution tanks are each fabricated from a 48-in. long piece of 6-in.-diameter, heat-resistant glass pipe and have PVC end flanges, neoprene gaskets, and stainless steel fittings and tubing. They are mounted horizontally in the basement section of the glovebox. Liquid and gas come from the scrubber to the tanks through ¾-in. stainless steel tubing and valves. The total capacity of each tank is approximately 22 L with an operating capacity of 19-L. The large volume allows for the liquids to settle calmly at the tank bottom while the gas exits continuously at the top of the tank. The gas then passes through a vacuum trap to ensure that there are no entrained liquids entering the process vacuum system.

When full, the active tank is valved out and the standby tank is valved in. A liquid sample is taken from the filled tank to check for radiological materials and caustic concentration. A sample valve is provided on the tank along with a vent line and valve to permit sampling and draining of the solutions in the tank. Once the liquid in the tank is verified to meet release criteria and appropriate approvals obtained, it is discharged to Building 241-Z, Tank D-8, for disposal.

2.3.3.2.5 Vacuum Trap. The offgas from the spent scrub solution tanks flows to a vacuum trap before entering the 26-in.-Hg vacuum system in the plant. The trap ensures that liquids do not enter the plant vacuum system. Liquids in the vacuum trap drain back to the spent scrub solution tanks. If a significant amount of liquid enters the trap, a polyethylene float will rise to plug the flow and shut off the vacuum. This would stop the vacuum source to the calciner offgas system and result in pressurization of the calciner which would be vented through the relief weight device to the glovebox.

The vacuum trap is fabricated from stainless steel plate, perforated plate, and a 6-in.-long piece of 3-in.-diameter, heat-resistant, glass pipe. The glass pipe contains the float which shuts

off the vacuum. The glass pipe has steel plates on each end which contain the inlet and outlet connections.

2.3.3.2.6 Process Air System. The plant process air system supplies air at approximately 65 psig for use by the calciner process. The plant air system is described in Chapters 5 and 6 of the PFP FSAR (FDH 1999). Process air from the plant air system is used in the calciner process to provide cooling air to the feed injector nozzle and to assist in aerosolizing the feed solution from the injector. The air system also provides the back pulse air required to clean the calciner off-gas filters.

A rotameter is located on the air line to the feed injector to indicate air flowrate. The rotameter contains an integral needle valve to allow adjustment of the air supply to ensure that an adequate vacuum is maintained in the calciner. When the needle valve is fully open, the air supply rate is approximately 40 scfh which is the normal setpoint. Too much air could overwhelm the calciner vacuum system and pressurize the calciner which would release material out of the relief cap into the glovebox. A solenoid valve is located upstream of the rotameter which is used to isolate the air supply to the feed nozzle. During process startup, the valve is energized to open (fails closed) to supply air to the nozzle. The valve is interlocked with both the manual and seismic shutdown systems to close when the switches are actuated. Closure of the valve prevents potential pressurization of the calciner, due to air flow from the accumulator tank in the filter back-pulse air line, during a seismic event and release of significant airborne material. This valve is not seismically qualified. A check valve is provided in the air line near the feed injector to ensure that feed solution does not enter the air system should the air pressure drop below the feed pressure which is approximately 60 psig.

A manual isolation valve is located on the air supply line outside of the glovebox to shut down the air supply when the calciner process is not operating. In addition, two solenoid valves are located on the air supply line outside of the glovebox which automatically isolate the supply line during a seismic event. The valves are seismically qualified and the calciner manual shutdown system and the PFP ventilation seismic shutdown system automatically deenergize the solenoids, resulting in closure of the valves. This prevents the compressed air from potentially pressurizing the calciner and releasing significant quantities of airborne material.

An air filter-trap assembly is located on the air line outside of the glovebox to remove oil which may be in the supplied air. Oil in the air to the calciner could react in the calciner and result in an overpressure condition. The filter-trap assembly is equipped with a drain line and valve which is maintained open to continuously drain any accumulated oil to a collection vessel.

A pressure sensor is located on the air supply line outside of the glovebox to monitor the supply pressure. The sensor is interlocked with the solution feed pump to prevent operation of the pump if the air pressure is less than 60 psig.

Filter back-pulse air is provided by the plant air system through an accumulator tank. The tank supplies air to three solenoid valves providing air to the three off-gas filters. A controller periodically energizes each of the solenoids to open the valves, one at a time, to provide a short burst of air to clean the off-gas filters. The valves are not opened in any

particular sequence but each is opened once every 1 to 2 minutes. A solenoid valve is located downstream of the accumulator tank which is used to isolate the air supply to the off-gas filters. During process startup, the valve is energized to open (fails closed) to supply air to the three solenoid valves providing back-pulse air to the off-gas filters. The solenoid isolation valve and the three sequencing solenoid valves are interlocked with both the manual and seismic shutdown systems to close when the switches are actuated. The valves are closed during a seismic event to prevent injecting air into the calciner. Air injected into the calciner could potentially result in a pressurization and release of airborne material. Closure of these valves is required, even though the two solenoid valves on the incoming process air line are also closed, since the accumulator contains a reservoir of air which could continue to pressurize the calciner even after the incoming air line is isolated. These valves are not seismically qualified.

Two check valves, in series, are located on the inlet line to the accumulator tank for the offgas filter back-pulse air supply. The valves, together with the solenoid valve on the air supply line to the feed nozzle, prevent backflow of air from the accumulator to the feed nozzle which could pressurize the calciner and release airborne material during a seismic event. The check valves are not seismically qualified.

2.3.3.2.7 26-in.-Hg Vacuum System. The plant 26-in.-Hg vacuum system provides the vacuum requirements for the calciner process. The plant has several vacuum systems which are described in detail in the PFP FSAR (FDH 1999). The 26-in.-Hg vacuum system is connected to the vacuum trap which in turn is connected to the calciner process equipment. The vacuum trap prevents liquids from the calciner process from entering the vacuum lines.

A vacuum controller, located outside the glovebox, adjusts the vacuum level according to a control signal received from the calciner vessel. The controller is set to maintain a vacuum in the calciner of approximately 8-in.-Hg. A solenoid valve, located in the vacuum control line from the calciner, closes each time the solenoid valves on the filter back-pulse lines open to prevent significant contamination from being drawn into the control line. Vacuum gauges are provided on both the calciner vessel and the vacuum trap inlet to monitor performance of the system.

2.3.3.2.8 Caustic Supply System. The caustic supply system supplies makeup solution to the off-gas scrubber to maintain the proper concentration of caustic. The main components of the system are a caustic supply drum, caustic pump and a check valve.

The caustic supply drum is a 55 gal. plastic drum which contains 30% NaOH solution. The caustic pump draws solution from the drum and pumps it through metal tubing to the scrubber tank at a constant rate. The pump is a diaphragm-operated metering pump essentially the same as the solution feed pump to the calciner. It has an adjustable capacity between 0 and 15 L/hr at a maximum pressure of approximately 100 psig. The pump injects the caustic solution into the scrubber in discrete pulses. The frequency and volume of the pulses are both adjustable.

The caustic supply line is draped with plastic for personnel protection should the line develop a leak. A check valve is installed in the supply line to prevent backflow of contaminated

solution from the scrubber to the caustic drum or to the room through a leak. A manual isolation valve is also located on the caustic supply line.

2.3.3.2.9 Chilled Water System. The chilled water system provides cooling water to the cooling coil in the scrubbers. The cooling water maintains the temperature of the scrubber solution at levels which ensure condensation of the water vapor in the offgas and proper reaction of the calciner off-gases.

The cooling water is supplied from a commercial chiller unit in Room 187 which is adjacent to the calciner room. The water capacity of the system is approximately 5 gal. The circulating water pump is an integral part of the chiller unit. All major components required to supply the chilled water are located in the chiller unit. The chilled water is supplied to the scrubber through ½ in. stainless steel tubing. Isolation valves for the cooling water supply and return lines are located external to the calciner glovebox.

2.3.3.2.10 Fire Protection System. The fire protection system for Room 188 of the PPSL consists of sprinkler system which is described in the PFP FSAR (FDH 1999) and has not been altered by the installation of the Laboratory Prototype Calciner. There is no automatic or manually actuated fire protection system for the glovebox containing the calciner equipment. A temperature sensor is provided in the glovebox which actuates a high temperature warning light on the process control panel if the temperature exceeds 50 °C. A dry chemical fire extinguisher is available for fire protection. The extinguisher is equipped with a bayonet for ease of puncturing glovebox gloves in the event of a glovebox fire.

2.3.3.2.11 Electrical Power. The plant electrical power system, described in the PFP FSAR (FDH 1999), provides power at the required voltage and current for operation of the calciner electrical equipment. There are no special requirements for calciner operation other than the silicon-controlled rectifiers and related controllers for the calciner heaters. There are two emergency shutdown systems associated with electrically operated equipment in the calciner system which are described in the next section.

2.3.3.2.12 Emergency Shutdown Systems. There are two emergency shutdown systems for equipment in the calciner process. These systems are in addition to the interlocks and controls provided for individual calciner equipment which are discussed in previous sections along with the applicable equipment.

Manual Shutdown System: One emergency shutdown system is manually actuated at the calciner process control panel. It is used to quickly shut down the process equipment when an operational upset has occurred. Actuation of the manual shutdown switch automatically cuts off electrical power to the calciner heaters, agitator, filter back-pulse air solenoid valves, feed pump and the caustic pump.

Seismic Shutdown System: The second emergency shutdown system is automatically actuated by interconnection with the existing plant ventilation seismic shutdown system which is described in the PFP FSAR (FDH 1999). This is intended to terminate the calciner process to prevent the potential generation of significant quantities of airborne plutonium oxide due to

pressurization of the calciner from seismically initiated equipment failure. The system automatically deenergizes the following components:

- calciner heaters including dome heater
- process air supply solenoids to close valves A thru G shown in Figure 7
- agitator motor
- feed pump motor

Figure 15 shows the control logic for the calciner interconnection with the PFP ventilation seismic shutdown system. The figure also identifies the safety class electrical components of the control system. Figure 16 shows the safety class valves associated with the calciner air supply shutdown portion of the seismic shutdown system. The electrical components shown in Figure 15 and the solenoid operated valves shown in Figure 16 are the only safety class components associated with the seismic shutdown for the Laboratory Prototype Calciner.

In addition to the equipment deenergized by the seismic shutdown system, two check valves, valves H and I on Figure 7, are provided in the inlet line to the accumulator for the offgas filter back-pulse air supply. These valves prevent backflow of air from the accumulator to the calciner feed nozzle after the seismic shutdown system has terminated calciner operations. The check valves are redundant to the solenoid isolation valve, valve C on Figure 7, on the air supply line to the feed nozzle.

2.3.3.2.13 Ventilation Systems. The Building 234-5Z ventilation supply system provides air to Room 188. The E-3 Exhaust System draws air from the room through HEPA filters and exhausts it to the atmosphere through the 291-Z-1 Stack. The E-4 Exhaust System draws air from Room 188 into Glovebox 188-1 through glovebox inlet HEPA filters. The air passes through the glovebox and exits through a non-testable HEPA filter into the E-4 system. The air then passes through additional HEPA filters and is exhausted through the 291-Z-1 Stack.

The ventilation supply and exhaust systems for Building 234-5Z maintain the calciner room at a negative pressure relative to the nonradiological areas of the building. The glovebox is maintained at a negative pressure relative to the room which is indicated by a differential pressure gauge. The relative pressure differentials ensure that air flows from clean areas to progressively more contaminated areas. The ventilation supply system and the E-3 and E-4 exhaust systems are described in detail in the PFP FSAR (FDH 1999).

2.3.3.2.14 Radiation Protection. Radiation protection for personnel involved in calciner operations primarily consists of personal dosimetry, a fixed head air sampler and a continuous airborne radiation monitor (CAM) in Room 188. Personal dosimetry, the air sampler and the CAM are as described in the PFP FSAR (FDH 1999) and require no special provisions due to operation of the calciner.

2.4 PROCESS DESCRIPTION

The process for stabilization of plutonium-bearing (plutonium nitrate) solutions, using the Laboratory Prototype Calciner consists of two principal operations:

- Solution transfer to Room 188.
- Solution processing in Glovebox 188-1.

These operations are discussed in the following sections. In addition, product sampling, testing, packaging and transfer to storage are discussed for completeness.

2.4.1 Solution Transfer to Room 188

Solutions to be processed in the laboratory calciner primarily originate from two areas as follows:

- Solutions transferred from Glovebox HC-227S in Room 227.
- Solutions transferred from the PR container storage area, Room 236.

2.4.1.1 Solutions Transferred from Glovebox HC-227S in Room 227

The tanks in Glovebox HC-227S contain solutions to be stabilized in the Laboratory Prototype Calciner. The solutions are blended and sampled to ensure they meet the requirements for processing identified in Section 2.1. Acceptable solutions are loaded into 3 L polybottles which are normally filled to a maximum of 2.5 L so that two bottles can be completely emptied into the calciner feed tank. To prevent pressurization and limit the buildup of hydrogen in the polybottle, a vent hole is provided in the closure cap.

The polybottles are bagged out of the glovebox in a plastic bag, either polyvinylchloride or polyethylene, which is then closed with a "horsetail." A "horsetail" closure is accomplished by twisting the end of the bag and placing tape around the twisted section to maintain closure. The taped section is then cut to separate the bagged item from the bag-out port. The exposed end of the twisted section is then taped. This closure method is intended to prevent pressurization of the bag due to radiolytic generation of gases. The bag and contained bottle is then placed in a second plastic bag which is also "horse-tailed" for closure. The "horse-tailed" end of the second bag is usually folded in half and taped again. The bag-out bag and the overpack bag may be heat sealed on one end and "horse-tailed" on the other end or they may be "horse-tailed" on both ends.

The plastic-bag-enclosed polybottles may be placed in either of two different containers, an Isolated Transport Container (ITC) or a PR container, for transfer from Room 227. In the case of the ITC, bagged polybottles are simply placed in the ITC and the lid snapped in place. The lid is loose fitting and does not require any special provisions to prevent pressurization or

hydrogen buildup due to radiolysis. The bagged bottle leans against the side of the ITC since it is too long to completely lay on its side. Once placed in the ITC, it is hand carried to Room 188 in the PPSL for processing the solution through the calciner in Glovebox 188-1. Alternatively, it may be taken to Room 179 of the PPSL for temporary storage in Gloveboxes 10 or 12. Respiratory protection is not required during transfer of solutions in ITCs or for receipt of solutions in either Room 179 or 188. Temporary storage in Gloveboxes 10 or 12 consists of bagging in the bagged polybottles or loading them in through an airlock. Respiratory protection is required during bag-in and bag-out operations. Once inside the glovebox, the plastic bags around the polybottles are removed and disposed of. When the calciner operations personnel are ready to process the solutions, the polybottles are again bagged-out of one of the gloveboxes in Room 179, overpacked in a second bag and transferred to Room 188. The transfer may be done by hand carrying the bagged bottles or by again placing them in an ITC. It is noted that there is no temporary storage pad in either Room 179 or Room 188 for the ITC. Therefore, the polybottles must be loaded into the gloveboxes from the ITCs without any interim storage.

When a PR container (see Figure 4) is used for solution transfers, the bagged polybottle is placed in a positioning rack inside the container. The rack keeps the bottle upright during container movement or storage. A vent clip and gasket are placed on the container rim and the lid is placed on the container. The lid is secured by a bolted lock ring. A pallet jack is then used to transport the container to Room 236, the PR Container Storage Area, for interim storage. Although not the normal mode of operation, a PR container may occasionally be transferred by pallet jack directly from Room 227 to the hallway outside of Room 188 with the subsequent operations as described in Section 2.4.1.2.

2.4.1.2 Solutions Transferred from the PR Container Storage Area, Room 236

When the solutions in Room 236 are to be processed in the calciner, the container is retrieved from the room in accordance with appropriate transfer documentation. Since Room 236 may contain hundreds of drums, it is important that the correct container be identified since some drums are unvented and could pose a hazard when opened due to pressurization or the presence of hydrogen. Only vented drums are permitted to be transported to Room 188. When the correct container has been identified, it is transported using a pallet jack to the hallway outside of Room 188. The container is then slid across the floor of Room 188 to a position near the glovebox where it is opened and unloaded. Care is taken when sliding the container across the floor so as not to disturb fixed contamination that exists on the floor. Workers use respiratory protection while moving the container into Room 188 and during subsequent opening and unloading. There is no limit on the number of containers that may be brought into Room 188 but space in the room essentially limits the number of containers to three.

2.4.2 Solution Processing in Room 188, Glovebox 188-1

As mentioned in Section 2.4.1, solutions may be received in ITCs or in PR containers. Prior to opening the ITCs or PR containers, they are moved into Room 188. This is typically done when laboratory personnel enter the room to initiate startup of the calciner process. Since respiratory protection is required for opening the ITCs or PR containers and loading the solutions

into the glovebox, it is also worn when the ITCs or PR containers are moved into the room. This conserves time between the movement of the ITCs and PR containers and subsequent opening. However, respiratory protection is not required just for the movement of the ITCs or PR containers. The respiratory protection also provides protection for personnel from the very unlikely event of airborne contamination caused by sliding PR containers across the floor which has fixed contamination.

When receiving material, appropriate documentation is examined to ensure that the proper material is being received. In addition, in the case of PR containers, the presence of a vent clip is verified to ensure that the container is not pressurized and that there is no potential for flammable quantities of hydrogen in the container. Even though a vent clip is present, PR containers are grounded and spark-resistant tools are used as added protection against ignition of flammable quantities of hydrogen.

The containers are opened and a Radiological Control Technician (RCT) checks the container for dose rate and loose contamination. The bagged polybottle is then retrieved and placed on its side in the glovebox airlock for transfer to the glovebox processing area. The glovebox ventilation system maintains the airlock at negative pressure relative to the room atmosphere. The outer airlock door is closed, the inner door is opened, and the bagged polybottle is withdrawn from the airlock into the main part of the glovebox. Both bags are cut open and the polybottle is removed. The opposite ends of the bags are cut off so the bags are not considered a container for criticality purposes. The lid is removed from the feed tank and the cap is removed from the polybottle. The contents of the polybottle are poured into the tank. The feed tank lid simply rests on top of the tank and is replaced after the solution is poured in the tank.

The empty polybottle is then bagged out of the glovebox, overpacked in another bag, and placed in the PR container or ITC for reuse. The empty bags are bagged out periodically and transferred as waste. Following the same process, another bottle of feed solution may be loaded into the glovebox for addition to the feed tank or to be stored in the glovebox for later addition to the tank. Due to criticality considerations, only one bottle of any solution, empty or full, may be in the glovebox at any time. Therefore, before adding additional bottles of solution for processing or before adding flushing solution at the end of the process run, any bottle previously placed in the glovebox must be removed.

Once the feed tank has been filled and bag-out operations completed, an RCT checks the room for airborne contamination. If the contamination levels are acceptable, respiratory protection equipment may be removed. To initiate processing operations in the calciner, the agitator and heaters are turned on. The agitator speed is set at approximately 60 rpm by adjusting the motor speed and using a stop watch. The vacuum is then turned on along with the pressurized air supply. The vacuum is started before the air supply to prevent pressurizing the calciner which would raise the relief cap and potentially spread plutonium oxide powder into the glovebox. The vacuum and air supply are then adjusted, as necessary, to obtain the proper vacuum and airflow in the calciner. The air supply to the calciner feed injector nozzle is set, using a needle valve, at approximately 40 scfh as indicated by the rotameter in the air line. The

vacuum is adjusted such that there is about an 80-in.-w.g. vacuum in the calciner. The offgas filter back-pulse air system is then started.

The heater controller is set to increase the temperature of the calciner at a rate of 5 °C to 10 °C a minute to avoid excessive stresses on the calciner components. During the heatup period, the caustic feed pump for the scrubber is started. This must be done before initiation of pumping of feed solution to the calciner.

After the calciner has reached operating temperature, approximately 1000 °C, the feed nozzle cleanout rod is lowered, the isolation valve on the feed line near the feed tank is opened and the feed pump is started. The differential pressure across the calciner filters and the calciner vacuum gauge are observed to indicate that solution is being fed to the calciner. The isolation valve on the product drop tube is opened to allow excess plutonium oxide product in the calciner to fall into the collection jar.

During steady state operation, the feed tank level and elapsed time are monitored to determine the solution feed rate and the feed pump is adjusted accordingly to maintain the desired feed flowrate, normally about 4 L/hr. Feed solution and process air enter the calciner through the feed injector nozzle. The air cools the nozzle to prevent the solution from boiling in the nozzle, which could result in plugging, and the air assists in aerosolizing the liquid feed. As the feed solution enters the hot bed of plutonium oxide in the calciner, it quickly evaporates and is converted from plutonium nitrate to plutonium oxide. The resultant offgases are drawn off by vacuum through the three filters at the top of the calciner and flow to the scrubber. Due to the dusty atmosphere in the calciner, the filters tend to clog. Therefore, the filter back-pulse system periodically, approximately once per minute, injects air through the filters to blow the dust off.

While injecting feed solution into the calciner, the agitator continually sweeps hot bed material over the nozzle to ensure that the feed contacts hot material and to prevent the pressurized feed from creating a hole in the bed. In addition to sweeping material over the feed nozzle, the agitator sweeps the bed material by the product drop tube. As the level of the bed increases due to the oxidized plutonium from the feed solution, the level rises higher than the drop tube and some of the material falls through the tube to the product collection vessel. When the collection vessel contains approximately ½ L of plutonium oxide product, it is removed and emptied into ½ L, lead-lined, slip-lid cans. Only two ½ L cans of product, in addition to a full product collection vessel, are permitted in the glovebox at one time due to criticality prevention requirements.

The off-gases from the calciner flow to the scrubber where the vapors and gases are neutralized and reacted to limit the emission of NO_x compounds. Caustic solution is continually added to the scrubber to maintain the proper pH level. Due to the condensing vapors and caustic addition, the level of the solution in the scrubber rises. The solution overflows into the scrubber outlet line to one of the two spent scrub solution tanks along with the gases from the scrubber which are drawn through the scrubber by the vacuum system. The scrubber solution is visually monitored for color changes which would occur if a calciner filter broke and allowed significant quantities of plutonium oxide dust to be drawn from the calciner to the scrubber. Should a significant change in color occur, the calciner operations are terminated. This can be

accomplished through an orderly shutdown of the operating equipment or by actuating the emergency shutdown switch which automatically shuts off most of the operating equipment.

The gases and liquid from the scrubber flow to one of the two spent scrub solution tanks until that tank is full. The tank is then isolated and the second tank is placed in service. A sample is taken of the liquid in the full tank to determine if it is acceptable for transfer to the waste collection tanks in Building 241-Z. If the sample is acceptable, appropriate approvals for the transfer are obtained and the spent scrub solution is drained to Tank D-8 for disposal to the Hanford tank farms.

The gases from the spent scrub solution tanks flow to a vacuum trap and then through the plant 26-in.-Hg vacuum system. The vacuum system then discharges the gases through the plant ventilation exhaust system. If liquids are drawn from the spent scrub solution tanks into the vapor trap, a float will block off the vacuum line to prevent the liquid from entering the vacuum system. This will result in loss of vacuum to the calciner equipment and pressurization of the calciner vessel. The process operations would be manually terminated if this situation occurred.

2.4.3 Product Sampling, Testing, Packaging and Transfer to Storage

Product sampling, testing, packaging and transfer to storage are not specifically included in this addendum as part of the calciner process. The following discussion is provided for information and completeness.

As mentioned previously, the plutonium oxide product overflows from the calciner into a product collection vessel. This is then emptied into ½ L slip-lid cans for eventual transfer out of the glovebox for long term storage in the Building 2736-Z vaults. Prior to transfer and storage, the plutonium oxide product is tested to ensure that it meets vault storage requirements (BWHC 1998) and DOE requirements for long-term storage (DOE 1996). The plutonium oxide in the slip-lid can is thoroughly mixed by hand. A small sample, approximately 10-20 g, is taken from the can and placed in a sample vial. The vial is bagged out of the glovebox, overpacked with a second bag and placed in an ice cream carton. The carton is transferred to the Analytical Laboratory for loss-on-ignition (LOI) testing to verify that the product meets the storage requirements (BWHC 1998). The laboratory also tests the plutonium oxide density to verify that it is a maximum of 5.5 g-Pu/cm^3 as required by the criticality analysis.

If the plutonium oxide sample meets the LOI requirement for storage of material, the lid is placed on the can and taped closed. The slip-lid can is bagged-out of the glovebox and the bag is closed by heat-sealing. A horsetail is not required since there is no significant potential for pressurization of the bag or hydrogen generation. In addition, a horse-tailed bag would not fit in the storage container. It is noted that there is a limit of about 1000 g of plutonium oxide in the slip-lid can due to a 3 W heat loading limit for the PVC plastic bags used for bag-out. Scales are provided in the glovebox basement level to weigh the cans before and after filling.

The bagged-out slip-lid can is inserted in an overpack can (a large tomato can) which is crimp-sealed for closure. The tomato can is then taken to the hallway outside of Room 188

where it is overpacked in a 7-in. can. The can is appropriately labeled and transferred to the Building 2736-Z storage vaults. Transfer operations are as discussed in the PFP FSAR (FDH 1999).

3.0 HAZARD ANALYSIS

A hazards analysis was performed to identify and evaluate hazards associated with the stabilization of Plutonium nitrate solutions using the PFP Laboratory Prototype Calciner. This chapter summarizes the methodology and the results of the hazard analysis performed. The techniques used in identifying the hazards associated with the operation of the calciner were a Preliminary Hazards Analysis (PHA) and a Hazards and Operability Analysis (HAZOP). A complete discussion of the Hazards Analysis and the hazards tables resulting from the work is presented in Appendix A.

The scope of the PHA and HAZOP included the range of activities involved in the transport of plutonium nitrate solutions in a PR Container or Isolated Transport Container (ITC) to Room 188, processing the solutions in the calciner and then to the transport of the over-packed cans of plutonium oxide product to the vaults for long term storage.

3.1 METHODOLOGY

The hazards analysis was performed using two distinct techniques with differing data collection forms. The PHA and HAZOP are similar but focus on different aspects of the calciner system and operations. A PHA was used to identify the hazards associated with the movement of the plutonium nitrate solutions to Room 188 and into Glovebox 188-1 and the removal of the plutonium oxide product from Glovebox 188-1 and transfer to storage vaults. A HAZOP was selected as the method to identify the hazardous conditions associated with the operation of the Laboratory Prototype Calciner to process the plutonium nitrate solution into plutonium oxide.

The activities associated with the movement of the Pu nitrate solutions into Glovebox 188-1 and the removal of the Pu oxide over-packed can from Glovebox 188-1 into vault 190 were evaluated via a PHA. The PHA is a form-driven exploratory method for identifying hazards and candidates for controls. The PHA process is a systematic approach whereby a system, process, or activity are divided into basic elements and the hazards associated with the system, process operations, or activities are identified. Then potential causes of the hazards are determined, potential consequences of the hazards are evaluated, and possible or existing engineered and administrative safety features are identified. A detailed discussion of the PHA technique can be found in *Guidelines for Hazard Evaluation Procedures* (AIChE 1992).

The PHA was developed using a table to guide and record the results of the hazard identification and evaluation process. The PHA form is shown in Table A-1 of Appendix A. The purpose and contents of each column in the PHA table are described in detail in Appendix A.

The calciner process is amenable to the HAZOP method because the calciner is a system in which specific points or nodes can be identified where process parameters such as temperature, pressure, and flow can be examined for variations that can lead to hazardous conditions. The purpose of a HAZOP study is to carefully review a process or operation in a systematic way to determine whether deviation from prescribed procedures or parameters can

lead to undesirable consequences. A HAZOP leader guides a team through the design using a fixed set of guide words. These guide words are applied at specific points or nodes in the design and are combined with specific process parameters to identify potential deviations from the intended operation. For example, the guide word "No" combined with the process parameter "Flow" results in the deviation "No Flow."

The HAZOP findings are documented on a HAZOP Form which is shown in Table A-2 of Appendix A. A more detailed description of the HAZOP and PHA techniques are provided in Appendix A.

For both the PHA and the HAZOP, the engineered safety features and controls specific to the processing of plutonium nitrates were not credited in assigning the consequence rankings. This was to allow determination of whether Safety Significant or Safety Class equipment or controls were warranted.

The mitigative effects of features previously designated at the plant as Safety Significant or Safety Class were credited in assigning the consequence rankings in the tables. For example, the Building 234-5Z Safety Class structure and E-3 ventilation system were credited with protecting onsite workers and the offsite public outside the PFP from accidents that breach glovebox confinement. The effects of energetic events on the glovebox structure, however, were assessed to determine if the hazardous event can compromise the Safety Significant confinement function provided by the glovebox structure and ventilation system.

The selection of accidents for quantitative analysis was performed using a binning process as recommended by DOE-STD-3009-94 (DOE 1994a) and HNF-PRO-704 (HNF 1997).

All accidents are binned according to the potential accidents identified in the PHA and HAZOP tables (Appendix A, Tables A-5 and A-6). The binning is based on grouping similar accidents that challenged similar barriers. The potential accidents were grouped into 15 bins which are summarized in Table 1. Matching characteristics for the specific hazards to these respective bins was completed using the same ID as in the PHA and HAZOP tables. The results of the binning are presented in Table 2.

A generalized summary of the bins (labeled accident groups in Tables 1 and 2) includes:

Group A1 – Process Upset – No Worker Impacts. Events in this group are production upset events which do not result in the release of radiological material or in a significant increase in worker exposure, but the occurrence of the events degrades the normal operation of the Laboratory Prototype Calciner and possibly decreases product output.

Group A2 – Process Upset – Worker ALARA concerns. Process upsets of a more serious nature than those of Group A1 are characterized by a release of radiological material within the glovebox and a resultant increase in worker exposure. Dealing with the upset often results in additional dose to facility workers, especially in the cleanup or repair process where additional worker doses are incurred.

Group B – Radiological Release Inside Glovebox. Events considered in this group take credit for the mitigative containment of the glovebox. The principal control is the maintenance of a negative pressure differential between the glovebox and the surrounding room. Release of radiological material to the glovebox , while not a danger by worker inhalation, does increase sources of direct radiation and, in a similar manner as Group A2, results in additional worker exposure as a result of recovery operations.

Group C – Radiological Release From Glovebox. The potential for a release of plutonium or other contamination from the glovebox during an event exists whenever there is a loss of confinement such as a damaged or torn glove or failure of the ventilation system, but can also occur during bag-out operations and airlock transfers.

Group D1 – Deflagration in Glovebox. Several sources of flammable gas and potential sources of ignition which could lead to a deflagration in the glovebox were identified by the PHA and HAZOP processes. These events from Tables A-5 and A-6 of Appendix A are assigned to this accident group.

Group D2 – Deflagration Outside of Glovebox. A flammable gas deflagration in a PR container due to the presence of radiolytically-generated hydrogen was identified by the PHA as a potential event resulting from the transfer of solutions for processing in the Laboratory Prototype Calciner.

Group E – Criticality. Relatively large masses of plutonium are handled during prototype laboratory calciner operations. Placing a large mass of plutonium in a glovebox or having sufficient material in a non-safe geometry could result in an accidental nuclear criticality. Controls to prevent criticality typically include administratively controlled mass and spacing limits, hardware that physically separates plutonium containers, limited quantities of water in the gloveboxes, controlled water addition by fire protection systems, and limits on the size and number of containers in gloveboxes. Events identified in the PHA and HAZOP as having the potential to result in a criticality are assigned to this group. However, the analysis of hazardous conditions presenting criticality concerns is performed as part of a Criticality Safety Evaluation Report (CSER) for the Laboratory Prototype Calciner and, therefore, these hazards are not evaluated further in this addendum. The results of the CSER are incorporated into a Criticality Prevention Specification for implementation within the facility which provides adequate protection from criticality hazards.

Group F1 – Fire in Glovebox. The PHA identified several causes of a glovebox fire, including electrical motor burnout, incompatible chemical reactions, or combustible materials coming into contact with hot furnace surfaces.

Group F2 – Fire Outside of Glovebox. This accident group is similar to Group D2 because the flammable material and ignition source are the same. However, the postulated reaction, fire versus a deflagration, is much less energetic and results in different consequences.

Group G – Industrial Hazards. The hazards in this group are the same ones faced by workers in standard industrial activities, such as falls, burns, shocks, and including to some degree, exposure to chemical hazards.

Group H – Release to Vacuum System. The hazards in this group include lowered efficiency NO_x, as well as possible equipment damage from corrosion caused by processing chemical carryover, and possible contamination of the vacuum system.

Group I – Toxic Chemical Release Inside Facility. Several strong acids and bases used in significant quantities in the laboratory prototype calciner have the potential for spills and pressurized leaks. Reactions of incompatible chemicals are possible. The calciner has a collection system for the off gas products of the calciner which can be a source of toxic release.

Group J – Radiological Release Inside Facility. This category is similar to Group C above. In Group J, the hazards are those from radionuclides headed for the glovebox , or coming from it to a vault, in which the container is contaminated or containment is lost. A dropped container would be an example.

Group K – Inadequate Stabilization of Product. The PHA identified numerous process upsets and failures that could result in inadequately stabilized plutonium oxide. If this condition was not detected before the oxide was packaged, the container could rupture in storage due to internal pressurization.

Group NPH – Natural Phenomena Initiator. Group NPH includes events resulting from natural forces such as earthquakes, rain, snow, flooding, high winds, and fires.

After binning, the accidents were further sorted according to the magnitude of their consequences. The accident sorting criteria used was based entirely on qualitative consequence ranking. Each failure or hazardous condition identified by the PHA and HAZOP was assigned a consequence as defined below.

Consequence Rank

S0 No effect outside the glovebox confinement systems; negligible safety concerns for the facility worker.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker.

S1* Potential severe harm or potential death from industrial injury, radiological dose, or chemical exposure to facility worker. Hazardous conditions sufficient to cause severe harm or death to facility workers are typically associated with events which may result in significant pressurization of or damage to the glovebox structure with potential release of radiological material. Therefore, events with sufficient energy to impact the glovebox in a manner which may cause a release of radiological material are assigned an S1* consequence rank. This is a

conservative approach since such events will not necessarily result in harm or death to facility workers.

S2 Potential significant radiological dose consequences or chemical exposure to onsite workers located outside the facility.

S3 Potential significant radiological dose consequences or chemical exposure to the offsite population.

3.2 HAZARD ANALYSIS RESULTS

The PHA and HAZOP tables in Appendix A identify 42 S0 events, 89 S1 events, 34 S1* events, and 9 S2 events.

The results of binning by groups and sorting by the consequence rankings from above are presented in tabular form in Table 2. For each group, all S1* and S2 events are sorted out and collected into a subgroup for evaluation as accidents as shown in Table 2. All S1 events in each group are collected into a second subgroup for evaluation as abnormal operations. Finally, all S0 events in each group are collected into a third subgroup identifying events with negligible consequences. Categorizing hazardous events as either "abnormal operations" or "accidents" is consistent with the NRC Regulatory Guide 3.39 format of the PFP FSAR. In this way, every hazard was binned into one of the accident groups and sorted by its consequence ranking. As noted in the following discussion of each group, in some cases only S1 or S0 events exist for some groups.

3.2.1 Accident Selection

Selection of accidents for quantitative analysis is the final sort that began with the grouping and sorting process described above. For each accident group with an S1* or S2 consequence, a representative accident is chosen for further quantitative analysis. This representative accident bounds the consequences of similar accidents in the accident group it represents. Similar accidents challenge analogous barriers. Analogous barriers reflect the same design philosophy for prevention and mitigation as the representative accident, even though the similar accidents may be in different locations. If there is only one accident of a given type, it is analyzed as a unique representative accident. If several accidents are similar in the bin, one or more can be combined to form the representative accident, or several representative accidents can be chosen for further analysis.

The accident scenario is then fully developed for the chosen representative accident and then refined consequences compared to the hazards it represents. The safety classification implications and control requirements that the representative accident determines are required are then generalized to be required for all the hazards in the group.

From the Laboratory Prototype Calciner accident groupings, discussed below, four groups were selected as requiring accident analysis scenario development. The representative accidents were chosen from the following four groups.

- Fire in the Glovebox (Group F1)
- Deflagration in the Glovebox (Group D1)
- Deflagration outside the Glovebox (Group D2)
- Seismic Event (Group NPH, Natural Phenomenon Hazards)

The rationale for choosing the representative accidents is discussed below along with the rationale for not developing scenarios from the remaining groups. The rationale for choosing and rejecting is also contained in the comments and justification column of Table 2. In Table 2, selected representative accidents and abnormal occurrences are highlighted by using bold and all capitalized print.

Group A1 – Process Upset – No Worker Impacts. All entries in this group have a consequence ranking of S0. Because they result in no effect outside of the glovebox confinement system and negligible safety concerns to facility workers, hazards with S0 consequences are not evaluated further.

Group A2 – Process Upset – Worker ALARA concerns. Only events with a consequence category of S1, abnormal occurrences, are contained in this group, so the group is forwarded to the Abnormal Occurrence Selection section, Section 3.2.2. Consequences from these events involve increased worker exposure from radiation or chemical hazards because of activities needed to recover from the occurrence.

Group B – Radiological Release Inside Glovebox. All entries in this group have a consequence ranking of S1 with the exception of one S0 negligible safety concern so the group is forwarded to the Abnormal Occurrence Selection section, Section 3.2.2.

Group C – Radiological Release From Glovebox. Both events with a consequence category of S1, abnormal occurrences, and S0, negligible safety concerns, are contained in this group so the group is forwarded to the Abnormal Occurrence Selection section, Section 3.2.2.

Group D1 – Deflagration in Glovebox. The PHA identified several causes of a deflagration in the glovebox. From these, three accidents , 04.01 deflagration of hydrogen in a bag or bottle, 08.03.17 deflagration in the calciner due to organic feed, and 08.03.18 deflagration in the calciner due to oil from feed air supply, were chosen to be representative accidents. Event 04.01 was chosen because it involves one of the largest amounts of dispersible material, the 2.5 L of solution in a polybottle, and one of the largest energy sources, hydrogen deflagration, for dispersion. Events 08.03.17 and 08.03.18 were chosen because they are similar to each other and involve a large amount of dispersible material, the plutonium oxide in the calciner, with a large energy source for dispersion.

Group D2 – Deflagration Outside of Glovebox. There was only one accident in this group, 03.01/1 deflagration in the PR container that ejects the lid. It was selected as a representative accident because of its potential for severe injury to facility workers.

Group E – Criticality. The PHA and HAZOP identified several hazardous events for the Laboratory Prototype Calciner operations that could potentially lead to a criticality. Events identified in the PHA and HAZOP as having potential to result in a criticality are assigned to this group. However, the analysis of hazardous conditions presenting criticality concerns is performed as part of a Criticality Safety Evaluation Report (CSER) for the Laboratory Prototype Calciner and, therefore, these hazards are not evaluated further in this addendum. The results of the CSER are incorporated in a Criticality Prevention Specification for implementation within the facility which provides adequate protection from criticality hazards.

Group F1 – Fire in Glovebox. The PHA and HAZOP identified several causes of a glovebox fire, including electrical motor burnout, incompatible chemical reactions, or combustible materials coming into contact with hot furnace surfaces. Only S1* consequence events were identified in this grouping so a representative accident was identified. Two events in this group 06.01 and 08.13.07 are the same event, a fire involving combustibles in the glovebox, that were identified by the two different hazard analysis methods. Event 06.01 was identified in the PHA while 08.13.07 was identified by the HAZOP process. This event, (both 06.01 and 08.13.07) was chosen to be a representative accident from the others in the group because it involved the greatest amount of fuel and would create the greatest dispersal mechanism for this type of event.

Group F2 – Fire Outside of Glovebox. There is only one accident in this group, 03.02/2, a hydrogen burn of a polybottle and the bag around it. This accident is bounded by the deflagration event 03.01/1 in Group D2 where it is the representative accident for a deflagration outside of a glovebox.

Group G – Industrial Hazards. Occupational hazards are not evaluated further as the associated risk is not uniquely related to plutonium processing operations.

Group H – Release to Vacuum System. All entries in this group have a consequence ranking of S0. Because they result in no effect outside of the glovebox confinement system and negligible safety concerns to facility workers, hazards with S0 consequences are not evaluated further.

Group I – Toxic Chemical Release Inside Facility. Chapter 9, Section 9.2.8 of the PFP FSAR analyzes toxic chemical releases. The consequences of accidents in Group I are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in Section 9.2.8 of the PFP FSAR.

Group J – Radiological Release Inside Facility. Chapter 9, Sections 9.1.1 and 9.1.3 of the PFP FSAR analyzes abnormal operations involving radioactive liquid and powder spills. The consequences of abnormal occurrences in Group J are not unique to the laboratory prototype

calciner operations and are considered to be adequately addressed by the analyses in Sections 9.1.1 and 9.1.3 of the PFP FSAR.

Group K – Inadequate Stabilization of Product. Chapter 9, Section 9.1.3 of the PFP FSAR analyzes radioactive powder spills. The consequences of abnormal occurrences in Group K are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in Section 9.1.3 of the PFP FSAR.

Group NPH – Natural Phenomena Initiator. Event 08.16.00/02 was chosen as the representative accident because of all of the accidents in Group NPH, it involves the largest amount of dispersible material combined with the least mitigation to exposed onsite workers outside of the facility to radiological consequences.

3.2.2 Abnormal Occurrence Selection

The six groups (A2, B, C, G, I, and J) where abnormal occurrence events were identified are contained in Table 2. There were no abnormal occurrence events identified in any of the other groups. From the six groups, no unique representative abnormal events associated with calciner operations were identified. The rationale for not developing scenarios for any of the abnormal events is discussed below and also in the comments and justification column of Table 2.

Group A2 – Process Upset – Worker ALARA concerns. Only events with a consequence category of S1, abnormal occurrences, are contained in this group. Consequences from these events involve increased worker exposure from radiation or chemical hazards because of activities needed to recover from the occurrence. No representative abnormal occurrence was selected from this group and hazards are not evaluated further because the associated risk is covered in various abnormal operations evaluated in the PFP FSAR and is not uniquely related to operation of the prototype laboratory calciner operation.

Group B – Radiological Release Inside Glovebox. All entries in this group have a consequence ranking of S1 with the exception of one S0 negligible safety concern. Chapter 9, Sections 9.1.1 and 9.1.3 of the PFP FSAR, analyze abnormal operations involving radioactive liquid and powder spills. Chapter 9, Section 9.1.2, analyzes pressurized liquid releases. Chapter 9, Section 9.2.8, analyzes toxic chemical releases. The consequences of abnormal occurrences in Group B are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in Sections 9.1.1, 9.1.2, 9.1.3, and 9.2.8 of the PFP FSAR.

Group C – Radiological Release From Glovebox. Both events with a consequence category of S1, abnormal occurrences, and S0, negligible safety concerns, are contained in this group. Chapter 9, Section 9.1.9 of the PFP FSAR analyzes a glovebox glove breach. Chapter 9, Sections 9.1.1 and 9.1.3 of the PFP FSAR analyzes abnormal operations involving radioactive liquid and powder spills. The consequences of abnormal occurrences in Group C are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in Sections 9.1.9, 9.1.1, and 9.1.3 of the PFP FSAR.

Group G – Industrial Hazards. Industrial hazards are not evaluated further as the associated risk is covered by various occupational health and safety programs existing within the facility.

Group I – Toxic Chemical Release Inside Facility. Chapter 9, Section 9.2.8 of the PFP FSAR, analyzes toxic chemical releases. The consequences of abnormal occurrences in Group I are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in Section 9.2.8 of the PFP FSAR.

Group J – Radiological Release Inside Facility. Chapter 9, Sections 9.1.1 and 9.1.3 of the PFP FSAR analyzes abnormal operations involving radioactive liquid and powder spills. The consequences of abnormal occurrences in Group J are considered to be adequately addressed by the analysis in the PFP FSAR.

3.2.3 Evaluation of Impacts on Existing FSAR Accidents

The previous sections discussed the new accidents and abnormal occurrences (Section 3.2.2) associated directly with Laboratory Prototype Calciner operations which were identified through the PHA/HAZOP process. In addition, an evaluation is required to determine if the initiation of calciner operations has any impacts on the accidents and abnormal events analyzed previously in the PFP FSAR (FDH 1999). In order to examine the incremental doses that may accrue from operation of the Laboratory Prototype Calciner to the existing abnormal operations and accidents analyzed in the PFP FSAR, each abnormal operation and accident analyzed in the FSAR has been evaluated for impacts assuming operation of the calciner. This evaluation is documented in Table 3 for abnormal operations and Table 4 for accidents. As can be seen from the tables, effects on the accidents and abnormal operations currently analyzed in the FSAR are not expected from operation of the calciner, except for the case of the Seismic Event. For the seismic accident analysis, calciner operations result in an increased release from the laboratories portion of the PFP facility. The effect of the calciner on the seismic event analyzed in the FSAR is evaluated in Section 4.2.5.

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4.0 ACCIDENT ANALYSIS

Accident analyses documented in Safety Analysis Reports (SAR) demonstrate that facility design and operation incorporate adequate features to protect the public, onsite workers, and the environment from the consequences of credible accident scenarios. The design incorporates appropriate engineered safety barriers and administrative controls for postulated hazards to prevent the occurrence of accidents or to mitigate the resulting consequences to acceptable levels. Bounding accidents, whether requiring mitigation or not to maintain acceptable consequences, are referred to as design basis accidents (DBAs). These accidents are the most severe circumstances for which facility features must comply with functional goals to prevent unacceptable consequences to the public, facility and onsite workers, and the environment. DBAs are analyzed for the Laboratory Prototype Calciner in this chapter and compared to the Risk Evaluation Guidelines presented in Figure 9-34 of the PFP FSAR (FDH 1999).

4.1 ABNORMAL OCCURRENCES

Abnormal occurrences associated with operation of the Laboratory Prototype Calciner are discussed and evaluated in Section 3.2.2. There were six groups in Table 2 (A2, B, C, G, I, and J) where abnormal occurrence events, defined as those events with S1 hazards, were identified out of the total of 15 accident groups. There were no abnormal occurrence events identified in any of the other groups. From the six groups, there were no unique representative abnormal events associated with calciner operations. As discussed in Section 3.2.2, all of the abnormal occurrences identified in Table 2 have been shown to be adequately addressed by existing analyses in the PFP FSAR (FDH 1999).

4.2 ACCIDENTS FOR THE LABORATORY PROTOTYPE CALCINER

To demonstrate that the facility design and operation incorporate adequate safety controls, the accident analysis fully develops and evaluates the representative accidents identified in the hazards analysis.

4.2.1 Hydrogen Deflagration in Room 188 from Opening Drum

Plutonium nitrate solutions generate hydrogen, oxygen, and NO_x due to radiolysis. As discussed in Chapter 2.0, the plutonium nitrate solutions are brought to Room 188 in 3 L polybottles that have been placed in PR containers, which are DOT 17H, 55 gal drums, or Isolated Transport Containers (ITC), which are plastic pails with snap-closed lids. Radiolytically generated hydrogen in the polybottle vents through a hole in the bottle cap into the air space of the PR container or ITC. This section evaluates the potential for a flammable buildup of hydrogen in the PR container and ITC and the potential for a hydrogen deflagration caused by a mechanical or static spark during opening.

4.2.1.1 Scenario

Three liter polybottles are used to transfer the solutions from Glovebox HC-227S to Glovebox 188-1. The bottles, filled in Glovebox HC-227S with 2.5 L of solution, have a double-bag overwrap. The bottle is bagged-out of the glovebox, and the second bag is then put in place. The bottles are transported to Glovebox 188-1 in either PR containers or in ITCs which are only large enough to contain one polybottle. Temporary storage of these containers between departure from Glovebox HC-227S and arrival at Glovebox 188-1 is usually necessary.

Temporary storage of PR containers with polybottles is in Room 236. If the storage is prolonged, free hydrogen, generated by radiolytic decomposition of the solutions, first accumulates in the polybottles, moves by venting or diffusion to the plastic bags, and finally vents and diffuses into the PR container. If the concentration of hydrogen in any space reaches the lower flammability limit (LFL), ignition of the gas is possible. A deflagration in the PR container would present a serious hazard to facility workers close to the container from the ejected lid. The analysis in Appendix B calculates the radiolytic generation rate of hydrogen from a polybottle containing 2.5 L of plutonium nitrate solution and calculates the time to reach flammable levels in the PR container (55 gal drum), assuming no leakage or diffusion of hydrogen from the container. The calculations in Appendix B indicate that the time to reach a 1 vol% hydrogen concentration in the container atmosphere (25% of the 4 vol% LFL) could be as low as 22.6 days for a 4 M solution of nitric acid, or 55.3 days for an 8 M solution, when no leakage path through the container lid seal is available. Using 25% of the LFL for hydrogen as the limit for accumulation in a container applies the standard safety factor considered acceptable for the presence of hydrogen.

The analysis in Appendix C calculates the potential hydrogen concentration in drums containing 2.5 L of plutonium nitrate solution that vent through minute holes in the drum lid gasket or are vented through holes created by clips placed between the drum and drum lid. The analysis in Appendix C shows that flammable concentrations are not possible in vented drums. An administrative control has been determined to be necessary to ensure only drums containing vent clips (or equivalent) are opened in Room 188, to ensure the safety of workers opening the drum. The consequence and probability analyses provided in this section evaluate the potential of hydrogen deflagrations due to the inadvertent opening of non-vented drums in Room 188.

Temporary storage of a polybottle in an ITC is accomplished by transfer to Room 179 where the polybottle is removed and temporarily stored in a glovebox. After placement of the polybottle in a glovebox, the double-bag overwrap is removed. When the polybottle is to be transferred to Room 188 for solution processing in the calciner, the polybottle is bagged out of the Room 179 glovebox, overwrapped in a second bag and transferred to Room 188. The transfer is accomplished either by hand carrying the bagged polybottle or by placing it in an ITC. The process steps for temporary storage of a polybottle transferred in an ITC limits the amount of time that a polybottle is in the ITC and, consequently, the amount of hydrogen that may accumulate in the ITC. Similarly, the amount of hydrogen in the bag-out and overwrap bags would be limited due to the relatively short time that the polybottle is in the bag. If, for some reason, this method of storage of the polybottle out of the ITC is not possible, storage in the ITC does not present the same hazard of hydrogen buildup as it does in the PR container. The reason

is that the ITCs have snap-closed lids that are loose fitting and, therefore, not leak tight. The analysis of Appendix C, showing flammable concentrations are not possible in vented PR containers, is also applicable to the ITCs.

If it is postulated that leakage is not possible from the bags, a flammable mixture could be present in the bags surrounding the polybottle and in the bottle itself. This would present a hazardous condition for the movement of the bagged polybottle from the PR container or ITC into Glovebox 188-1, and for the unbagging and opening of the bottle in the glovebox. The PR container or ITC would be opened in Room 188, and the polybottle would be hand carried to the Glovebox 188-1 airlock for transfer into the glovebox. Analysis of the overpressure caused by the deflagration of hydrogen in the bags is presented in Section 4.2.2 and, therefore, is not further developed in this section.

4.2.1.2 Mitigation

Mitigation is provided at each level of confinement by providing a leak path for escape of the hydrogen. A vent hole in the polybottle lid allows passage of hydrogen generated from the solution in the bottle, to vent to the surrounding bag. The inner bag is closed by twisting the end of the bag and taping the twisted section, creating a "horsetail," and then taping over the exposed end of the twisted section. For the outer bag, the "horsetail" may be folded in half and taped. Tape is wrapped around the horsetail to keep it in place. Creases and crevices in the horsetailed plastic provides passages for the hydrogen to escape from one bag into the other and then out into the drum free space. A vent clip placed on the lip of the drum opening before placing the drum lid on, leaves gaps in the drum lid seal for hydrogen to escape from the drum. Calculations in Appendix C demonstrate that hydrogen concentrations in the drum will not approach the LFL for any length of storage time as long as there is a vent clip in place.

Administrative procedures are instituted that prohibit opening of any drum that does not have a vent clip installed between the lid and the drum lip, or holes drilled in the drum lid. Administrative procedures are also in place that prohibit movement of the bagged bottles if there is any indication, such as inflated bags, of gas buildup in the bagged polybottles.

For defense in depth, workers opening the drums and handling the polybottles are dressed in protective clothing and use respiratory protection. In addition, non sparking tools are used, and the drum is grounded to prevent any sparks which could ignite any hydrogen present in the drum.

4.2.1.3 Probability

Using the most conservative leak rate from measurements performed on four unvented and four vented drums, the calculations in Appendix C show that both weapons grade and "worst case" fuels grade plutonium nitrate in 4 M nitric acid stored in vented PR can drums will not reach a flammable hydrogen concentration. A hydrogen burn during the opening of a vented drum is therefore not considered to be credible. A hydrogen deflagration requires the inadvertent opening of a non-vented drum, meaning the wrong drum would have to be selected from the temporary storage location. Given the labeling of the drums and worker training, the likelihood

of selecting the wrong drum is judged to be in the range of one per hundred drums transported. Given the independent check of the drum identification and paperwork and the visual check for a vent clip before opening the drum in Room 188, it is judged that only one in 100 incorrectly selected drums would be opened and not sent back to storage. Because of the use of bonding, grounding, and spark-proof tools, it is judged that the frequency of a hydrogen deflagration can be lowered by another order of magnitude. The combination of faults gives the following accident probability, on a per drum basis:

$$\text{Probability of hydrogen burn per drum} = (1 \times 10^{-2})(1 \times 10^{-2})(0.1) = 1 \times 10^{-5}/\text{drum}$$

Assuming 100 drums are transported and opened per year the annual probability is 1×10^{-3}. The accident is in the Unlikely frequency range (1×10^{-2}/yr to 1×10^{-4}/yr).

4.2.1.4 Consequence Analysis

Quantitative calculations are not provided because the accident requires failure of operators and lab workers to follow administrative controls. Qualitatively, should an unvented drum containing hydrogen be opened and ignited, the potential airborne release of plutonium nitrate solution is considered to be adequately represented by the radioisotope-bearing pressurized liquid container accident analyzed in Section 9.1.2 of the PFP FSAR (FDH 1999). Tests have been performed on 55 gal drums that show that ignited hydrogen will not turn the drums into shrapnel. The lid and bottom of the drum are weaker than the cylindrical portion of the drum, as hoop stresses greater than the tensile strength of the steel are required to fail the cylindrical portion of the drum. The lid is ejected or the bottom fails in the burn causing the drum to be propelled upward (DOE 1993). Severe worker injuries and damage to equipment in the room can occur in the drum deflagration. Significant damage, however, to the Building 234-5Z confinement system would not be expected due to size of the building and the distance of the accident site from the E-3 and E-4 filters and fans. The consequences outside the plant from radiological material released within the room would be negligible due to filtration provided by the facility ventilation system HEPA filters.

4.2.1.5 Conclusions

Severe worker injuries are possible should hydrogen be ignited in a PR container or ITC. The radiological consequences of a deflagration are expected to be negligible outside the plant. Calculations provided in Appendix C show that the concentration of hydrogen in vented PR containers and ITCs used to transport 3 L polybottles of plutonium nitrate solution will be below flammable limits, no matter how long the container or ITC has been in storage. To ensure only PR containers with safe levels of hydrogen are opened in Room 188, vent clips are administratively required to be installed on the PR containers used to transport and temporarily store 3 L polybottles of plutonium nitrate solution. Independent verification of PR container identity and the presence of the vent clip are required before opening in Room 188. Vent clips are not required for ITCs since the lids are loose fitting and not sealed.

4.2.2 Hydrogen Deflagration in Glovebox 188-1 from Opening Bagged Polybottle

As discussed previously, the 3 L polybottles of plutonium nitrate solution are double bagged before being placed into the PR container (55 gal drum) or ITC for transport to Room 188. In Room 188, the double bagged polybottle is removed from the PR container or ITC, hand carried to Glovebox 188-1 and loaded into the glovebox through an airlock. Free hydrogen, due to radiolytic decomposition of the solutions, may be present in these bagged polybottles. If a flammable concentration of hydrogen develops, it can be ignited by mechanical friction or static spark during transfer of a bagged bottle to the glovebox or during the opening of the bag or bottle inside the glovebox.

4.2.2.1 Scenario

From the analysis of Appendix B, an equilibrium hydrogen concentration of 5.1×10^{-6} moles H_2/cm^3, generated by radiolytic decomposition of plutonium nitrate solution and assuming diffusion but no leakage from the bagged polybottle, is initially present in the bags and polybottle. The volume of the bag and the headspace of the polybottle (assuming 2.5 L of plutonium nitrate solution) is estimated in Appendix B to be 6.8×10^3 cm^3. The equilibrium quantity of H_2 in the bag and bottle is thus 3.5×10^{-2} moles of hydrogen.

The polybottle overwrap bags are cut open using scissors. As the bags open, a flammable mixture of hydrogen and air may be released. Because of its low ignition energy, nominally small heat producing sources (e.g., friction and static generation) can result in the ignition of hydrogen.

4.2.2.2 Mitigation

Assuming that there is no leakage from the bagged polybottle, and that there is a flammable mixture in the bags, the first line of defense for the worker transporting the bagged bottle from the PR container or ITC to the glovebox is the protective clothing, including respiratory protection, that is worn. The multi-layered clothing would protect the worker from flame and dispersed chemicals, and the respiratory protection from inhalation of vapor or particulate. Mitigation from release from the facility is provided by the ventilation exhaust systems, which consist of the E-4 exhaust system for Glovebox 188-1 and the E-3 exhaust system for Room 188. The E-4 exhaust system will sweep and dilute any hydrogen released from a bag or bottle during opening in the glovebox. Room CAMs are available for alerting workers to airborne contamination. A bayonet-equipped fire extinguisher is available for extinguishing small fires in the glovebox should a hydrogen burn also ignite combustibles. In addition, magnesium oxide may be placed in the glovebox for use in extinguishing fires.

4.2.2.3 Probability

The assumption for this accident scenario is that there is no leakage from the bags. For this to happen, the horsetail would have to be twisted so tightly and taped so completely that hydrogen could not leak out. The method of plastic bagging of waste with a horsetail closure, specifically because of its breathing capability, has been successfully used at Hanford and around

the DOE complex for many years. Reasons for the success can be seen in the hydrogen generation and leakage calculations presented in Appendix C. In Appendix C the hydrogen concentration in non-vented drums is calculated based on measured leak rates. Using the slowest experimentally measured leak, an equivalent leak path hole area of 2.29×10^{-4} cm^2 was calculated. An equilibrium (long time) concentration of hydrogen for these conditions was just barely into the flammable range. However, it was concluded that vented drums or other vented containers would have openings at least 10 times larger than those estimated, and flammable hydrogen concentrations would not be possible. It is very unlikely that the twisted neck of a plastic bag could be made tight enough to close the creases and crevices down to leak path areas less than the equivalent leak path area determined in Appendix C. A hydrogen deflagration, resulting from the buildup of hydrogen in a bagged bottle with subsequent ignition, requires that the bag be extra tightly twisted and abnormally taped to prevent hydrogen escape. Given the effort required to do this and worker training in correct handling and packaging, a seal like this is conservatively judged to be in the range of one in 100 polybottles bagged and sealed.

If a bag is sealed leaktight, some amount of time is required for hydrogen to build up to a flammable concentration. Normal operations move the freshly filled polybottle in a PR container from Glovebox HC-227S to Room 236 for temporary storage, then to Room 188 and into Glovebox 188-1. Filled polybottles in ITCs are usually transferred directly to Glovebox 188-1 but may be placed in temporary storage as discussed in Section 4.2.1.1. From calculations in Appendix B where the 47.5 L volume of an ITC reaches 25% of the lower flammability limit in 5 days, the concentration in the bag could reach the same condition in less than 2 days. For 100% of the LFL, the time would be closer to 6 to 8 days. Overnight delays may occur occasionally, but longer delays during regular operations would be infrequent. A mechanical friction or static spark must also be present to ignite the flammable mixture. Opening of the bag is accomplished by cutting the bag with scissors. Given these conditions, it is estimated that only one in 100 sealed bags would both have a flammable mixture and be exposed to a source of ignition. This combination of faults gives the following accident probability, on a per bagged polybottle basis:

$$\text{Probability of hydrogen burn per bag} = (1 \times 10^{-2})(1 \times 10^{-2}) = 1 \times 10^{-4}/\text{bag}$$

In Section 4.2.1.3, it was assumed that 100 polybottles are transported and opened per year. The annual point estimate probability is therefore 1×10^{-2}. The burning of flammable gas released from bagged 3 L polybottles is an unlikely event, defined in Table 9-49 of the PFP FSAR (FDH 1999) as having an annual probability in the range of 1×10^{-2} to 1×10^{-4}.

4.2.2.4 Consequence Analysis

If it is assumed that hydrogen does not leak from the bagged polybottle as the bag is opened, a flammable mixture of hydrogen and air will be released. If the hydrogen does not burn as it exits the opened bag, it will, given its high diffusivity, rapidly mix with the glovebox atmosphere. Glovebox 188-1, with dimensions of 96 in. by 83 in. by 44 in., with two additional spaces of 37 in. by 38 in. by 36 in. and 37 in. by 30 in. by 36 in., has a volume of 7,230 L. To

account for the calciner and associated equipment in the glovebox, the glovebox air volume is reduced by a factor of 10%. Subtracting the 723 L volume of the calciner portion of the glovebox yields a volume of 6,507 L. Applying the ideal gas law, this volume can contain 290 moles of gas. If the 3.5×10^{-2} moles of hydrogen released from the bag were to mix uniformly within the volume of the glovebox, the resultant concentration would be 0.01%, which is significantly below the lower flammability limit of 4%. Accordingly, the hydrogen would not burn but would be swept from the glovebox via the E-4 exhaust system and further diluted.

As the hydrogen is released from the bag and mixes with the glovebox atmosphere, localized concentrations within the flammability range will exist for a short period of time. Assuming that all of the hydrogen is released as a puff and is ignited before mixing below the lower flammability limit, the instantaneous energy release would be:

$$Q = (240 \text{ kJ/g-mole})(3.5 \times 10^{-2} \text{ moles}) = 8.4 \text{ kJ}$$

where:

Q = heat generated, kJ
kJ/g-mole = heat of combustion of hydrogen

Conservatively assuming 100% of the heat from the hydrogen burn is transferred to the air in the glovebox, the increase in temperature can be calculated by:

$$\Delta T = Q/mC_P$$

where:

ΔT = change in temperature, K
Q = heat generated, kJ
m = mass of air in glovebox, kg
C_p = specific heat of air, kJ/kg-K

The mass of air in Glovebox 188-1 is equal to the volume of air multiplied by its density:

$$m = (\text{volume})(\text{density}) = (6.51 \text{ m}^3)(1.16 \text{ kg/m}^3) = 7.55 \text{ kg}$$

Note that the pressure inside the glovebox is approximately -0.3 psig (14.4 psia) due to three successive pressure drops between (1) the atmosphere and the building non-radiation zone, (2) the building non-radiation zone and radiation zone, and (3) the building radiation zone and the glovebox interior. The glovebox air density used in this analysis is not corrected for the lower pressure because the calculations for glovebox temperature increase due to the hydrogen

burn and the resulting pressure change are not sensitive to the slight difference in air density due to the slight negative pressure in the glovebox.

Solving for ΔT yields a temperature increase of:

$$\Delta T = 8.4 \text{ kJ}/(7.55 \text{ kg})(1.007 \text{ kJ/kg-K}) = 1.10 \text{ K}$$

Applying the ideal gas law, the pressure in the glovebox given a temperature rise of 1.10 K is calculated as follows:

$$(P_{final}/P_{initial}) = (T_{final}/T_{initial})$$

$$P_{final} = (14.7 \text{ psia})(300 \text{ K} + 1.1 \text{ K})/(300 \text{ K}) = 14.75 \text{ psia}$$

The increase in pressure is therefore 0.05 psig.

A pressure increase of 0.05 psi is not expected to damage the glovebox containment boundary. Walden (1980) suggests gloves fail at an overpressure of 0.6 psig. A pressure increase of 0.4 psig could breach the glovebox via failed bag-in/bag-out ports. The increased pressure could result in a short-lived air flow and pressure increase through the E-4 exhaust system. Increased flow through the HEPA filters increases the pressure drop across the filters and, if large enough, could lead to filter failure. Data obtained from the Tank 241-Z-361 Justification for Continued Operation (JCO) (BWHC 1999c) indicates that filters can typically withstand pressure drops up to 0.36 psi (10 in. w.g.) before failure would be expected. The JCO for Tank 241-Z-361 also indicates that the typical pressure drop across HEPA filters at rated flow is a maximum of 1.3 in. w.g. The pressure rise of 0.05 psi in the glovebox due to the deflagration is equivalent to 1.4 in. w.g. Combining the maximum operational pressure drop of 1.3 in. w.g. with the 1.4 in. w.g. pressure increase from the deflagration yields a maximum pressure drop across the E-4 exhaust system filters of 2.7 in. w.g. Consequently, the pressure increase caused by the deflagration is not expected to adversely impact the E-4 exhaust filters. If the filters were significantly impacted by the deflagration, pressure monitoring instrumentation for the filters would indicate either high pressure, if the filters were plugged, or low pressure, if the filters breached. In addition, periodic filter integrity testing would eventually indicate degraded filters. The air flow increase through the E-4 filters would have no appreciable impact on stack emissions since the increased flow would occur for such a short time.

Although a pressure increase of 0.05 psig can be conservatively calculated, such an increase would not be realized for three principal reasons. First, 100% of the hydrogen contained in a sudden release would not burn as assumed. A stoichiometric mixture of 3.5×10^{-2} moles of hydrogen and air has a volume of 0.5 L, which would fill approximately 0.01% of the glovebox. Accordingly, the hydrogen would burn as an unconfined cloud, the efficiency of which can be significantly less than 100%. As stated in *Evaluation of Unconfined*

Vapor Cloud Explosion Hazards (Pugh 1987), when small unconfined vapor clouds are ignited, the vapors usually burn without pressure effects and with a low flame speed. Second, 100% of the heat from the hydrogen burn would not be transferred to the air as assumed above, i.e., the system is not adiabatic. Third, Glovebox 188-1 is not a sealed vessel. Qualitatively considering these factors, it is concluded that the release and subsequent ignition of hydrogen from a bag will not breach Glovebox 188-1 since there would be little or no pressure increase. This conclusion is consistent with operating experience at PFP and throughout the DOE complex.

The analyzed scenario does not result in breach of the glovebox. Any quantity of plutonium potentially suspended inside Glovebox 188-1 by burning hydrogen remains confined to the glovebox will be drawn through the E-4 exhaust system and filtered by a least two stages of HEPA filters before discharge to the environment.

If the deflagration occurred in Room 188, outside of the glovebox, the volume of the room is much larger than the glovebox and the pressure increase would be correspondently less, and bounded by the analysis of the glovebox. The dispersal of the nitrate solution by the accident outside of the glovebox is bounded by the analysis of the radioisotope-bearing pressurized liquid container in Section 9.1.2 of the PFP FSAR (FDH 1999) where 5 L of nitrate solution is released.

4.2.2.5 Conclusions

The release and ignition of hydrogen from a bagged 3 L polybottle is an unlikely event. If the deflagration occurred in the glovebox, the small pressure increase, if any, due to the burning hydrogen would not be sufficient to breach the glovebox. Occurrence of the accident outside of the glovebox in a larger volume would not have greater consequences. Accordingly, from a pressurization event perspective, the hydrogen does not pose a risk to workers, the public, or the environment.

If the accident occurred outside of the glovebox, the dispersal of the nitrate solution by the accident is bounded by the analysis of the radioisotope-bearing pressurized liquid container in Section 9.1.2 of the PFP FSAR (FDH 1999).

4.2.3 Flammable Gas Deflagration in the Laboratory Prototype Calciner

The aqueous solutions processed by the Laboratory Prototype Calciner contain small concentrations of entrained organic solvent residuals from processing. It is possible that the immiscible organic material in the feed solution may coalesce and separate out from solution in the feed tank and be injected as a slug into the prototype calciner. It is also possible that oil, overflowing from traps in the calciner air supply line, could be introduced through the feed nozzle into the calciner. Because the prototype calciner operates at very high temperatures (approximately 1000 °C), the injection of a slug of organic (TBP or compressor oil) may result in a flammable gas deflagration inside the calciner.

4.2.3.1 Scenario

The hazard analysis documented in Appendix A recognized the possibility that organic material could be injected into the calciner and result in a deflagration.

The most likely organic material to be pumped into the calciner is a mixture of TBP and its degradation products di-butyl phosphate (DBP) and mono-butyl phosphate (MBP). At temperatures below the auto-ignition point, the TBP and its decomposition products are likely to break down into butene, water vapor, and pyrophosphoric acid vapor (or acid decomposition products), based on experimental data reported in WHC (1994). Flammable hydrocarbons lighter than butene are also possible. For the purposes of this analysis, it is conservatively assumed that a stoichiometric mixture of butene and air develops in the calciner and is then ignited.

It is further assumed in this scenario that a total of approximately 50 ml of concentrated TBP is in the feed (in a separable phase). This quantity corresponds to 1% of a full 5 L feed tank. This material is assumed to be fed into the calciner at a rate of 1 ml/s until the supply of TBP is exhausted. This means that after the initial deflagration in the calciner, deflagrations could continue for the next 49 seconds. Variations in the rate at which material is fed to the calciner would alter the frequency and, potentially, the magnitude of a given deflagration or series of deflagrations. However, the results of this analysis are not sensitive to feed rate variations.

The calciner fails because of the initial deflagration (see Section 4.2.3.4). The flames jetting from the failed calciner in the subsequent deflagrations are assumed to generate sufficient heat to fail one of the fire-resistant plastic windows or window seals in Glovebox 188-1, creating a pathway for contamination to reach the room. This assumption is based on a calculated flame temperature of 3500 °C (see Section 4.2.3.4) due to the butene deflagration. If the flame were to impinge on the window, the heat is sufficient to damage or weaken the window and create a release pathway.

Although it is possible for flammable gases to be generated inside the calciner and to pass into the calciner offgas system, deflagrations inside the scrubber or phase separator tank are bounded by the calciner deflagration case analyzed here. Although the energy release and pressures produced in those tanks could be similar to the calciner case, the scrubber and phase separator tanks contain negligible radiological material in comparison to the calciner (e.g., 4 kg PuO_2).

4.2.3.2 Mitigation

Mitigation for this scenario is provided by minimizing the quantity and concentration of organic material that may be introduced into the calciner. As discussed earlier in Section 4.2.3, two potential sources of organic material potentially could be introduced into the calciner: concentrated TBP in the plutonium nitrate feed solution or air compressor lubrication oil.

Organic material in excess of 1% concentration in the plutonium nitrate feed solution is not permitted to be introduced into the calciner. Chapter 5.0 states that the feed solution is limited to 1% organic content with no visible, separable phase. This requirement has been shown to be effective in prior calciner operations and needs to be retained for future operations.

Additionally, to prevent the injection of compressor lubrication oil into the calciner, it is necessary to ensure that the compressed air oil trap is operational and continuously drained.

4.2.3.3 Probability

As discussed previously, two potential sources of organic material potentially could be introduced into the calciner: TBP in the plutonium nitrate feed solution or air compressor lubrication oil.

Organic material in excess of 1% concentration in the plutonium nitrate feed solution is not permitted to be introduced into the calciner. As stated in Section 2.1, the feed solution is limited to 1% organic content with no visible, separable phase of organic material. It is considered unlikely that a concentrated slug of TBP (or other organic material) would be injected into the calciner. This probability is based on: (1) the requirement to sample for organic content, (2) the requirement to confirm that no separable layer exists, (3) visual inspection of the aqueous feed prior to calciner operations, and (4) the prior operational history of calciner operations.

Feed preparation procedures require steps to sample for the presence and concentration of organic. Feed found to be excess of 1% organic content is rejected from the process. In addition, the feed is analyzed to determine if a separable layer either exists, or is likely to exist after sampling. If the feed contains (or is likely to contain) a separable phase, it is not processed in the calciner.

Prior to the start of the calciner operation, the operator inspects the feed for a separable layer. It is recognized that if the feed container does contain a separable layer of only 50 ml (1% of 5 L), it may not be easily spotted by the operator. Based on the dimensions of the feed container, this layer would only be approximately 1/16-in.-deep. Prior operational history of the calciner processing more than 60 L of solutions, primarily plutonium nitrate, and using similar inspection procedures supports the unlikely frequency since deflagrations have not been experienced, although small pressurizations of the calciner have occurred from process upsets.

Collectively, based on the discussion presented here, the probability of introducing a slug of TBP (or other organic material) into the calciner is estimated to be unlikely.

Similarly, it is considered unlikely that air compressor lubrication oil would be injected into the calciner. WHC (1996) also recognized and eliminated this hazard by modifying the filter trap drain lines so that they are left permanently open.

Therefore, in order for compressor lubrication oil to be injected into the calciner, a number of failures would be required. Currently, the drain on the air line trap is kept open, with air line condensate/oil draining into an open 3 or 5 gal container. The line between the trap and

open drain container would have to fully plug and remain plugged for an extended period to allow the trap to fill. Overflow of the trap with oil would then be required. In order for the trap to overfill, numerous operator surveillance activities would need to be missed (i.e., not recognizing a plugged drain line or material buildup in the trap).

The scenario analyzed is this section is estimated to have an annual probability that falls in the unlikely range (i.e., 10^{-4} to 10^{-2}).

4.2.3.4 Consequence Analysis

For this accident analysis, it is conservatively assumed that a stoichiometric mixture of flammable gas and air develops in the calciner and is ignited. As discussed in Section 4.2.3.1, the most likely material to be pumped into the calciner is a mixture of TBP and its degradation products DBP and MBP. The TBP and TBP decomposition products are expected to break down into butene, water vapor, and pyrophosphoric acid vapor (or acid decomposition products). For the purposes of this analysis, the volume of the calciner vapor space taken up by water and acid vapor (or acid decomposition products) is conservatively ignored. The vapor space gas mixture is assumed to be composed only of air and butene gas, with the oxygen from the air and the butene in stoichiometric proportion. The air for the combustion reaction is supplied by the atomizing injector.

The internal volume of the calciner, excluding the volume of the internal dome heater and the volume of the ceramic filters has been estimated to be 7.7 L. Assuming a PuO_2 mass of 4 kg at its maximum estimated bulk density of 5.67 kg/L (Hillesland 1997), the maximum freeboard volume in the calciner vessel is 7.0 L. Variations in the density of the PuO_2 (creating slightly more or less freeboard volume) do not have a significant effect on the pressures that are generated in the calciner.

If it is assumed that the flammable mixture in the freeboard volume is at the normal offgas operating temperature of 626 °C (see Figure 14) at the time of ignition and at atmospheric pressure, the total quantity of butene and air in the calciner at the time of ignition, per the ideal gas law, is 0.095 g-mol. The balanced equation for the reaction of butene in air is as follows:

$$C_4H_8 + 6O_2 + 22.6N_2 \rightarrow 4CO_2 + 4H_2O_{(vapor)} + 22.6N_2$$

The ratio of N_2 to O_2 in the above equation reflects the ratio of N_2 to O_2 in atmospheric air. Based on the above equation, of the 0.095 total moles of gas initially in the calciner, 3.21×10^{-3} moles are butene molecules to ensure a stoichiometric mix. The mole fraction of butene in the calciner air is 3.50×10^{-2} (3.50%). Similarly scaling the remaining reactant and product species coefficients for the total number of moles of gas initially in the calciner gives the following balanced equation:

$$3.21 \times 10^{-3}\ C_4H_8 + 1.9 \times 10^{-2}\ O_2 + 0.073\ N_2 \Rightarrow$$

$$1.28 \times 10^{-2}\ CO_2 + 1.28 \times 10^{-2}\ H_2O_{(vapor)} + 0.073\ N_2$$

The heat of combustion for butene is 19,496 BTU/lb (Section 22 of Perry [1950]), or 2537 kJ/g-mol. The total heat released in the deflagration is therefore 8.14 kJ ([2537 kJ/g-mol][3.21 x 10^{-3} g-mol]) or 7.71 BTU.

To calculate the pressure that is generated inside the calciner, the ideal gas law is used. In order to accurately determine the pressure created by the combustion products of the deflagration inside the calciner, it is first necessary to determine the temperature that is created inside the calciner. To do this, the following equation is used:

$$Q = mc_v\Delta T \qquad (1)$$

where:

Q = energy created by reaction, 8.14 kJ (1,945 cal)
m = mass of product, g (see following equation for values)
c_v = specific heat of product, cal/g-°C (assumes constant volume reaction)
ΔT = temperature difference, °C

Tailoring this equation to the combustion products of the reaction analyzed here and solving for ΔT gives:

$$\Delta T = Q/(m_{CO2}c_{v(CO2)} + m_{H2O}c_{v(H2O)} + m_{N2}c_{v(N2)}) \qquad (2)$$

where:

Q = 1,945 cal
m_{CO2} = 0.528 g
m_{H2O} = 0.216 g
m_{N2} = 2.04 g
$c_{v(CO2)}$ = 0.260 cal/g-°C
$c_{v(H2O)}$ = 0.480 cal/g-°C
$c_{v(N2)}$ = 0.219 cal/g-°C

The c_v values shown here were calculated using an iterative procedure to account for the wide temperature range associated with this reaction. Using a polynomial expansion method similar to that found in Chapter 6 of Lindeburg (1994) and a final iterative temperature of 1,997 °C (2270 K), the listed specific heats are developed.

Solving equation (2) gives a ΔT of 2,830 °C. Calculating a final temperature of the reaction gives 3,456 °C ($\Delta T + T_i$ = 2,830 °C + 626 °C). To determine the final pressure in the calciner, the ideal gas law is used. Input parameters include the calculated final temperature (3,456 °C), the interior freeboard volume of the calciner (7.0 L), and the total number of moles of combustion products in the calciner (0.099 g-mol). The final pressure is calculated to be 63 psi.

The calciner is constructed of stainless steel pipe. The pipe will have reduced strength at the extreme operating temperature of the calciner (up to 1000 °C) and would likely rupture due to the pressure generated as a result of the deflagration. Calculations performed in Appendix E show that the calciner would fail at a pressure of approximately 24 psi. It is clear that rupture of the calciner would be expected as a result of a deflagration of butene vapors.

The production of shrapnel fragments that could penetrate the glovebox structure, however, is not anticipated, due to the ductility of the metal at high temperatures. The shape and design of the agitator prevent it from being ejected out of the top of the calciner. The product collection jar, however, is likely to rupture in the accident. Pressure relief will occur through the product drop tube on the bottom of the calciner because of the broken product collection jar, through the calciner pressure relief port, and through any openings that might develop in the calciner shell. Plutonium dioxide powder will be expelled out of these relief paths into the glovebox air. It is assumed in the scenario that the calciner fails such that flames and hot gases are directed toward the fire-resistant window in Glovebox 188-1.

The hot offgases generated from the calciner deflagration expanding through the calciner relief paths will cause a pressure increase in the Glovebox 188-1 air. The gas flow from the calciner will be limited to sonic velocity through the calciner relief paths.

For this analysis, the pressure increase in the glovebox is calculated using equation (2) that has been modified using the specific heat (c_v) for air and the mass of air present initially in the glovebox. The c_v for air is taken to be 0.171 cal/g-°C and the mass of air initially present is calculated using the ideal gas law. Section 4.2.2.4 states that the available expansion volume in the glovebox is 6,570 L. If the initial temperature of the glovebox air is 300 K, the number of moles of air present in the glovebox is 267 g-mol (7,743 g).

If the heat generated in the calciner deflagration is transferred to the glovebox air, equation (2) can be solved for ΔT:

$$\Delta T = Q/(m_{air}c_{v(air)}) \qquad (3)$$

Substituting the values stated previously gives a ΔT of only 2.4 K. This means that the final temperature of the glovebox air is 302.4 K.

Substituting this temperature value into the ideal gas law gives a final pressure of 14.8 psi in the glovebox. This is an increase of only 0.1 psi over the initial pressure. Based on the

discussion provided in Section 4.2.2.4, the confinement capability of the glovebox structure is not expected to be compromised as a result of this overpressure. In addition, as also discussed in Section 4.2.2.4, the E-4 exhaust system filters are not expected to be affected by this small of an overpressure.

A breach of the glovebox, however, is postulated in this scenario. Because the flames and heat from each deflagration are assumed to be directed toward one of the fire-resistant plastic windows, it is assumed that the confinement capability of that plastic window is compromised by melting, burning a hole through it or damaging the window seal. This provides a release path to Room 188.

Following the initial deflagration, it is postulated that TBP continues to be injected into the calciner at a flow rate 1 ml/s. The glovebox ventilation exhaust system (E-4) is assumed to continue to operate. This provides a source of air for subsequent deflagrations. Therefore, deflagrations are assumed to continue for the next 49 seconds until the remaining TBP is exhausted. As the deflagrations are occurring, process air continues to flow into the calciner. The air violently disturbs (i.e., sparges) the bed of plutonium oxide powder creating airborne material and spreading contamination to the glovebox and the room.

The fire is not expected to spread outside of Glovebox 188-1. If other combustibles are present in the glovebox, it is possible that they could catch fire and contribute to the release. Besides the plastic window that is assumed to fail in this scenario, the remainder of the glovebox is made of steel and glass (see Section 2.3.3.1).

It is conservatively assumed in this scenario that the equivalent of 4 kg of PuO_2 is subject to release. This value is equivalent to a full bed of material. Using 4 kg is intended to cover the amount of Pu that is vented in the initial deflagration, the amount spilled from the broken product collection container, and amount created from the subsequent process air sparging and deflagrations. Two off-normal events that occurred during prior operation of the calciner demonstrate that large releases are possible. In one of the off-normal events (i.e., pressurization of the calciner), it was estimated that 50 to 60 g of material was released in a period of 15 to 30 s. Section 4.2.5.1 provides additional discussion of these events.

All of this material is conservatively assumed to be available for release (i.e., airborne release fraction [ARF] = 1). This value seems reasonable given that the process air continues to be injected into the calciner during and after the assumed deflagrations. The respirable fraction for this release is estimated to be 3%, based on Figure 9-28 in the PFP FSAR (FDH 1999). The figure is based on data for plutonium fluoride which is assumed to also be representative of plutonium oxide. Applying the ARF x RF (1 x 0.03) to the 4 kg of material assumed to be released gives a respirable quantity of 120 g (4,000 g x 0.03).

For the purposes of this analysis, it is conservatively assumed that the all of the plutonium aerosol generated is exhausted via the E-3 exhaust system servicing Room 188. The E-3 exhaust system has only a single stage of HEPA filtration whereas the E-4 exhaust system (which exhausts Glovebox 188-1) has two stages. While it is likely that some portion of the plutonium aerosols would be exhausted through the E-4 exhaust system that services the glovebox, there is

no justifiable basis for determining the aerosol split that may be realized through the ventilation exhaust systems. Therefore, if it is assumed that the entire quantity of plutonium aerosol is vented through the one stage of HEPA filtration in the E-3 exhaust system, the calculation of released quantity will be conservative. The minimum acceptable collection efficiency, as indicated by testing, is 99.95%. Applying this value to the 120 g of plutonium released via the E-3 exhaust pathway, results in the discharge of 0.06 g from the 291-Z-1 Stack, all of which is respirable.

The doses due to the release of 0.06 g of plutonium can be calculated by using the methodology from Section 9.3.6 of the PFP FSAR (FDH 1999) as follows:

$$D(rem) = Q(g) \cdot \chi/Q'(s/m^3) \cdot R(m^3/s) \cdot C(rem/g)$$

where:

D = Dose, rem

Q = Quantity of plutonium released, 0.06 g

χ/Q = Atmospheric dispersion coefficient for elevated release, 1.62×10^{-5} s/m^3 for onsite receptor and 5.73×10^{-6} s/m^3 for offsite receptor from Tables 9-39 and 9-40, respectively, of the PFP FSAR (FDH 1999)

R = Breathing rate, 3.3×10^{-4} m^3/s

C = Gram plutonium to dose conversion factor for Class Y, >10% ^{240}Pu, 90th percentile; 1.7×10^{8} rem/g (EDE) and 2.7×10^{9} rem/g (Bone Surface) from Tables 9-46 and 9-47, respectively, of the PFP FSAR (FDH 1999)

Therefore, the EDE doses are:

- onsite = 5.5×10^{-2} rem
- offsite = 1.9×10^{-2} rem

The bone surface doses are:

- onsite = 0.87 rem
- offsite = 0.31 rem

4.2.3.5 Conclusions

The results of the preceding analysis show that the consequences of a bounding calciner deflagration are below the risk acceptance guidelines (Table 9-49 of the PFP FSAR [FDH 1999]) for an unlikely event. The reason the doses remain so small is the functioning of the E-3 exhaust system HEPA filters during and after the calciner deflagration event.

4.2.4 Glovebox 188-1 Fire

Section 4.2.3 analyzed the impacts of a deflagration occurring inside the calciner and, potentially, impacting the confinement capability of Glovebox 188-1. The fire analysis in this section evaluates the potential for a significant fire to occur in the glovebox due to combustible materials coming into contact with the hot process equipment.

4.2.4.1 Scenario

The hazards identification team determined that a glovebox fire could be initiated in one of the following ways:

- Pump or motor burnout
- An accumulation of flammable waste materials is placed next to a hot surface.

There is one pump and one motor within the glovebox. The pump transfers feed from the feed tank into the calciner. The agitator drive motor drives the agitator. Neither the pump nor the motor is near the area where waste is normally accumulated. The feed pump is at the bottom of the glovebox beneath the floor of the operating area. The agitator drive motor is up high in the glovebox, well above the operating deck.

The waste in the glovebox is comprised primarily of plastic bags, ice cream cartons and polybottles. The feed solution is transferred to Glovebox 188-1 in polybottles within plastic bags. The waste is kept at the far right hand side of the glovebox near the bag-out port. This location is well away from the pump and the agitator motor. There are two fire-resistant plastic windows in the glovebox. The windows are situated above the floor of the operating area. The bottom of the windows are near the center of the calciner. The top of the windows are near the top of the glovebox. The agitator drive motor is not near the plastic windows. Therefore, motor burnout would not start the plastic windows on fire as they are too far away and the motor is small.

A pump or motor burnout could create a small, short duration fire. However, as is discussed above, this fire would not likely involve combustible materials and, therefore, would not be expected to be large enough to disperse radioactive material or cause operator injury.

A fire could conceivably start if combustible material was brought in contact with hot surfaces. Hot surfaces include the calciner, the calciner off-gas piping and the product piping and collection jar. In general, the hot surfaces are either well insulated or located near the top of the glovebox far from the normal location of waste accumulation. The calciner is insulated to prevent heat loss and operator injury. The insulation extends from the base of the calciner, 4 in. above the glovebox operating area floor, upward to just above the calciner off-gas outlet nozzle. The insulation temperature remains below 50 °C (WHC 1996). There is also insulation around the feed and product tubes between the base of the calciner and the operating floor.

The off-gas lines can become quite hot. The off-gas temperature is around 330 °C (FDH 1998a). The off-gas lines are in the upper half of the glovebox, in the vicinity of the plastic

panel. The plastic panel also contains a few gloves with additional ports for other gloves. The off-gas piping extends above the insulation and is cooled by radiation and convection to the glovebox air. The pipes are ¾-in. tubing. One of the off-gas tubes comes out of the calciner towards the panel. The tube is then routed parallel to the panel, about 6 in. away, for about 8 in. It then travels back toward the center of the glovebox. Except for this short run, the hot off-gas tubes are at the center of the glovebox about 22 in. from the panel and gloves. Operation of the calciner during testing showed that the plastic panel and gloves are unaffected by the heat from the off-gas tubes. Waste accumulations are on the operating deck far from the off-gas tubing. It is possible that a hole could be melted in a glovebox glove if the operator inadvertently touches an off-gas tube or if the gloves are left inside the glovebox near the portion of the off-gas tubing that passes close to the glovebox. This location is recognized by the operators as being hot and care is taken to keep the gloves away.

The product line can also become hot. The product line drops down below the calciner into the lower portion of the glovebox. There are no plastic panels or waste at this location; however, there are gloveports in the glass windows at this location. Gloves could touch the hot tube or collection jar. Both are located about 18 in. from the side of the glovebox and are small. Care is taken to keep the gloves away from this location. This location is recognized by the operators as being hot and care is taken to keep the gloves away.

Lastly, the gap between the calciner base and the glovebox operating floor can get hot. The heat comes from radiation through the calciner base and convection of the hot dome air (heated by the internal dome heater) down into the gap. The gap is 4 in. tall and 16 in. in diameter. The feed tube, product tube, and dome heater are inside of a 5 in. diameter circular area near the centerline of the calciner. The calciner is supported by 4, ½ in. posts on an 8 in. diameter circle. The posts are within a base tray that is square in shape having sides 16 in. long. The sides of the base are made of 1 in. by 1 in. angle iron. As a result, the actual gap is only 3 in. wide. If waste should get into this gap, close to the heat sources near the center of the calciner, it could be ignited. The fire would likely be small, as it is not expected that much waste can get to this location. The area contains feed tubing, scrubber tubing and waste tubing. The plastic windows are about 18 in. above the floor and about 16 in. from the center of the calciner. The separation distance prevents propagation to the windows. It is possible that a glove or other combustible, such as window seals, could burn but the fire would not propagate.

As a result, under normal operational conditions there would be no fire due to contact of gloves, plastic windows or waste with hot surfaces. It is possible, however, for a hole to be burned in a glove and it is possible for small fires to occur. It is also possible that debris from maintenance could be inadvertently left near a hot surface. It is believed that this fire, if it occurs and is not extinguished, would remain small, as large accumulations of debris would almost certainly be removed following maintenance.

Even if a fire should start, there is a dry chemical, bayonet-equipped, portable fire extinguisher external to the glovebox. The bayonet can be pushed through any number of gloved, glovebox ports to fight fires inside the glovebox. There is also a wet pipe sprinkler system in the room.

All except two of the glovebox windows are made of wire-reinforced glass, not plastic. Because of this, ignition of combustibles leading to a fire that can directly or indirectly result in the dispersal of radioactive material outside the glovebox is not considered to be credible.

Even though a fire in the glovebox during normal operations is not considered credible, it is possible for a seismic event to result in a fire within this glovebox. The analysis of a seismically initiated fire in Glovebox 188-1 is included in Section 4.2.5.

4.2.5 Glovebox 188-1 Seismic Event

This section presents unmitigated and mitigated Design Basis Earthquake (DBE) accident analyses for the Laboratory Prototype Calciner. The purpose of these analyses is to quantify the incremental risk associated with calciner operations relative to analyses contained in Chapter 9 of the PFP FSAR (FDH 1999).

The calciner is housed in Glovebox 188-1 of the Plutonium Process Support Laboratory (PPSL). The PPSL encompasses Rooms 179 through 191 and Rooms 201 and 202 of Building 234-5Z. The structural response of Building 234-5Z to the DBE is discussed in Chapter 9, Section 9.2.4.1.1 of the PFP FSAR. Seismic analyses and evaluations have concluded that Building 234-5Z can resist DBE motions without collapse. However, internal structures (e.g., gloveboxes), systems (e.g., ventilation), and components (e.g., motors) can be damaged.

Chapter 9, Section 9.2.4.2.1I of the PFP FSAR states that gloveboxes in the PPSL are not seismically qualified and assumes that powders and solutions contained therein are spilled. Glovebox 188-1 has been upgraded and is qualified to withstand seismic events to prevent a criticality as a result of the seismic event and for personnel protection from a falling glovebox. Although the glovebox will not topple, glovebox windows, equipment within the glovebox, and supporting services are not qualified and may or may not fail during a seismic event.

Section 4.2.5.1 presents an unmitigated DBE accident analysis where no controls are credited with shutting down the calciner. The unmitigated consequences are shown to exceed radiological risk acceptance guidelines such that a control is warranted. Section 4.2.5.2 presents the mitigated DBE accident analysis that assumes that an interconnection to the PFP ventilation seismic shutdown system deenergizes calciner equipment and systems to prevent pressurization of the calciner and generation of airborne material. Section 4.2.5.3 analyzes the same event as Section 4.2.5.2 but further postulates a seismic induced fire. The mitigated consequences are shown to meet most of the radiological risk acceptance guidelines.

4.2.5.1 Unmitigated Seismic Event

To identify credible DBE scenarios, an event tree was developed that postulated the success or failure of calciner systems and components (Appendix F). The systems and components selected for inclusion in the event tree were those whose failure could directly and significantly contribute to the release of plutonium. The event tree identified thirty unique sequences initiated by a seismic event, nine of which were judged to result in large releases.

Large releases were determined to result primarily from event sequences leading to a pressurized calciner due to continuing feed injection along with the process air supply to the calciner. This information combined with the hazards analysis binning and accident selection (Section 3.2.1) led to selection of the unmitigated scenario presented here. Although the HAZOP recorded an S2 consequence (onsite receptor), the subsequent analysis found possible offsite receptor consequences. The individual frequencies (or annual probabilities) of the nine event sequences resulting in large consequences ranged from 1.5×10^{-5}/y to 9×10^{-7}/y. Summing the nine event sequences yields a frequency of 2.7×10^{-5}/y. Consequently, a seismic event potentially leading to large releases is considered credible and has been analyzed for potential consequences and comparison with the applicable risk acceptance guidelines.

The main function of the event tree for the unmitigated seismic analysis was to determine the credibility of a postulated large release from the calciner process equipment and, if credible, to determine the set of conditions leading to the largest consequence. The probability values used in the event tree were based on qualitative engineering judgement without any attempt to perform field evaluations of the various component and system designs to determine their ability to withstand a seismic event. Consequently, for risk acceptability comparisons for the unmitigated seismic event analysis, all component and system failures were assumed to occur with a probability of 1 rather than the estimated value in the event tree. Therefore, for risk acceptability purposes, the accident dose consequences are evaluated against the guidelines at the annual seismic event probability of 1×10^{-4}. This is conservative since larger doses are acceptable at lower probability values, which would be the case if components were determined to fail at probabilities less than 1.

The specific scenario selected to quantify the unmitigated consequences of a DBE assumes that the 26-in.-Hg vacuum system servicing the calciner fails. The calciner is assumed to continue operating and feed to the calciner is assumed to continue. Given loss of vacuum and continuation of feed, the calciner will pressurize to the point that the pressure relief cap actuates. Detailed scenario development and dose calculations are presented in Appendix F. The entire 4.0 kg of plutonium contained in the calciner and 2.25 kg of plutonium in the liquid feed is conservatively assumed to be ejected from the calciner. Figure 9-28 of the PFP FSAR (FDH 1999) provides data for respirable fraction (RF) for plutonium fluorides that yields a value of 0.03. Although the data in the figure is for plutonium fluoride, it is assumed that it is also applicable to plutonium oxide. Applying the 0.03 RF to the plutonium oxide and an airborne release fraction (ARF) of unity, the respirable release is calculated to be 188 g ($6{,}250 \text{ g} \times 0.03 = 187.5 \text{ g}$).

In Appendix F, the onsite and offsite doses were calculated for both the "no ventilation" and the "ventilation" cases. In the "no ventilation" case, both the ventilation supply and exhaust fans are assumed to shut down during the earthquake. Although the ventilation system is non-operational, airborne radiological material can escape to the environment via open doors due to wind effects. Chapter 9, Section 9.2.4.7.1 calculates that 38% of the airborne material is released. The release for the unmitigated scenario is, therefore, 71 g. From Appendix F, the corresponding onsite and offsite doses are 1040 rem EDE and 22 rem EDE, respectively. These doses exceed the radiological risk acceptance guidelines shown in Table 9-49 of the PFP FSAR (FDH 1999) for an event with an annual probability of 1×10^{-4}.

In the "ventilation" case, the E-3 and E-4 exhaust fans are assumed to continue to operate but the associated ventilation system HEPA filters are assumed to fail. Chapter 9, Section 9.2.4.7.2 calculates that, as a result of settling within the facility, 84% of the airborne material is released to the environment. The release for the unmitigated scenario is therefore 158 grams. The corresponding onsite and offsite doses calculated in Appendix F are 79 rem EDE and 28 rem EDE, respectively.

Based on the large doses potentially resulting from an unmitigated seismic event, a mitigative feature was selected and is discussed in the following section, Section 4.2.5.2.

4.2.5.2 Mitigated Seismic Event

The previous section demonstrated the need for a mitigative feature to prevent unacceptable consequences resulting from a seismic event. The mitigative feature selected, as discussed in the following paragraphs, is to interconnect various calciner process equipment and systems to the existing PFP ventilation seismic shutdown system. This interconnection deenergizes various components and, thereby, prevents pressurization of the calciner and potential release of significant quantities of airborne material. This section analyzes a seismic event involving the calciner process equipment incorporating the mitigation afforded by the interconnection to the seismic shutdown system.

The mitigative feature selected involves the principal operating equipment for the calciner having been interconnected to the PFP ventilation seismic shutdown system. This interconnection results in deenergizing the following components:

- calciner heaters including the dome heater
- process air supply solenoids to close valves A through G shown in Figure 7.
- agitator motor
- feed pump motor

Deenergizing the above equipment prevents the potential pressurization of the calciner and generation of significant airborne material by shutting off the air supply to the calciner feed nozzle and to the offgas filters and by shutting off the calciner feed solution. Shutting off the agitator limits the potential for sweeping material out of the calciner bed. Shutting off the heaters reduces the potential for boiling of solutions released into the glovebox and potential ignition of flammable materials.

In addition to the components deenergized by the seismic shutdown system, two check valves (designated as valves H and I on Figure 7) are provided in the inlet air line to the accumulator supplying air for the offgas filter back-pulse operation. These valves prevent backflow of air from the accumulator to the feed nozzle which could result in pressurization of the calciner and generation of airborne material. The check valves are redundant to the solenoid valve (valve C on Figure 7) on the air supply line to the feed nozzle which is deengerized to close by the seismic shutdown system.

Incorporation of the interconnection to the PFP ventilation seismic shutdown system, when factored into the accident analysis for a seismic event, results in offsite dose consequences below the Risk Acceptance Guidelines (RAG) and onsite dose consequences for the accumulator depressurization case that are slightly above the RAG, as demonstrated in the remainder of this section and and in Section 4.2.5.3. Descriptions of the components interlocked with the seismic shutdown system and the related design requirements are provided in Chapter 2.0. The related controls and safety designation are provided in Chapter 5.0.

4.2.5.2.1 Scenario. It is assumed that the calciner is operating at its normal, maximum operating temperature (e.g., a calciner wall temperature of 1000 °C) at the time of the DBE. Similar to the unmitigated analysis, it is assumed that the DBE results in a loss of calciner vacuum. The interconnection to the PFP ventilation system seismic shutdown system is assumed to function as designed, thereby shutting down the heaters, agitator motor, and feed pump, and closing the solenoid valves on the incoming air supply header which provides air for the feed nozzle and for filter back-pulse operation.

Closing the air supply solenoid valves prevents continuous pressurization of the calciner given a loss of vacuum. However, it is assumed that the solenoid and check valves (Figure 7, valves C, H and I), between the air accumulator (nominally pressurized to 70 psig) and the feed nozzle fail such that air flows through the calciner bed as the accumulator depressurizes. This airflow through the bed results in the suspension of plutonium oxide. Also, assuming failure of solenoid valves D, E, F and G (Figure 7), air from the accumulator could also flow to the calciner filters, which would dislodge any accumulated material. Given loss of vacuum, depressurization of the accumulator will pressurize the calciner to the point that the pressure relief cap lifts, thereby releasing plutonium suspended within the calciner into the glovebox.

After the air accumulator depressurizes, it is assumed that the calciner, feed tank, and product receiver vessel structurally fail in a manner that releases their contents into the glovebox as described below.

Calciner Failure. The calciner contains 4 kg of plutonium as an oxide powder. Because the calciner metal parts are at high temperatures, it can be postulated that the calciner body or flange bolts fail due to the additional stress caused by the DBE. If the calciner body would fail, it is likely that failure would result in the release of some of the plutonium oxide powder. However, it is conservatively assumed that all of the powder is released.

The seismic event could cause failure of the calciner chamber heater/insulation sections. These half-sections could become detached from the calciner body, thereby exposing the heating elements at an initial temperature as high as 1250 °C and the body which could be at 1000 °C. Another possibility is failure of the upper insulation sections. This would expose the upper part of the calciner body which is at a lower temperature than the chamber region.

If the calciner fails and exposes hot surfaces and hot powder, heat would be lost by radiation, conduction, and convection to the glovebox walls, decks, ceiling, air, and any liquids that come into contact with the hot surfaces. The calciner body and inner chamber (with dome) are cylindrical and would be expected to retain partial cylindrical shape. Some of the calciner

flanges could be expected to remain attached in their design configuration. These features limit the metal contact surface available for heat transfer to the feed liquid. Therefore, only a fraction of the calciner heat stored in the metal mass could transfer heat to the feed liquid.

The plutonium oxide powder released from the calciner would land on the intermediate level of the glovebox and some could fall to the floor of the glovebox through openings in the intermediate level deck. Some of the powder could be entrained in the glovebox air as it falls to the floor of the glovebox. The convective air currents driven by the hot segments and pieces from the failed calciner would tend to suspend plutonium oxide powder. In addition, hot oxide powder could loft some surface material due to thermally driven air currents. If hot powder were to contact plutonium-bearing feed liquid, it could cause boiling of the liquid and consequent release of plutonium. Some of the plutonium oxide powder that is postulated to boil the liquid might be resuspended by puffs of vapor.

Product Receiver Vessel. The product receiver vessel can hold 0.750 kg of plutonium as an oxide powder. The vessel is constructed of glass and is assumed to fail, releasing all of its contents. The plutonium oxide powder in the receiver vessel cools after exiting the calciner, and thus is not at the maximum temperature of the calciner. As was the case with the calciner powder, the falling receiver vessel powder can become airborne. The powder could also come into contact with feed liquid causing boiling of the liquid.

Liquid Feed Tank. The liquid feed tank holds 5 L of feed solution containing 2.25 kg of plutonium assuming a plutonium concentration of 450 g/L. The tank is constructed of glass and is assumed to fail releasing all of its contents. Solutions from the failed liquid feed tank could fall to the glovebox intermediate level floor and spread out. If the floor were perfectly flat and perfectly level, the depth of the liquid would be approximately 0.1 cm. The intermediate level deck ends before it reaches one of the glovebox walls. Also, there is one opening in the intermediate level deck under the calciner and another a short distance away. Thus, the liquid might drain to the floor of the glovebox. If the intermediate deck is not level, the liquid may simply drain to the lowest spot on that deck. If the intermediate level is uneven, some liquid might form one or more pools.

Some liquid could flow adjacent to hot pieces of the failed calciner (e.g. metal, heaters, insulation) or hot plutonium oxide powder. Some portion of the solution, therefore, could vigorously boil or flash to steam, causing an additional aerosol generation and release to the glovebox air.

4.2.5.2.2 Mitigation. Mitigation is provided by the interconnection to the PFP ventilation seismic shutdown system that terminates calciner process equipment and system operations during a seismic event. The interconnection to the seismic shutdown system and the actions accomplished upon detection of a seismic event are discussed in Section 4.2.5.2.

4.2.5.2.3 Probability. The annual probability of the 0.2g DBE is given in the PFP FSAR (FDH 1999) as $1x10^{-4}$. The events in the scenario postulated above are assumed to occur with a conditional probability of one (1) given the occurrence of the earthquake.

4.2.5.2.4 Consequence Analysis. The accident scenario assumes that 4.75 kg of plutonium as an oxide powder and 2.25 kg of plutonium as plutonium nitrate solution is released into the glovebox. Physical forces acting to suspend this material include free falling through air, boiling, aerodynamic entrainment, and evaporation. The movement and distribution of the plutonium oxide powder and plutonium nitrate materials within the glovebox cannot be accurately predicted. However, the distribution impacts the quantity of material released into the facility due to the potential for the liquid contacting hot surfaces and boiling. To quantify the onsite and offsite doses, the following assumptions are made:

1. The accumulator, at a pressure of 70 psig, depressurizes by airflow through the feed nozzle into the calciner bed that contains 4000 g Pu.

2. The steady-state concentration of respirable Pu in the calciner head space due to normal operations is 2.2 g. This value is derived in Appendix I.

3. A total of approximately 4.75 kg of plutonium as an oxide powder is released from the calciner and product receiver vessel, a fraction of which becomes airborne while falling. The term "approximately" is used as 2.2 g Pu are present in the calciner head space per assumption 2.

4. 5 L of liquid containing 2.25 kg of plutonium is released from the feed liquid tank, a fraction of which becomes airborne while falling.

5. Half of the feed liquid is assumed to absorb the heat stored in half of the plutonium oxide powder (2.375 kg) and one-fourth of the heat stored in the major metal calciner segments.

6. The other half of the feed liquid is assumed to fall, splatter, and come to rest in a benign location and evaporate.

7. The other half of the powder (i.e., that not contributing to heating of the liquid) is subject to entrainment by thermally-generated air currents.

The assumptions above are judged to form a reasonable and conservative basis for consequence analyses for a seismic event. The quantity of respirable airborne plutonium is calculated in the following subsections. The glovebox panels and HEPA exhaust filters are not seismically qualified, so all releases into Glovebox 188-1 are assumed to be available for release from Building 234-5Z.

4.2.5.2.4.1 Analysis of Releases from Glovebox 188-1 into the Facility.

Airborne Release from Accumulator Depressurization. The accumulator tank has a volume of 2.3 L and is normally pressurized to 70 psig during calciner operation. Based on tests conducted with the laboratory prototype calciner, the accumulator depressurizes in 15 seconds. As the accumulator depressurizes, air flows through the feed nozzle (at an initial velocity of 21 m/s) and into the bed thereby suspending plutonium oxide. The release due to accumulator air passing through the bed is 9 g Pu as an oxide powder. In addition, it is assumed that the calciner headspace contains 2.2 g Pu resulting from normal operation for a total release of 11.2 g Pu. The derivation of these values is presented in Appendix I. Appendix I also presents an evaluation of airflow through the ceramic filters versus through the feed nozzle and concludes that the feed nozzle release is larger.

Airborne Release From Falling Plutonium Oxide Powder. Falling powder is made airborne due to the shearing forces imparted during freefall. The applicable release fraction is based on data for free-fall spills of fine uranium oxide powders from a height of 1 meter (DOE 1994b, Section 4.4.3.1.2). This data is applicable since plutonium oxide and uranium oxide have similar bulk densities and particle size distributions. The airborne release fraction (ARF) of 8×10^{-5} multiplied by the respirable fraction (RF) of 0.5 gives a respirable release fraction of 4×10^{-5}. Use of this value is conservative as the powder has less than one meter to fall. Thus, the respirable release due to falling powder is:

$$M_f = 4750 \text{ g} \times (4 \times 10^{-5}) = 0.190 \text{ g}$$

Airborne Release From Falling Plutonium Nitrate. Falling solutions are made airborne due to shearing forces imparted during freefall and impact. The applicable release fraction is based on data for free-fall spills of uranyl nitrate hexahydrate (UNH) from a height of 3 meters (DOE 1994b, Section 3.2.3.1, Table 3-6). The UNH data are stated to apply to any solution containing heavy metal salts where the liquid alone has a density in excess of ~1.2 g/cm^3 (considered a "concentrated heavy metal solution"). The ARF (1×10^{-5}) multiplied by the RF (1.0) gives a respirable release fraction of 1×10^{-5}. Use of this value is conservative as the distance from the feed tank to the intermediate level is much less than a meter, and the distance from the intermediate to basement levels is less than one meter. Thus, the respirable release due to falling plutonium nitrate is:

$$M_s = 2250 \text{ g} \times (1 \times 10^{-5}) = 0.023 \text{ g}$$

Airborne Release from Boiling Plutonium Nitrate. As stated in assumption 3 above, half of the feed liquid is assumed to absorb the heat stored in half of the powder (i.e., 2375 g) and one-fourth of the heat stored in major calciner metal segments. Detailed calculations are presented below.

Heat Content of Plutonium Oxide Powder. It is assumed that half of the feed liquid (2.5 L) is heated by 2375 g of hot plutonium oxide powder. Heat transfer from the powder to the steel glovebox metal floor is conservatively neglected. The heat available in the powder to boil the solution (Qp) is given by:

$$Qp = Mp \times Cp \times (T_{ip} - T_{bl})$$

where:

Mp = mass of available plutonium oxide powder, g
Cp = average specific heat of powder over the temperature range, cal/g-°C
T_{ip} = initial temperature of the powder, °C
T_{bl} = boiling temperature of solution, °C

It is assumed that the initial temperature of the oxide powder is 1000 °C. This is conservative as the powder in the receiver vessel will be at a significantly lower temperature. The *Chemistry of Actinide Elements* (Katz 1986), Table 7.70, "Thermodynamic properties of plutonium dioxide," provides the following correlation for the specific heat that covers the temperature range of interest, 100-1000 °C.

$$Cp\ (J/K\ mole) = 92.80 + (8.702 \times 10^{-4}) \times T - (20.648 \times 10^{5})/T^{2}$$

where:

T = temperature in K and the temperature range is 192-1400 K

This correlation was used to obtain the oxide specific heat in cal/g-°C using the following data:

Gram molecular weight of PuO_2 = 271.1 (assuming the material is 89.95 % ^{239}Pu, 9% ^{240}Pu, 1% ^{241}Pu, 0.05% ^{242}Pu) and 4.184 J/cal.

The correlation shows that the specific heat changes by about 6% in the range of 300-1000 °C. Therefore, an average specific heat of 0.08 cal/g-°C (value at 600 °C) for the oxide powder was chosen. The boiling temperature of a 4 M nitric acid solution is a few degrees above 100 °C. However, 100 °C was used and is conservative because the hot materials deposit less energy with increasing boiling point. A change of +/- 10 °C in the boiling point results in a change of the amount vaporized by less than 3%. The available heat in the powder is:

$$Qp = 2375\ g \times 0.08\ cal/g\text{-}°C \times (1000 - 100)\ °C$$

$$Qp = 1.71 \times 10^5 \text{ cal}$$

Heat Content of the Failed Calciner. It is assumed that the feed tank liquid comes into contact with some segments of the failed calciner. It is further assumed that one-fourth of the heat stored in the calciner metal (stainless steel) mass heats some of the liquid. The metal parts assumed to obtain the mass include the lower flanges, body, and inner chamber for a total of 26 kg (see Appendix G). The metal parts are conservatively assumed to be at 1000 °C although some of the metal could be substantially cooler. An average stainless steel specific heat of 0.14 cal/g-°C (ORNL 1975) yields the total heat stored in the metal as:

$$Qc = Mc \times Cp \times (T_{ip} - T_{bl})$$

$$Qc = 26{,}000 \text{ g} \times 0.14 \text{ cal/g-°C} \times (1000 - 100) \text{ °C}$$

$$Qc = 3.28 \times 10^6 \text{ cal}$$

Of this total heat, one-fourth, or 8.2×10^5 cal, is assumed to be available to boil liquid. Thus, the total heat available (Q_t)is:

$$Q_t = Qp + 0.25 \times Qc = (1.71 + 8.2) \times 10^5 = 9.9 \times 10^5 \text{ cal}$$

Volume of Boiled Plutonium Nitrate. It is again conservatively assumed that this heat is transferred to an ideal amount of liquid. The total heat required to vaporize the feed liquid (H_t) is:

$$H_t = \text{sensible heat} + \text{heat of vaporization}$$

$$H_t = C_l \times (T_{bl} - T_{il}) + H_v$$

where:

C_l = specific heat of liquid, cal/g-°C
T_{bl} = boiling temperature of liquid, °C
T_{il} = initial temperature of liquid, °C
H_v = heat of vaporization (value for water used)

The initial temperature of feed liquid is 70 °F (21 °C). The specific heat of 4 M nitric acid is obtained from Figure 3-12 of *Plutonium Reclamation Facility Engineering*

Technical Reference (RHO 1980) as 0.78 cal/g-°C. The latent heat of vaporization of water is 539 cal/g. The total heat to vaporize (H_t) is:

$$H_t = 0.78 \text{ cal/g-°C} \times (100 - 21) \text{ °C} + 539 \text{ cal/g} = 600 \text{ cal/g}$$

The mass of liquid boiled (M_{lb}) is:

$$M_{lb} = Q_t / H_t = 9.9 \times 10^5 \text{ cal}/600 \text{ cal/g} = 1650 \text{ g}$$

The mass of plutonium (M_p) available for release from boiling is:

$$M_p = \text{Volume of liquid boiled} \times \text{plutonium concentration}$$

$$= [M_{lb} \text{ (g)} / \text{Density (g/L)}] \times [\text{Pu (g/L)}]$$

The specific gravity of the solution is given in equation 3.16 of RHO (1980) as follows:

$$\text{Spg (at 25 °C)} = 1 + (0.031)(\underline{M}\ HNO_3) + (0.00146)(\text{g-Pu/L})$$

where:

$\underline{M}$ = molarity of the solution, 4
maximum concentration = 450 g-Pu/L

The specific gravity at 100 °C is approximately that at 25 °C.

$$SpG = 1.78$$

$$\text{Density (g/L)} = 1000 \times SpG$$

The mass of plutonium available for release from boiling is then:

$$Mp = [1650 \text{ (g)} / 1780 \text{ (g/L)}] \times 450 \text{ (g/L)} = 417 \text{ g}$$

DOE (1994b), Section 3.2.1.2, Heating of Pools, provides measurements of airborne plutonium during heating of pools to 90% evaporation of plutonium nitrate solution.

Table 3-2 of DOE (1994b) provides four data points at hot plate temperatures of 200 to 220 °F. The highest ARF is 1.8×10^{-3}, with a bounding value of 2×10^{-3} recommended. The recommended RF is 1. Thus, the respirable plutonium release from evaporation is:

$$Mp = ARF \times RF \times 417\ g$$

$$= (2 \times 10^{-3}) \times 417 = 0.84\ g$$

Airborne Release from Aerodynamic Entrainment of Plutonium Oxide. It is assumed that the other one-half of the plutonium oxide powder, i.e., that not associated with liquid boiling, is deposited as a bed.

DOE (1994b), Section 4.4.1, Table 4-10, "Thermal Stress [of chemically non-reactive powders]," presents the ARFs for a series of tests in which powder beds at varying temperatures where exposed to varying air velocities. The largest ARF given in Table 4-10 is 5.6×10^{-3} (ambient temperature and 1.17 m/s velocity). Other values are an order of magnitude or more lower. DOE (1994b) recommends use of the 6×10^{-3} value as the bounding ARF and a conservative RF of 1×10^{-2}. Thus, the respirable release is:

$$Wd = 2375\ g \times ARF \times RF$$

$$Wd = 2375\ g \times (6 \times 10^{-3}) \times (1 \times 10^{-2}) = 0.143\ g$$

The release is calculated as described above for entrainment of plutonium oxide in the next subsection.

Entrainment of Plutonium Oxide During Liquid Boiling. A fraction of the 2375 g of powder assumed to transfer heat to the plutonium nitrate solution could also become suspended by bubbles sparging through the wet powder. It is difficult to select a model for this phenomenon as the physical orientation of the two phases is uncertain. Conceivably, the two phases could be uniformly mixed, or could be adjacent to each other with interaction only occurring along one edge. It is assumed that the lofting of plutonium oxide powder as it interacts with the liquid can be approximated applying data on lofting of powder from a hot bed. The release is calculated as described above for entrainment of plutonium oxide. Therefore, the respirable release is 0.143 g.

Airborne Release from Evaporation. The 2.5 L of plutonium nitrate not involved in boiling is subject to evaporation which would occur slowly relative to the other processes described herein. DOE (1994b), Section 3.2.1.1, Heating of Shallow Pools, provides measurements of airborne plutonium during drying of shallow pools of concentrated plutonium nitrate solution. Table 3-1 of DOE (1994b) provides six data points at three air velocities and

four temperatures. The measured ARF for 50 °C and 1 m/s is 1.3×10^{-7}. The recommended RF is 1. Thus, the respirable release from evaporation is:

$$Qe = ARF \times RF \times 2.5\ L \times 450\ g\text{-}Pu/L$$

$$Qe = (1.3 \times 10^{-7}) \times (1.0) \times (2.5) \times (450) = 1.5 \times 10^{-4}\ g$$

This value is insignificant relative to the other release mechanisms.

Total Seismic Induced Release into the Facility. Summing the contribution from the above described mechanisms, the total seismic induced release is 12.54 g. Plutonium oxide releases are distinguished from nitrate releases because the dose conversion factors differ due to differences in Lung Clearance Class Y (indicating "years") and Lung Clearance Class W (indicating "weeks").

	Pu (g) as Oxide (Y)	Pu (g) as Nitrate (W)
Release from Accumulator Depressurization (9 g plus 2.2 g from "normal" head space loading)	11.2	
Release from falling plutonium oxide powder	0.19	
Release from falling plutonium nitrate		0.023
Release from boiling plutonium nitrate		0.84
Entrainment of plutonium oxide during boiling	0.143	
Aerodynamic entrainment of plutonium oxide	0.143	
Subtotals	11.676	0.863
Total	12.539 g	

As shown above, the majority of the release (i.e., 9 grams or 72%) is associated with depressurization of the accumulator. This release results from the assumed failure of non-safety class solenoid and check valves (Figure 7, valves C, H and I), prior to the assumed structural failure of the calciner assembly. Although they are not seismically qualified, the solenoid and check valves could function as designed, thereby preventing the 9 g Pu release. The same logic is true for solenoid valves D, E, F and G, thereby preventing a release due to air injected through the calciner filters. Alternatively, the check valves could fail open after the assumed structural failure of the calciner assembly, in which case air from the pressurized accumulator could be vented without suspending plutonium.

A failure modes and effects analysis of the calciner has been performed (BWHC 1999d). It was found that the likelihood of back flows from the accumulator through non-safety class solenoid and check valves is beyond extremely unlikely. Accordingly, the following section presents mitigated seismic event dose consequences assuming the valves fail as described in the

scenario, and assuming the valves function as intended. If the two check valves and the solenoid valve function as intended, the total release is 3.54 g Pu. This value includes the 2.2 g Pu normally present in the calciner headspace.

4.2.5.2.4.2 Dose Consequences of Release from Facilities due to Seismic Event.

The releases from Glovebox 188-1 due to the seismic event are categorized according to Lung Clearance Class (W or Y) and ^{240}Pu content (greater than or less than 10% ^{240}Pu). Appendix H, Seismic Event Dose Calculations, provides additional details of the analysis process and the dose calculations for just the laboratory calciner.

Plutonium nitrate solutions to be fed to the calciner originate primarily from weapons grade material. It is assumed, for this analysis, that all plutonium material associated with the calciner in Glovebox 188-1 has a ^{240}Pu isotopic content of less than 10%. Feed containing greater than 10% ^{240}Pu is blended to ensure that it has less than 10% ^{240}Pu content.

As discussed in Chapter 9, Section 9.2.4.7 of the PFP FSAR (FDH 1999), there are two release scenarios, i.e., "no ventilation" case and "ventilation" case. In the "no ventilation" case, the facility ventilation system is assumed to fail or to be shut down as a result of the earthquake. Material is released from the facility through open egress paths due to wind effects on the building. In the "ventilation" case, the E-3 and E-4 exhaust system is assumed to continue running, but with failed HEPA filters such that material is released through the 291-Z-1 Stack unfiltered. The FSAR analysis accounts for gravitational settling within the facility. Since material is drawn out of the facility faster in the "ventilation" case, a lower percentage of the material released from the laboratory calciner glovebox settles out before release in the "ventilation" case than in the "no ventilation" case. The elevated release in the "ventilation" case results in much higher dispersion than that in the "no ventilation" cases.

"No Ventilation" Case. For the "no ventilation" case, 38% of the material released into the laboratories is released from the facility as shown in Chapter 9, Section 9.2.4.7.1 of the PFP FSAR. The remaining 62% of the respirable plutonium material released into the laboratories settles out due to gravity. The releases from the laboratory calciner glovebox is shown in Appendix H to be about 4.765 g (Table H-1) assuming accumulator depressurization and about 1.345 g (Table H-3) assuming the valves function as intended.

The details of the analyses summarized in this section for the laboratory calciner releases only are found in Appendix H. Table H-1 provides the doses assuming accumulator depressurization. The doses are as follows:

	Onsite	Offsite
EDE	21.33 rem	0.45 rem
Organ	256 rem	5.46 rem

The offsite consequences meet the RAGs. The onsite consequences meet the EDE but exceed the organ RAGs of 25 rem and 250 rem, respectively.

Table H-3 provides the doses assuming the valves (Figure 7, valves C, D, E, F, G, H and I), function as designed. The doses are as follows:

Onsite		Offsite	
EDE	6.35 rem	EDE	0.13 rem
Organ	85.28 rem	Organ	1.81 rem

These consequences meet both the onsite and offsite RAGs.

"Ventilation" Case. In the "ventilation" case, gravitational settling within the facility is calculated in the FSAR to reduce the releases from the facilities by 16%. Thus, 84% of the material released inside the building escapes unfiltered through the exhaust stack. The total facility release from the laboratory calciner only is shown in Appendix H to be about 10.5 g (Table H-2) assuming accumulator depressurization and about 3.0 g (Table H-4) if the check valves function.

The details of the analyses summarized in this section are found in Appendix H. Table H-2 provides the doses assuming accumulator depressurization. The doses are as follows:

Onsite		Offsite	
EDE	1.61 rem	EDE	0.57 rem
Organ	19.38 rem	Organ	6.85 rem

These consequences meet both the onsite and offsite RAGs.

Table H-4 provides the doses assuming the valves (Figure 7, valves C, D, E, F, G, H and I), function as designed. The doses are as follows:

Onsite		Offsite	
EDE	0.48 rem	EDE	0.17 rem
Organ	6.45 rem	Organ	2.28 rem

These consequences meet both the onsite and offsite RAGs.

4.2.5.2.5 Conclusions - Mitigated Seismic Event. A conservative analysis has been performed to quantify the incremental risk associated with calciner operations in Glovebox 188-1 only

relative to seismic analyses contained in Chapter 9 of the PFP FSAR (FDH 1999). The effect of the seismic event on the calciner system and Glovebox 188-1 increases the doses significantly. If the two check valves and the solenoid valve are assumed to fail such that the air accumulator tank is vented through the calciner bed, the onsite consequences exceed the RAGs for an event with an annual probability of 1×10^{-4} (i.e., the probability of the DBE). However, the probability of the failure of the check valves alone coincident with a DBE is much lower than 1×10^{-4} and is judged to be "beyond extremely unlikely." A probabilistic failure analysis was performed of the solenoid and check valves (BWHC 1999d) and concludes that flow to the calciner via the air nozzle or filters during the seismic event is beyond extremely unlikely. If the valves function as designed, both the onsite and offsite consequences are within the RAGs for an event with an annual probability of 1×10^{-4}.

4.2.5.3 Mitigated Seismic Event with Fire

The scenario for a mitigated seismic event with a fire is the same as that described in Section 4.2.5.2, Mitigated Seismic Event, except that combustion of two plastic panels, half of the gloves, and materials that are typically found in the glovebox have been added. It is assumed that the interconnection to the PFP ventilation seismic shutdown system functions as described in Section 4.2.5.2. All of the assumptions, release mechanisms, and results in Section 4.2.5.2 are used herein. Section 4.2.4, Glovebox 188-1 Fire, provides additional information on a postulated fire in the glovebox due to an initiating event other than a seismic event.

4.2.5.3.1 Scenario. If hot plutonium oxide powder were to be released from the calciner, it could settle on combustible material and cause ignition. The ensuing fire would cause some of the powder that had settled on the combustible material to become airborne.

Good housekeeping practice requires that extraneous material in Glovebox 188-1 be removed on a regular basis. The material that is expected to be inside the glovebox include bags remaining from bagging-in containers, ice-cream cartons used for material transfer in through the sphincter port, and polybottles. A procedure requires all these containers to be converted to non-containers after their contents are unloaded inside the glovebox. Thus, bags are flattened and rolled up, cartons are flattened, and polybottles are cut into pieces. The non-containers are routinely removed by bagging-out of the glovebox. There are no procedural limits for Glovebox 188-1 on the amount of bags, ice cream cartons, and other typical process materials.

The operating procedures allow work to be performed using the gloves while the calciner system is in operation. Therefore, it can be postulated that some of the released hot powder lands on some gloves resulting in glove fire(s). It is further postulated that the burning gloves in the plastic panels (windows) could cause ignition of the plastic panels. Because the calciner is assumed to fail and its resulting configuration cannot be predicted, it could be postulated that the gloves and the panels are ignited by some part of the hot calciner coming into close proximity or direct contact with these components.

The calcining process creates powder and is not perfectly sealed. Thus, it can be postulated that there is some surface contamination, although small, on all inside surfaces of the

glovebox including the gloves and the plastic panels. If any of these ignite, some of the surface contamination can become airborne within the glovebox.

In developing a conservative scenario for the seismic event with a fire inside the glovebox, it was necessary to select a reasonable amount of material that could be assumed to ignite as a result of the earthquake. The feed and scrubber solutions are assumed to spill away from the fire. This assumption is conservative because a fire could be extinguished by the liquid. A corollary of this assumption is that there is also no transfer of heat from the fire to liquids in the glovebox. No credit is taken for operation of the room or glovebox fire protection features.

4.2.5.3.2 Mitigation. As discussed in Section 4.2.5.2 for the seismic event without fire scenario, mitigation is provided by operation of the seismic shutdown system that deenergizes calciner systems and equipment. However, there is no specific mitigation for the fire initiated by the seismic event. In addition, no credit has been taken for liquid, either in the feed or scrubber systems, to eliminate or mitigate a fire or for fire suppression systems in Room 188.

4.2.5.3.3 Probability. The annual probability of the DBE is given as 1×10^{-4}. The probability of a fire occurring as a result of the seismic event is assumed to be 1. Thus, the annual probability of the DBE with a fire is 1×10^{-4}.

4.2.5.3.4 Consequence Analysis. The scenario postulates a seismic event in which the calciner fails and releases all of its hot plutonium oxide powder. Some of the powder becomes airborne, lands on combustible material, and ignites it. Ignition of the gloves is assumed to occur. The resulting glove fires and/or radiation from or contact with hot calciner surfaces is postulated to cause ignition of the plastic panels. The gloves and panels are assumed to have surface contamination of small amounts of plutonium oxide powders. Some of this material will be released because of the fires.

4.2.5.3.4.1 Analysis of Releases from Glovebox 188-1 into Facility due to Fire.

Release from Combustion of Trash. It is assumed that the hot plutonium oxide powder released from the calciner bed contaminates the trash. Section 5.2 of DOE (1994b) provides values of ARF and RF for packaged waste and unconfined cellulose waste. The experiment for the unconfined waste used 10 g samples of tissue, paper or cloth in a pan with air forced upward through the pan at 0.06 to 1.04 m/s. The quantity of uranium in the waste being burned was about 0.1 to 2 g on samples of plastic and paper weighing 10 g. Thus, the highest ratio of contamination to combustible was 0.2. It is judged that larger quantities of plutonium on the waste will act more as a heated powder bed than contaminated waste. The bounding ARF was determined to be 1×10^{-2} and the RF was determined to be 1.0. The ARF multiplied by the RF for burning contaminated waste is therefore 1×10^{-2}.

It is assumed that there is 200 g of combustible waste present in the glovebox. This is equal to about 10 to 20 bags. This waste is assumed to be contaminated by 50 g of plutonium powder released from the calciner as a result of its failure. This ratio of 0.25 g of powder per gram of combustible is slightly greater than the tests referenced above. The mass of plutonium released from burning this material (W_b) is:

$$W_b = ARF \times RF \times 50\ g = 0.5\ g$$

Release of Surface Contamination due to Combustion of Gloves. It is assumed that, of the 38 gloves in the glovebox, the 19 that are closest to the calciner (i.e., within 3 ft) are ignited as a result of the calciner failure. All of these are on 8 in. gloveports. Eight gloves are on each of the two plastic panels. It is assumed that these gloves have a small amount of plutonium oxide powder as a result of routine calciner operation. The amount of this material is addressed in *An Estimate of Airborne Release of Plutonium from Babcock and Wilcox Plant as a Result of Severe Wind Hazard and Earthquake* (PNL 1978). For nuclear fuel cycle facilities in use for some period of time, the quantity of radioactive materials routinely found on contaminated surfaces can range from that which can only be removed by harsh, corrosive techniques to that which is readily visible to the unaided eye. A value of 0.7 g PuO_2 per ft^2 has been reported as just visible. This amount will be used as a bounding value for this evaluation. This approach is conservative because the operating time for the calciner in this glovebox could be an order of magnitude shorter than the time on which the above data are based.

The surface area of a single glove mounted in an 8 in. glove port is approximately 3.7 ft^2. The total surface area of 19 gloves is approximately 70 ft^2.

The surface contamination (W_g) is:

$$W_g = 70\ ft^2 \times 0.7\ g/ft^2 = 49\ g$$

DOE (1994b), Section 5.2.1.4 provides values for releases of surface contamination for uncontained polychloroprene (elastomer, rubber). Table 5-3 from that reference includes values for depleted uranium oxide (DUO) powder as ARF = 3.7×10^{-3} and RF = 0.16. Thus, the release from the gloves (W_g) is:

$$W_g = 49\ g \times (3.7 \times 10^{-3}) \times 0.16 = 0.029\ g$$

Release of Surface Contamination due to Combustion of Panels. It is assumed that either the ignition of the gloves or the radiant heat from the burning material leads to ignition of both the polymethylmethacrylate (PMMA) panels. The other glovebox panels are constructed of wire-reinforced glass. It is assumed that the PMMA panels have a small amount of plutonium oxide powder as a result of routine calciner operation. The value of 0.7 g/ft^2 of PuO_2 reported in DOE (1994b) is used as a bounding value for this evaluation.

The surface area of a single panel (~5 ft x 4 ft) is approximately 20 ft^2. The surface contamination (W_p) is:

$$W_p = 2 \times 20\ ft^2 \times 0.7\ g/ft^2 = 28\ g$$

DOE (1994b), Section 5.2.1.4 provides values for releases of surface contamination for PMMA. Table 5-4 from that reference includes values for a thick layer of DUO powder as ARF = 3.6×10^{-2} and RF = 0.84. Thus, the release from the two panels (W_p) is:

$$W_p = 28\ g \times (3.6 \times 10^{-2}) \times 0.84 = 0.85\ g$$

Summary of releases from Glovebox 188-1 due to the Seismic-Induced Fire. All of the mechanisms addressed above are listed below. The releases due to the fire are all from plutonium oxide powder .

	Pu (g) as Oxide (Y)	Pu (g) as Nitrate (W)
Combustion of trash	0.50	0
Combustion of 19 gloves	0.029	0
Combustion of 2 plastic panels	0.85	0
Total	1.379	

4.2.5.3.4.2 Doses for Additional Release from Glovebox 188-1 due to Fire.

The additional releases due only to the seismic-induced fire are calculated below for the "ventilation" and the "no ventilation" cases.

"No Ventilation" Case. For the "no ventilation" case, 38% of the material released into the laboratories is released from the facility. The remaining 62% of the respirable plutonium material released into the laboratories settles out due to gravity. The additional release from the building due to the fire is:

$$(1.379\ g) \times (0.38) = 0.524\ g$$

The details of the analyses summarized in this section are found in Appendix H, Sections 5.0 and 5.1.

From Appendix H, Section 5.1, the doses due only to the fire are as shown below:

Onsite		Offsite	
EDE	2.29 rem	EDE	0.05 rem
Organ	26.23 rem	Organ	0.56 rem

Table H-5 provides the doses that are the sum of those from seismic event and the fire for the laboratory calciner releases only assuming the accumulator depressurizes. The doses are as follows:

Onsite		Offsite	
EDE	23.62 rem	EDE	0.50 rem
Organ	282 rem	Organ	6.02 rem

The offsite consequences meet the RAGs. The onsite consequences meet the EDE and exceed the organ RAGs of 25 rem and 250 rem, respectively.

Table H-6 provides the doses assuming the valves function as intended. The doses are as follows:

Onsite		Offsite	
EDE	8.64 rem	EDE	0.18 rem
Organ	112 rem	Organ	2.37 rem

The onsite and offsite consequences meet the RAGs.

"Ventilation" Case. In the "ventilation" case, gravitational settling within the facility is calculated in the FSAR to reduce the releases from the facilities by 16%. Thus, 84% of the material released inside the building escapes unfiltered through the exhaust stack. Thus, the additional release from the facility due to the seismic-induced fire is:

$$(1.379\ g) \times (0.84) = 1.158\ g$$

The details of the analyses summarized in this section are found in Appendix H, Section 5.2. The increase in doses due to the fire are shown below:

Onsite		Offsite	
EDE	0.17 rem	EDE	0.06 rem
Organ	1.98 rem	Organ	0.70 rem

Table H-7 provides the doses which are the sum of those from seismic event and the fire for the laboratory calciner releases only assuming the accumulator depressurizes. The doses are as follows:

Onsite		Offsite	
EDE	1.78 rem	EDE	0.63 rem
Organ	21.36 rem	Organ	7.55 rem

The onsite and offsite consequences meet the RAGs.

Table H-8 provides the doses assuming the valves function as intended. The doses are as follows:

Onsite		Offsite	
EDE	0.65 rem	EDE	0.23 rem
Organ	8.43 rem	Organ	2.98 rem

The onsite and offsite consequences meet the RAGs.

4.2.5.3.5 Conclusions - Mitigated Seismic Event with Glovebox 188-1 Fire. A conservative analysis has been performed to quantify the incremental risk associated with calciner operations in Glovebox 188-1 only relative to the seismic analyses contained in Chapter 9 of the PFP FSAR (FDH 1999). The postulated fire in Glovebox 188-1 due to a seismic event increases the dose a small amount relative to those calculated in Section 4.2.5.2 for a seismic event without a fire.

If the two check valves and the solenoid valve are assumed to fail such that the air accumulator tank is vented through the calciner bed, the onsite organ consequences exceed the RAGs for an event with an annual probability of 1×10^{-4} (i.e., the probability of the DBE). However, the probability of the failure of the check valves coincident with a DBE is much lower

than 1×10^{-4} and is judged to be "beyond extremely unlikely" (BWHC 1999d). If the check valves function as designed, both the onsite and offsite consequences are within the RAGs for an event with an annual probability of 1×10^{-4} with the exception of the onsite organ dose, "no ventilation" case. Although organ doses have been calculated in this addendum for consistency with the PFP FSAR, current risk evaluation guidelines, as established HNF-PRO-704, *Hazard and Accident Analysis Process* (HNF 1997), are based on EDE only.

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5.0 EQUIPMENT SAFETY CLASSIFICATION AND OPERATIONAL CONTROLS

Chapters 3.0 and 4.0 identified potential hazards and accidents associated with the operation of the Laboratory Prototype Calciner. The hazard and accident analysis identify the engineered features and operational controls that provide for the prevention and mitigation of the potential consequences for each of these hazardous events and accidents. The safety classification for selected engineered features and operational controls are summarized in this chapter. Section 5.1 and Table 6 provide the safety classification for structures, systems, and components (SSC) relied upon to perform a safety function during calciner operations. Section 5.2 specifies the operational controls for the calciner which are intended to assure the availability of equipment and systems relied upon for the prevention and mitigation of abnormal events and accidents. In addition, the operational controls specify various limits and requirements to ensure that the analytical assumptions used in the accident analyses are implemented.

5.1 EQUIPMENT SAFETY CLASSIFICATION

As part of the hazard and accident analysis process, engineered features have been identified that provide for the prevention or mitigation of hazardous events. The proposed engineered features have been evaluated with respect to the criteria for safety classification specified in HNF-PRO-704, *Hazard and Accident Analysis Process* (HNF 1997). For accidents in which significant consequences to facility workers, on-site non-facility workers, or the public could potentially occur, the evaluation identified the engineered features and the associated safety functions being relied upon to prevent or mitigate the accident. Based upon the safety function being performed and the accident consequences, Safety Significant or Safety Class designations are assigned to the engineered features using a conservative application of the criteria provided in Table 5 of HNF-PRO-704. The resulting SSC safety designations for calciner operations are provided in Table 6 and are discussed below.

The E-3 and E-4 ventilation exhaust system HEPA filters and connecting ductwork are specifically credited in the accident analyses presented in Chapter 4, Section 4.2. The HEPA filters are credited with filtering airborne plutonium particulates with an efficiency of 99.95%. The E-3 and E-4 exhaust system HEPA filters and ductwork have been previously designated as Safety Class equipment in the PFP FSAR (FDH 1999).

The interconnection of calciner equipment to the PFP ventilation system seismic shutdown system represents a new Safety Class SSC specific to calciner operations. This interconnection is credited in Chapter 4, Section 4.2.5, with reducing the consequences of a DBE to below the risk acceptance guidelines by reducing the quantity of airborne plutonium. The PFP ventilation system seismic shutdown system has been previously designated as Safety Class equipment in the PFP FSAR (FDH 1999).

Glovebox 188-1 is equipped with a criticality drain. This drain is specifically identified in Appendix A as an engineered safety feature that functions to prevent a potential criticality. Glovebox criticality design features (including the Glovebox 188-1 criticality drain) have been previously designated as Safety Class equipment in the PFP FSAR (FDH 1999). The functional

requirement of criticality design features is to prevent criticality by maintaining a critically safe configuration.

The Glovebox 188-1 structure, including gloves, bag-out ports, sphincter seals, and pie plates) provides primary confinement and is implicitly credited in all glovebox "breach of confinement" events analyzed in the hazards and accident analyses presented in Chapters 3 and 4, respectively. Plutonium gloveboxes and hoods have been previously designated as Safety Significant equipment in the PFP FSAR (FDH 1999). The functional requirement of glovebox structures is to prevent or mitigate radiation exposure to facility workers by minimizing contamination spread. Definition of the glovebox safety boundary is provided in the PFP safety equipment list (FDH 1998b).

The continuous air monitor (CAM) located in Room 188 is specifically identified in Appendix A as an engineered safety feature that functions to protect facility workers. Room CAMs have been previously designated as Safety Significant equipment in the PFP FSAR (FDH 1999). The functional requirement for CAMs is to mitigate worker exposure to radioactive release by monitoring work areas and alerting facility workers to airborne radioactive concentrations exceeding limits. The PFP safety equipment list (FDH 1998b) further identifies room air samplers as being Safety Significant equipment.

5.2 OPERATIONAL CONTROLS

The controls outlined in this section are those which have been determined to be necessary for the safe operation of the calciner process. The controls have been developed from the hazards analysis and the accident analysis discussed in Chapters 3.0 and 4.0. The controls for the calciner are primarily associated with equipment and operations intended to prevent or mitigate events potentially posing worker safety issues.

5.2.1 Operational Safety Requirements

The controls specified in this section are in addition to those provided by the existing PFP operational safety requirements (OSR) (BWHC 1999e). Accordingly, adequate safety assurance for operation of the Laboratory Prototype Calciner requires implementing the existing operational safety requirements as well as the new controls specified in this section. The applicability of each existing OSR is provided in Table 7.

Note that criticality safety is implemented through application of the PFP criticality safety program. Criticality prevention requirements are specified in the criticality safety evaluation reports for the calciner and the associated PFP criticality prevention specifications.

The OSRs required as a result of Laboratory Prototype Calciner operations are as follows:

1. Prior to initiation of any calciner operations, the automatic seismic shutdown system shall be verified to be operable to limit the potential release due to a seismic event. This control limits the quantity of material that may be released following a seismic event. Surveillance requirements and frequencies for the seismic shutdown system related to the calciner process system are shown in Table 11.

2. The isotopic distribution of the plutonium in the calciner feed solution shall contain less than 10% ^{240}Pu in order to limit the potential doses as analyzed for the seismic accident. This control limits the consequences in the accident analysis by limiting the total quantity of the higher dose rate isotopes of plutonium allowed in the glovebox.

3. The maximum inventory in Glovebox 188-1 shall not exceed 7000 g of plutonium to meet the analysis assumption for material at risk in a seismic event.

These controls minimize the consequences presented in Section 4.2.5, Glovebox 188-1 Seismic Event. The controls are presented in tabular format in Table 8.

5.2.2 Additional Controls for the Laboratory Prototype Calciner

The controls in this section address equipment and define controls necessary to implement key assumptions upon which the safety analysis is based. In addition, in some cases, the controls outline specific actions required by operators under certain conditions of inoperability of equipment. These controls are not OSR level controls but are implemented by incorporation in operational specification documents, procedures and test plans. The controls are presented in tabular format in Tables 9 and 10 and are discussed below.

5.2.2.1 Operational Controls

1. Feed solutions for processing in the calciner shall be transported in polybottles in vented PR can containers (vent clip or drilled hole) or ITCs. Unvented containers shall not be accepted by the laboratory. The vents in the container preclude the accumulation of hydrogen or flammable gases that could be released or burned during the opening of the transfer container. The lids for ITCs are sufficiently loose so as not to require special venting mechanisms. (Note: these vents do not preclude hydrogen buildup in bag-out bags or polybottles.) Inadvertent burns of flammable gasses are included in the discussion of accidents in Sections 4.2.1, 4.2.2, and 4.2.3.

2. A Radiation Protection Program shall be in place to protect workers from exposure to ionizing radiation. A key element of worker protection for the calciner process is the requirement for the use of respiratory protection while unloading PR containers and ITCs in Room 188, while loading solution bottles into Glovebox 188-1, and while bagging out various materials from Glovebox 188-1 (includes use of bag ports or airlock). This prevents significant worker uptake if a release of material occurs. Worker hazards are included in the discussion of abnormal occurrences in Section 4.1.

3. Another key element of the Radiation Protection Program is the requirement that Glovebox 188-1 be verified to be at negative pressure relative to the room prior to initiation of any operations in order to prevent release of glovebox contamination to the room and personnel contamination.

4. Prior to calciner operation, proper ventilation flow in Glovebox 188-1 shall be verified in order to ensure adequate heat removal from the glovebox. This requirement assures maintaining the integrity of the process equipment in the glovebox as well as the integrity of the confinement function of the glovebox.

5. The calciner over-temperature protection system shall be operable prior to initiation of operations to prevent overheating and potential failure. The calciner operates at elevated temperatures and the vessel is postulated to be a potential fire source in the accident scenario in Section 4.2.4. The over-temperature limit prevents calciner failure which could initiate a fire scenario.

6. The CAM in Room 188 shall be verified to be operable prior to initiation of operations in order to ensure that operators are alerted to contamination releases into the room. All the accident scenarios in Chapter 4.0 include the possibility of release of contamination into the room occupied by the operators. Proper operation of the CAM alerts the operator that, in addition to the upset condition, some contamination has escaped from the glovebox.

7. A Fire Protection Program shall be in place to minimize the potential for and magnitude of any possible fires. For the calciner operations, these measures shall include housekeeping to limit combustible loading in the glovebox, operability of the glovebox temperature monitoring system to prevent excessively high temperatures and availability of a dry chemical, bayonet-equipped, portable fire extinguisher for fire protection.

8. The compressed air oil trap on the process air line in Room 188 shall be operational and continuously drained during calciner operation in order to prevent the injection of any oil from air compressor operation into the calciner with a resultant organic burn. A flammable gas deflagration is evaluated in Section 4.2.3.

9. Controls shall be implemented to prevent the introduction of incompatible chemicals in the feed tank or chemicals into the calciner that could cause a fire or deflagration. Introduction of organic into the calciner and the potential for flammable gas has been evaluated (Section 4.2.3) to consider the potential for incompatibility issues that could arise with the calciner. Introduction of new chemicals must be evaluated to ensure that the process remains within the analyzed bounds.

10. An Industrial Hygiene Program shall be in place to provide appropriate controls for worker protection from chemical hazards. Controls for calciner operations shall be implemented to ensure safe use and transfer of caustic solution (e.g. protective covering around caustic transfer line and valves) to minimize the chemical hazards to workers. Worker protection is discussed in Section 4.1 of the accident analysis.

5.2.2.2 Controls Required to Implement Key Analytical Assumptions

1. Transfer and receipt of feed solutions shall be limited to polybottles containing a maximum of 2.5 L of solution in a 3 L bottle to limit the hydrogen generation rate during transfers. The deflagration scenarios discussed in Sections 4.2.1, 4.2.2, and 4.2.3 assume certain quantities of hydrogen gas that could be present in the containers. Larger containers or larger headspaces could invalidate the conclusions of that analysis.

2. Plutonium nitrate feed solutions shall contain a maximum of 450 g-Pu/L for criticality control purposes, to limit hydrogen generation, and to remain within the bounds of the dose consequence analysis. The consequence analysis for the accident scenarios in Chapter 4.0 assumed this concentration of plutonium.

3. Plutonium nitrate feed solutions shall have a nitric acid concentration greater than 4 M to limit the hydrogen generation rate during container transfers and interim storage, if necessary. Hydrogen generation rates assumed in the deflagration scenarios, Sections 4.2.1, 4.2.2, and 4.2.3 are based on a nitric acid concentration of 4 M or greater. A lower concentration would result in larger hydrogen generation rates and higher concentrations in the containers evaluated.

4. Feed solutions shall be limited to plutonium nitrate. Other materials have not been evaluated for processing in the calciner and, therefore, are not supported by the accident analysis presented in this document.

5. Feed solutions shall be tested for a visible, separable layer of organic. Solutions with a visible, separable organic layer shall not be processed through the calciner in order to limit the potential for a significant organic burn in the calciner. In addition, the calciner feed solution shall be limited to 1% organic in order to limit the potential for an organic burn in the calciner. Organic burns inside the calciner are discussed in Section 4.2.3.

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6.0 SUMMARY AND CONCLUSIONS

As a result of the termination of plutonium production operations at Hanford, the PFP has significant quantities of unprocessed plutonium-bearing solutions in storage. These solutions are considered unsuitable for long-term storage and must be stabilized by conversion to plutonium oxide powder to meet storage requirements (BWHC 1998) for the PFP vaults and the DOE criteria (DOE 1996) for long term storage. Stabilization of the plutonium-bearing solutions is accomplished using a direct denitration process in a vertical calciner. The calciner, designated the Laboratory Prototype Calciner, and support systems/equipment are located in Glovebox 188-1 in Room 188 in the PPSL.

The prototype calciner is not specifically included in the PFP FSAR (FDH 1999) for solution stabilization operations, although general operations and process tests are included for the PPSL. Therefore, this addendum to the FSAR has been prepared to provide the authorization basis for DOE-RL approval of plutonium-bearing solution stabilization operations using the Laboratory Prototype Calciner. The scope of activities for which the authorization basis is developed is described in Chapter 1.0 in this addendum.

This FSAR addendum provides background information in Chapter 1.0 supporting the need for stabilization of plutonium-bearing solutions. Descriptions of the process chemistry, equipment and systems, and the process for stabilization operations are provided in Chapter 2.0. Chapter 3.0 provides a discussion of the Hazard and Operability (HAZOP) Analysis performed for the stabilization process and equipment. The chapter also presents a summary of the HAZOP results and the representative abnormal events and accidents derived from the HAZOP. The significant accidents identified through the HAZOP process are analyzed in Chapter 4.0 which demonstrates the acceptability of the stabilization operations through comparison with risk guidelines. During the performance of the HAZOP and accident analysis, candidate controls and safety equipment were developed to prevent or mitigate identified hazards. The controls and safety equipment developed during the hazard and accident analyses were evaluated and then consolidated in Chapter 5.0. The controls and equipment specified in Chapter 5.0 are in addition to those in the existing PFP FSAR (FDH 1999) and in the OSR document (BWHC 1999e).

Most of the hazards and accidents associated with operation of the Laboratory Prototype Calciner do not result in an on-site impact to non-facility workers, or an off-site impact to the public, but do have the potential to impact operations personnel. The principal exception to this is a seismic event which has the potential to pose a significant risk both on-site and off-site. This risk is caused by the potential loss of various calciner process and facility confinement features which could result in on-site and off-site radiological doses. As a result of the seismic accident analysis, certain calciner process equipment has been connected to the PFP ventilation system seismic shutdown switch. This ensures that calciner processing operations are terminated as a result of a seismic event which will mitigate the potential release of radiological materials from the PFP facility.

Based on the results of the hazard and accident analysis, this addendum demonstrates that calciner operations can be performed safely under all credible accident and abnormal event scenarios. Appropriate safety equipment and controls are in place to prevent or mitigate

accidents and abnormal events such that the risk to facility workers, non-facility on-site personnel and the off-site public is acceptable. The equipment and process described in this addendum along with the controls and safety items can be safely used for stabilization of plutonium-bearing feed solutions meeting the requirements defined herein.

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Note 1: These documents were originally prepared by a former Hanford Operating Contractor, Westinghouse Hanford Company. They have been adopted by the current Hanford Management and Integration Contractor, Fluor Daniel Hanford, Inc., and its major subcontractor, B&W Hanford Company.

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TABLES

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Table 1. Accident Grouping.

Number	Accident Group Title
A1	Process Upset - no worker impacts
A2	Process Upset - worker ALARA concern
B	Radiological Release Inside Glovebox
C	Radiological Release from Glovebox
D1	Deflagration in Glovebox
D2	Deflagration Outside of Glovebox
E	Criticality
F1	Fire in Glovebox
F2	Fire Outside of Glovebox
G	Industrial Hazards - not resulting in severe worker injury
H	Release to Vacuum System
I	Toxic Chemical Release Inside Facility
J	Radiological Release Inside Facility
K	Inadequate Stabilization of Product
NPH	Natural Phenomena Hazard (Seismic Event)

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection. (15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
A1.	PROCESS UPSET – NO WORKER IMPACTS				
		Accidents			
		There are no accidents (S2 or S1* events) identified for Group A1.			
		Abnormal Occurrences			
		There are no abnormal occurrences (S1 events) identified for Group A1.			
		Negligible Safety Concerns			
	08.01.08/1	Feed concentration too high	Requires changeout and cleanup	S0	Events in this group are production upset events and do not result in release of radiological material or significant increase in worker exposure. Because they result in negligible safety concerns to facility workers, hazards with S0 consequences are not evaluated further.
	08.02.01/2	Inadequate pump output causes nozzle plug	Yields low product from calciner	S0	
	08.02.01/3	Plugged calciner feed nozzle	Yields low product output	S0	
	08.02.02/1	Small pump stroke	Yields low product output	S0	
	08.02.04/1	Pump overheating and failure	Yields low product output	S0	
	08.03.00/2	Inadequate pump output	Yields low product output	S0	
	08.03.04	Feed supply valve shut off	Causes damage to pump	S0	
	08.04.08	Low vacuum	Degrades scrubber function	S0	
	08.04.16	Calciner motor drive overspeeds	Yields low product output	S0	
	08.05.04	Excess air to nozzle	Yields low product output	S0	
	08.05.09	Low vacuum	Degrades scrubber function	S0	
	08.06.01/1	High scrubber caustic flow	Prematurely fills tanks	S0	
	08.06.03	Scrubber temperature too low	Degrades scrubber function	S0	
	08.06.06/2	Inadequate vacuum	Allows calciner to pressurize	S0	
	08.06.09	High caustic flow rate	Results in high consumption	S0	
	08.07.07	Incompatible chemical reaction in scrubber	Requires cleanup	S0	
	08.07.08	Low vacuum	Degrades scrubber function	S0	
	08.07.10	Scrubber solution pH too low	D-8 tank pH affected	S0	
	08.07.11	Scrubber solution pH too high	Degrades scrubber function	S0	
	08.07.14/1	No sparging of spent scrubber solution	Degrades scrubber function	S0	
	08.11.00	Caustic flow to high	Degrades scrubber function	S0	
	08.12.00	Leak in chiller	Causes water spill in cell	S0	
	08.12.01	Leak in chiller	Yields elevated NO_X in vacuum system	S0	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
	08.13.00	Glovebox air flow is low	Inadequate air change	S0	
	08.13.01	Glovebox air flow is low	Inadequate air change	S0	
	08.13.13	Spills in glovebox	Cleanup required	S0	
	08.14.01	Excess air flow in glovebox	Potential containment damage	S0	
	08.14.02/1	Excess air flow in glovebox	Potential containment damage	S0	
	08.16.03	Loss of facility electrical power	Hazards of blackout at night	S0	
	16.00	Isolated Transport Container dropped or PR container dropped	Leak of solution through polybottle vent hole	S0	
A2.	PROCESS UPSET – WORKER ALARA CONCERN INCREASED WORKER EXPOSURE FROM RADIATION OR CHEMICAL DOSE				
		Accidents There are no accidents (S2 or S1* events) identified for Group A2.			
		Abnormal Occurrences			
	04.00/1	Damage to or cut of glove	Worker dose from cleanup	S1	ALARA concerns in recovering from the events
	05.01/1	Feed pumped to calciner before temperature reached	Worker dose from cleanup	S1	
	09.00/1	Solids buildup in nozzle	Worker dose from cleanup	S1	
	09.00/2	Pressurization of calciner due to solids buildup	Worker dose from cleanup	S1	
	08.01.02	Pump damage due to feed tank not refilled	Worker dose from cleanup	S1	
	08.02.01/1	Nozzle overheating & pump damage due to closed valve	Worker dose from cleanup	S1	
	08.02.02/2	Pump damage due to nozzle plugging	Worker dose from cleanup	S1	
	08.03.16	Back flow into air supply	Worker dose from cleanup	S1	
	05.01/2	Overflow of feed solution into collection jar	Worker dose from cleanup	S1	
	08.03.05	Feed pump stroke set to high	Worker dose from cleanup	S1	
	08.03.07/2	Back flow of feed due to air supply loss	Worker dose from cleanup	S1	
	08.03.07/3	Back flow of feed due to air supply loss	Worker dose from cleanup	S1	
	08.03.08/1	Plugging of calciner feed	Worker dose from cleanup	S1	
	08.03.08/2	Plugging of calciner feed	Worker dose from cleanup	S1	
	08.03.13	Back flow of feed due to air supply loss	Worker dose from cleanup	S1	
	08.04.00	Lack of powder bed causes plugging of calciner	Worker dose from cleanup	S1	
	08.04.13/2	Heater failure causes nozzle plugging	Worker dose from cleanup	S1	
	08.04.14/1	Low calciner temperature allows flooding	Worker dose from cleanup	S1	
	08.04.14/3	Low calciner temperature allows flooding	Worker dose from cleanup	S1	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection. (15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
	08.04.15/1	Plugging of injector due to agitator motor failure	Worker dose from cleanup	S1	
	08.04.15/2	Plugging of injector due to excess feed in bed	Worker dose from cleanup	S1	
	08.04.17	Feed into cool calciner results same as 08.04.14	Worker dose from cleanup	S1	
	08.05.01	Calciner pressurization due to lack or loss of vacuum	Worker dose from cleanup	S1	
	08.07.02	Spill of scrubber solution into glovebox	Worker dose from cleanup	S1	
	08.07.05/2	Calciner filter failure lets Pu into scrubber	Worker dose from cleanup	S1	
	08.07.12/1	Calciner filter failure lets Pu into scrubber	Worker dose from cleanup	S1	
	08.07.13/1	Flooding of calciner	Worker dose from cleanup	S1	
	08.13.21	Accumulation of radioactive material in glovebox	Worker dose from cleanup	S1	
	14.00/2	Contamination spread by unsealed drum	Worker dose from cleanup	S1	
	08.11.01	Contamination of fresh caustic supply due to siphoning	Worker dose from cleanup	S1	
		Negligible Safety Concerns			Accidents with S0 consequences do not require further analysis
	08.01.04	Phase separation of feed solution	Worker dose from cleanup	S0	
	08.01.05a	Phase separation of feed solution	Worker dose from cleanup	S0	
	08.01.06	Incompatible chemical reaction in feed tank	Worker dose from cleanup	S0	
	08.03.02	Feed line plugged	Worker dose from cleanup	S0	
	08.03.03	Feed pump failure	Worker dose from cleanup	S0	
	08.03.06	Nozzle plugging	Worker dose from cleanup	S0	
	08.03.07/1	Nozzle plugging	Worker dose from cleanup	S0	
	08.03.09	Low air flow to calciner	Worker dose from cleanup	S0	
	08.03.10	High air flow to calciner	Worker dose from cleanup	S0	
	08.03.12	Feed pump stroke set too high	Worker dose from cleanup	S0	
	08.03.14	Excessive air pressure to nozzle	Worker dose from cleanup	S0	
	08.03.15	Low operating temperature for nozzle	Worker dose from cleanup	S0	
	08.04.13/1	Low temperature in calciner	Worker dose from cleanup	S0	
	08.05.02	Leak in offgas line to scrubber	Worker dose from cleanup	S0	
	08.05.06	Low temperature in calciner	Worker dose from cleanup	S0	
	08.06.01/2	Excessive caustic feed to scrubber	Worker dose from cleanup	S0	
	08.07.00	High level of caustic in scrubber	Worker dose from cleanup	S0	
	08.07.03	Low level of caustic in scrubber	Worker dose from cleanup	S0	
	08.15.04	High temperature in product collection jar	Worker dose from cleanup	S0	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection.
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
B.	RADIOLOGICAL RELEASE INSIDE GLOVEBOX INCREASED WORKER EXPOSURE FROM RADIATION OR CHEMICAL DOSES				
		Accidents There are no accidents (S2 or S1* events) identified for Group B.			
		Abnormal Occurrences			
	04.00/2	Solution spilled inside glovebox	Releases Pu into glovebox	S1	Chapter 9, Sections 9.1.1 and 9.1.3 of the PFP FSAR analyzes Abnormal Operations involving radioactive liquid and powder spills. Chapter 9, Section 9.1.2 analyzes pressurized liquid releases. Chapter 9, Section 9.2.8 analyzes toxic chemical releases. The consequences of abnormal occurrences in Group B are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in the PFP FSAR.
	04.03	Incompatible chemical added to feed tank	Releases Pu into glovebox	S1	
	05.00	Pressurized calciner	Releases Pu into glovebox	S1	
	08.01.03	Overfilled feed tank spills on floor	Releases Pu into glovebox	S1	
	08.03.00/1	Nozzle plug pressurizes calciner	Releases Pu into glovebox	S1	
	08.03.01	Feed line break releases Pu into glovebox	Releases Pu into glovebox	S1	
	08.04.03	Plugged ceramic filters pressurizes calciner	Releases Pu into glovebox	S1	
	08.04.07	Loss of vacuum causes pressure relief cap to lift	Releases Pu into glovebox	S1	
	08.04.09	Pressure relief cap in place during cooldown	Releases Pu into glovebox	S1	
	08.04.18	Failed calciner	Releases Pu into glovebox	S1	
	08.05.00	Plugged ceramic filter pressurizes calciner	Releases Pu into glovebox	S1	
	08.06.02/1	Blocked flow to scrubber tank	Releases Pu into glovebox	S1	
	08.06.02/2	Backpressure to calciner by blockage in scrubber	Releases Pu into glovebox	S1	
	08.06.06/1	Overpressure in scrubber	Releases Pu into glovebox	S1	
	08.10.00	Plugged calciner filters	Releases Pu into glovebox	S1	
	08.15.00	Spill during transfer from collection jar to slip lid can	Releases Pu into glovebox	S1	
	08.15.02	Product collection jar breaks	Releases Pu into glovebox	S1	
	08.01.00	Feed tank failure	Release of solution into glovebox	S1	
	08.01.01	Feed tank failure	Release of solution into glovebox	S1	
	08.02.03/2	Oversupply from feed pump pressurizes calciner	Releases Pu into glovebox	S1	
	08.04.04	Overpressure in calciner	Releases Pu into glovebox	S1	
	08.04.06	Overpressure in calciner	Releases Pu into glovebox	S1	
	08.01.07b/1	Reaction in feed tank	Produces NOx	S1	
	08.13.11/2	Feed pump seal fails allowing spray leak	Release of solution into glovebox	S1	
	08.15.01	Drop of slip lid can	Releases Pu into glovebox	S1	
	09.01/3	Incompatible chemical reaction in feed tank	Release of solution into glovebox	S1	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
	10.00	Spill during transfer from collection jar	Releases Pu into Glovebox	S1	
		Negligible Safety Concerns			
	08.01.07a	Reaction of water and solution	Releases aerosols to glovebox	S0	Accidents with S0 consequences do not require further analysis.
	08.03.11	Feed line leak releases solution into glovebox	Release of solution into glovebox	S0	
	08.04.02/1	Product overflow tube set too high	No product collected in jar	S0	
	08.04.02/2	Plugging of product overflow tube	No product collected in jar	S0	
	08.04.11/1	Excessive temperature in calciner	Release of gases to vacuum system	S0	
	08.04.11/2	Excessive temperature in calciner	Increase vaporization in scrubber	S0	
	08.05.05	Excessive feed into calciner	Increases offgases	S0	
	08.05.07	Leak in offgas line	Release of gases to glovebox	S0	
	08.05.08	Excessive offgas temperature	Increased vaporization in scrubber	S0	
	08.05.11	Inadequate vacuum	Pressure rise in calciner	S0	
	08.06.00	Scrubber vessel leak	Release of caustic to glovebox	S0	
	08.07.01/1	Leaking spent scrubber tank	Spill of solution to glovebox	S0	
	08.07.01/2	Spent scrubber tank sample valve left open	Spill of solution to glovebox	S0	
	08.07.06/1	Wrong spent scrubber tank valved in	Release of gases to glovebox	S0	
	08.07.06/2	Leak in scrubber tank	Release of gases to glovebox	S0	
	08.09.01	Loss of vacuum	Release of gases to glovebox	S0	
	08.13.05	Pressure release from calciner	Release of gases to glovebox	S0	
	08.13.06	Chemical reactions in glovebox tanks	Release of gases to glovebox	S0	
	08.13.14	Spill of Pu solution, or caustic	Release of solution into glovebox	S0	
	08.14.04	Glovebox exhaust filter failure	Elevated release to E-4 system	S0	
	08.15.03	Collection jar misaligned	Allowing air into calciner	S0	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection.
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
C.	RADIOLOGICAL RELEASE FROM GLOVEBOX				
		Accidents			
	01.03	Glove pulled off or torn during drum movement	Release of Pu to room	S1*	Chapter 9, Section 9.1.9 of the PFP FSAR analyzes a glovebox glove breach. Chapter 9, Sections 9.1.1 and 9.1.3 of the PFP FSAR analyzes radioactive liquid and powder spills. The consequences of accidents in Group C are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in the PFP FSAR.
	02.01	Glove pulled off or torn during caustic supply change out	Release of Pu to room	S1*	
	03.03	Loss of glovebox confinement due to open airlock	Release of Pu to room	S1*	
	03.05	Glove torn during polybottle load in	Release of Pu to room	S1*	
	08.04.10/1	Calciner overheating fails calciner	Release of Pu to room	S1*	
	08.04.10/2	Calciner overheating fails calciner	Release of Pu to room	S1*	
	08.13.04	Pressurized air leak in glovebox causes air flow out	Loss of confinement	S1*	
	09.01/1	Incompatible chemical reaction in feed tank	Release of solution to room	S1*	
	09.03/1	Breach of glovebox confinement boundary	Release of Pu to room	S1*	
	09.03/2	Breach of glovebox confinement boundary	Release of Pu to room	S1*	
	11.00	Breach of glovebox confinement boundary	Release of Pu to room	S1*	
	13.00	Breach of glovebox confinement boundary	Loss of confinement	S1*	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
	08.13.02	Ventilation imbalance allows reverse flow in glovebox	Contamination spread	S1	
		Negligible Safety Concerns			
	08.13.03	Pressure rise in glovebox	Negligible consequence because glovebox still more negative than room	S0	
	08.13.12	Loss of glovebox ventilation	Glovebox temperature increase	S0	
D1.	**DEFLAGRATION INSIDE OF GLOVEBOX**				
		Accidents			
	04.01	**DEFLAGRATION OF HYDROGEN IN BAG OR BOTTLE**	**RELEASE OF PU INTO GLOVEBOX WITH POTENTIAL RELEASE INTO THE ROOM**	**S1***	**EVENT 04.01 CHOSEN TO BE A REPRESENTATIVE ACCIDENT BECAUSE IT INVOLVES ONE OF THE LARGEST AMOUNTS OF DISPERSIBLE MATERIAL, THE 2.5 L OF SOLUTION IN A POLYBOTTLE, AND ONE OF THE LARGEST ENERGY SOURCES, HYDROGEN DEFLAGRATION, FOR DISPERSION.**
	04.02	Reaction in feed tank with potential burning of gases	Release of Pu into glovebox	S1*	
	08.03.17	**DEFLAGRATION IN CALCINER DUE TO ORGANIC IN FEED**	**RELEASE OF PU INTO GLOVEBOX WITH POTENTIAL RELEASE INTO THE ROOM**	**S1***	**EVENTS 08.03.17 AND 08.03.18 CHOSEN TO BE REPRESENTATIVE ACCIDENTS BECAUSE THEY ARE SIMILAR TO EACH OTHER AND INVOLVE A LARGE AMOUNT OF DISPERSIBLE MATERIAL, THE PLUTONIUM OXIDE IN THE CALCINER, WITH A LARGE ENERGY SOURCE FOR DISPERSION.**
	08.03.18	**DEFLAGRATION IN CALCINER DUE TO OIL FROM FEED AIR SUPPLY**	**RELEASE OF PU INTO GLOVEBOX WITH POTENTIAL RELEASE INTO THE ROOM**	**S1***	
	08.04.05	Deflagration in calciner due to organic in feed	Release of Pu into glovebox with potential release into the room	S1*	Event 08.04.05 is essentially the same as 08.03.17 and is bounded by that analysis.
	08.13.09	Deflagration in calciner due to organic in feed	Release of Pu into glovebox with potential release into the room	S1*	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
	08.13.16	Deflagration in calciner due to organic in feed	Release of Pu into glovebox with potential release into the room	S1*	
		Abnormal Occurrences There are no abnormal occurrences (S1 events) identified for Group D1.			
	08.01.07b/2	**Negligible Safety Concerns** Reaction in feed tank with potential burning of gases	No release expected	S0	
D2.	**DEFLAGRATION OUTISDE OF GLOVEBOX**				
	03.01/1	**Accidents** **DEFLAGRATION IN DRUM EJECTS LID**	**POTENTIAL SEVERE INJURY TO WORKER**	**S1***	**EVENT 03.01/1 CHOSEN TO BE A REPRESENTATIVE ACCIDENT BECAUSE OF THE POTENTIAL FOR SEVERE INJURY TO FACILITY WORKERS**
		Abnormal Occurrences There are no abnormal occurrences (S1 events) identified for Group D2.			
		Negligible Safety Concerns There are no negligible safety concerns (S0 events) identified for Group D2			

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection. (15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
E.	CRITICALITY				
		Accidents			
	06.00	Multiple polybottles in glovebox	Potential CPS violation	S1*	Controls to prevent criticality are contained in the CSER and the CPS for the plutonium handling operations associated with the Laboratory Prototype Calciner operations.
	08.01.05B	Phase separation of Pu due to incorrect solution Ph	Potential CPS violation	S1*	
	08.01.05C	Phase separation of Pu due to incorrect solution Ph	Potential CPS violation	S1*	
	08.01.08/2	High Pu concentration in feed tank	Potential CPS violation	S1*	
	08.04.14/2	Low temperature causes calciner to flood with Pu nitrate	Potential CPS violation	S1*	
	08.04.14/4	Low temperature causes calciner to flood	Potential CPS violation	S1*	
	08.07.04	Filter failure causes PuO_2 buildup in spent scrub solution tank	Potential CPS violation	S1*	
	08.12.02/2	Insufficient cooling in scrubber	Potential CPS violation	S1*	
	8.13.20	Buildup of Pu oxide sludge in glovebox from spills	Potential CPS violation	S1*	
	08.13.22	Activation of room fire suppression system	Potential CPS violation	S1*	
	08.16.00/03	Seismic event pools Pu & solution in glovebox corner	Potential CPS violation	S1*	
	09.01/4	Incompatible chemical reaction in feed tank	Potential CPS violation	S1*	
	16.01	CPS mass violation during canister transport	Potential CPS violation	S1*	
		Abnormal Occurrences			
		There are no abnormal occurrences (S1 events) identified for Group E.			
		Negligible Safety Concerns			
	08.07.05/1	Ceramic filter failure results in possible transfer of Pu to Tank D8	Potential CPS violation	S0	Accidents with S0 consequences do not require further analysis
	08.07.13/2	Flooding of calciner damages ceramic filters	Potential CPS violation	S0	
	08.07.14/2	Inaccurate sample results in possible transfer of Pu to Tank D8	Potential CPS violation	S0	
	08.07.15	Inaccurate sample results in possible transfer of Pu to Tank D8	Potential CPS violation	S0	
	08.08.00	Ceramic filter failure results in possible transfer of Pu to Tank D8	Potential CPS violation	S0	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
F1.	FIRE IN GLOVEBOX				
		Accidents			
	06.01	FIRE INVOVLING WASTE BAGS, ICE CREAM CARTONS, AND OTHER FLAMMABLE WASTE	RELEASE OF PU INTO GLOVEBOX WITH POTENTIAL RELEASE INTO THE ROOM	S1*	EVENTS 06.01 IDENTIFIED IN THE PHA AND 08.13.08 FROM THE HAZOP WERE CHOSEN TO BE REPRESENTATIVE ACCIDENTS BECAUSE OF ALL OF THE ACCIDENTS IN GROUP F1, THEY ARE SIMILAR TO EACH OTHER AND INVOLVE THE GREATEST AMOUNT OF COMBUSTIBLE WASTE.
	08.02.04/2	Electric motor burnout	Potential loss of confinement	S1*	
	08.13.08	FIRE INVOLVING COMBUSTIBLES	LOSS OF CONFINEMENT	S1*	
	09.01/2	Incompatible chemical reaction	Potential fire in feed tank	S1*	
		Abnormal Occurrences			
	08.13.10	Overheated calciner	Potential fire of combustibles	S1	
	08.13.15	Glovebox fire	Potential fire of combustibles	S1	
		Negligible Safety Concerns			
		There are no negligible safety concerns (S0 events) identified for Group F1.			
F2.	FIRE OUTSIDE OF GLOVEBOX				
		Accidents			
	03.02/2	Hydrogen burn of bag and bottle	Potential release of Pu into Room 188	S1*	Event 03.02/2 is bounded by the deflagration event in Group D2.
	08.13.07	Fire involving combustibles in room	Potential release of Pu into Room 188	S1*	
		Abnormal Occurrences			
		There are no abnormal occurrences (S1 events) identified for Group F2.			

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection.
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
G.	**INDUSTRIAL HAZARDS**				
		Accidents			
		There are no accidents (S2 or S1* events) identified for Group G.			
		Abnormal Occurrences			
	01.0	Industrial hazards to facility worker	Hazards to worker	S1	Occupational hazards are not evaluated further as the associated risk is not uniquely related to plutonium processing operations.
	08.13.11/1	Electrical shock to facility worker	Hazards to worker	S1	
	08.15.05	Facility worker burned by hot calciner product	Hazards to worker	S1	
		Negligible Safety Concerns			
		There are no negligible safety concerns (S0 events) identified for Group G.			
H.	**RELEASE TO VACUUM SYSTEM**				
		Accidents			
		There are no accidents (S2 or S1* events) identified for Group H.			
		Abnormal Occurrences			
		There are no abnormal occurrences (S1 events) identified for Group H.			
		Negligible Safety Concerns			
	08.05.03/1	Broken offgas line	Inadequate scrubbing of offgas	S0	Because they result in negligible safety concerns to facility workers, hazards with S0 consequences are not evaluated further.
	08.05.03/2	Relief cap off of calciner	Inadequate scrubbing of offgas	S0	
	08.05.10	Excessive evaporation of caustic	Degrades scrubber function	S0	
	08.06.04/1	Loss of chiller	Reduced scrubbing of offgas	S0	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection.
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
	08.06.04/2	Loss of chiller	Reduced scrubbing of offgas	S0	
	08.06.05	Plant vacuum system upset	Loss of vacuum	S0	
	08.06.07	Low caustic level	Release of NO_X from vacuum system to facility stack	S0	
	08.06.08	Acid put in caustic scrubber	Vigorous reaction with heat generation in scrubber	S0	
	08.07.09	Scrubber pH low	NO_X release	S0	
	08.09.00	Liquid accumulation in vacuum system	Degrades scrubber function	S0	
	08.09.02	Vacuum system leaks	Degrades scrubber function	S0	
	08.11.05	Scrubber pH low	Degrades scrubber function	S0	
	08.12.03/1	Insufficient cooling in scrubber	Degrades scrubber function	S0	
	08.12.03/2	Insufficient cooling in scrubber	Degrades scrubber function	S0	
	08.12.04	Insufficient cooling in scrubber	Degrades scrubber function	S0	
I.	**TOXIC CHEMICAL RELEASE INSIDE FACILITY**				
		Accidents			
	01.04a	Caustic spill in glovebox	Release of caustic	S1*	Chapter 9, Section 9.2.8 analyses toxic chemical releases. The consequences of abnormal occurrences in Group I are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in Section 9.2.8 of the PFP FSAR.
	01.04b	Caustic spray leak	Release of caustic	S1*	
	02.00	Caustic drum leak	Worker chemical burn	S1*	
	03.01/2	NO_X release	Hazard to worker	S1*	
	08.11.03/1	Caustic spill	Release of caustic	S1*	
	08.11.03/2	Caustic spill	Release of caustic	S1*	
	08.11.04	Caustic spray leak	Release of caustic	S1*	
	09.02	Acid bottle dropped	Worker chemical burn	S1*	
		Abnormal Occurrences			
	02.02	Caustic drum leak	Worker chemical burn	S1	
		Negligible Safety Concerns			
	08.12.05	Loss of scrubber refrigeration fluid	Exposure to refrigerant	S0	

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection.
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
		Accidents			
	01.02	PR container or ITC tips and releases solution	Potential release of Pu solution into room	S1*	Chapter 9, Section 9.1.1 and 9.1.3 of the PFP FSAR, analyzes abnormal operations involving radioactive liquid and powder spills. The consequences of accidents in Group J are considered to be adequately addressed by the analyses in the PFP FSAR.
	13.01	Release due to dropped slip lid can	Release of Pu into room	S1*	
		Abnormal Occurrences			
	01.01	Chipped floor paint uncovers contamination	Worker inhalation of airborne contamination	S1	Chapter 9, Section 9.1.1 and 9.1.3 of the PFP FSAR, analyzes abnormal operations involving radioactive liquid and powder spills. The consequences of abnormal occurrences in Group J are considered to be adequately addressed by the analyses in the PFP FSAR.
	03.00/1	Particulate released when PR container opened	Worker exposure to radiological material	S1	
	03.00/2	Particulate released when PR container opened	Worker exposure to radiological material	S1	
	03.02/1	Bottle dropped or bag torn during handling	Worker inhalation of airborne contamination	S1	
	03.04	Bag rupture during loading into airlock	Contamination of worker	S1	
	07.00	Bag rupture during handling	Spread of contamination	S1	
	11.01	Sample vial dropped after bagout	Spread of contamination	S1	
	14.00/1	Inadequately sealed container allows release	Spread of contamination	S1	
	15.00	Second overpack applied in hallway	Contamination spread during transport of PR container	S1	
		Negligible Safety Concerns			
		There are no negligible safety concerns (S0 events) identified for Group J.			

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection.
(15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
		Accidents			
	08.02.03/1	Excessive feed flow causes inadequate mixing of feed to calciner	Yields inadequate stabilization of product that may pressurize final storage container	S1*	Chapter 9, Section 9.1.3 of the PFP FSAR, analyzes radioactive powder spills. The consequences of abnormal occurrences in Group K are not unique to the laboratory prototype calciner operations and are considered to be adequately addressed by the analyses in the PFP FSAR.
	08.04.01	Low calciner bed	Yields inadequate stabilization of product that may pressurize final storage container	S1*	
	08.04.12/1	Low heat in calciner	Yields inadequate stabilization of product that may pressurize final storage container	S1*	
	08.04.12/2	Low heat in calciner	Yields inadequate stabilization of product that may pressurize final storage container	S1*	
	11.02	Rupture of container in storage	Release of Pu	S1*	
		Abnormal Occurrences			
		There are no abnormal occurrences (S1 events) identified for Group K.			
		Negligible Safety Concerns			
		There are no negligible safety concerns (S0 events) identified for Group K.			

Table 2. Binning, Sorting, and Representative Abnormal Event and Accident Selection. (15 Sheets)

Accident Group	Event ID	Hazards Description	Consequence Description	Consequence Category	Comments and Justification for Selection of Representative Accidents and Abnormal Occurrences
		Accidents			
	08.16.00/01	Seismic event with potential continuous operation of calciner with loss of vacuum causing continuous release of plutonium through calciner relief port	Release of Pu to room through failed glovebox, windows, seals, and penetrations	S2	
	08.16.00/02	**SEISMIC EVENT WITH POTENTIAL CONTINUOUS OPERATION OF CALCINER WITH LOSS OF VACUUM CAUSING CONTINUOUS RELEASE OF PLUTONIUM THROUGH CALCINER RELIEF PORT AND ALSO FAILURE OF E-3 AND E-4 HEPA FILTERS**	**RELEASE OF PU TO ENVIRONMENT**	**S2**	**EVENT 08.16.00/02 CHOSEN AS THE REPRESENTATIVE ACCIDENT BECAUSE OF ALL OF THE ACCIDENTS IN GROUP NPH, IT INVOLVES THE LARGEST AMOUNT OF DISPERSABLE MATERIAL COMBINED WITH THE LEAST MITIGATION TO EXPOSE ONSITE WORKERS OUTSIDE OF THE FACILITY TO RADIOLOGICAL CONSEQUENCES.**
	08.16.00/04	Seismic event with potential toppling of glovebox and failure of E-3 and E-4 HEPA filters	Release of Pu to environment	S2	
	08.16.00/05	Seismic event with failure of Swagelok fitting allowing product collection jar to drop and break releasing plutonium oxide and failure of E-3 and E-4 HEPA filters	Release of Pu to environment	S2	
	08.16.00/06	Seismic event with puncture or toppling of 55 gallon drum of caustic from falling debris	Release of caustic to environment	S1*	
	08.16.00/07	Seismic event with spray leak of caustic from failed fitting or line	Release of caustic to environment	S1*	
		Abnormal Occurrences			
		None			

Table 3. Effect of the Laboratory Prototype Calciner Operations on Prior PFP Abnormal Occurrences. (3 Sheets)

PFP FSAR Section	PFP Abnormal Operations	Effect on Current Analysis Posed by Calciner Operations	Comments
9.1.1	Radioisotope-Bearing Liquid Spills	**No effect.** Analysis generically covers spills of plutonium nitrate solution within the facility. The analysis adequately covers potential spills of plutonium materials in the load in/load out of Glovebox HC-188-1.	The spill scenario is applicable to the Lab Prototype Calciner . The scenario analyzed is a bounding 10-L of plutonium nitrate from a height of 3 m. Analysis credits building ventilation system and a single stage of HEPA filtration with mitigating the release to the atmosphere.
9.1.2	Radioisotope-Bearing Pressurized Liquid Container	**No effect.** Analysis adequately bounds pressurized releases that could occur from the 3 liter containers to be used to support calcine operations in Glovebox HC-188-1.	Analysis postulates that 5 L of solution are ejected upon depressurization when opening container; splatter release fraction is for 3 m fall. E-3 ventilation system and single stage HEPA filter is credited with limiting release to the atmosphere.
9.1.3	Radioisotope-Bearing Powder Spills	**No effect.** Analysis covers PuO_2 spills outside of gloveboxes. Analysis adequately covers potential spills of powder inside or outside the product handling glovebox.	1 kg powder spill is assumed to occur from height of 3 m, releasing 1.2 g. E-4 and E-3 ventilation systems and single stage HEPA filtration credited with limiting release to atmosphere.
9.1.4	Radioisotope-Bearing Pressurized Powder Container	**No effect.** Analysis covers, generically, pressurized powder releases from cans in gloveboxes, vaults or rooms. Improper calciner operation has the potential to produce insufficiently stabilized PuO_2, with potential canister rupture during handling or NDA testing in the 2736-ZB Building or potential canister rupture in the storage vaults in the 2736-Z Building. Ruptured canister releases are considered to be adequately represented by the pressurized powder release evaluated in Section 9.1.4.	Analysis is based on historical facility airborne contamination levels measured following off- normal events. Single stage HEPA filter is credited with limiting release to the atmosphere.
9.1.5 9.1.5A 9.1.5B	Stack Release Resulting from Filter Changes Dropped Filter , Filter Room 309 and 310 Filter Room 26, 236-Z Building	**No effect.** Second stage filter source term is insignificantly effected by laboratory prototype calciner operations. Changes to analysis not required.	Analysis assumes filter is dropped containing twice the contamination levels ever measured on the secondary filters.

Table 3. Effect of the Laboratory Prototype Calciner Operations on Prior PFP Abnormal Occurrences. (3 Sheets)

PFP FSAR Section	PFP Abnormal Operations	Effect on Current Analysis Posed by Calciner Operations	Comments
9.1.6	Overpressure of Remote Mechanical C Line Pressure Vessel	**No effect.** The RMC Line pressure vessel is no longer used. Accident no longer relevant.	
9.1.7A	Excessive Building Pressurization--234-5Z	**No significant effect.** Analysis presents qualitative argument that the consequences of building pressurization would be low because the structure remains intact and multiple failures would have to occur for a significant quantity of radiological material to be released from Zone 4 areas into Zone 3 areas.	Potential source term added by calciner operations is small in comparison to the total source term in the plant.
9.1.7B	Excessive Pressurization of 236-Z Building	**No effect.** Calciner operations not relevant to 236-Z.	
9.1.7C	Excessive Building Pressurization 2736-ZB Building	**No effect.** The analysis concludes that the building pressurization does not result in a significant release to the environment because the building has no significant levels of contamination and the building structure is not compromised by the overpressure.	
9.1.7D	Excessive Building Pressurization 2736-Z Building	**No effect.** The analysis concludes that building pressurization would not cause the storage packages to rupture or the vault structure to be compromised. The analysis concludes there is no loose radiological material stored in the vaults. Storage of material processed in the laboratory prototype calciner presents no new hazards to the storage vaults.	
9.1.7E	Excessive Building Pressurization, 241-Z Building	**No effect.** Calciner operations not relevant to 241-Z.	
9.1.7F	Building Depressurization--All Plutonium Finishing Plant Operations	**No effect.** The analysis in Section 9.1.7F concludes that depressurization of Building 234-5Z will not result in structural failures. The analysis also concludes that the RMC line pressure will remain more negative than room pressure should the building depressurize due to dry air supply regulating valve. Based on the conclusions of the analysis in Section 9.1.7F, the laboratory prototype calciner will not contribute to an environmental release.	Any contamination spread from the calciner glovebox (Glovebox HC-188-1) to the room would pass through the E-3 HEPA filters before discharge to the atmosphere.

Table 3. Effect of the Laboratory Prototype Calciner Operations on Prior PFP Abnormal Occurrences. (3 Sheets)

PFP FSAR Section	PFP Abnormal Operations	Effect on Current Analysis Posed by Calciner Operations	Comments
9.1.8	Loss of Ventilation	**No significant effect.** An air flow reversal from the exhaust stack is concluded to only result in minor contamination spread from Zone 4 to Zone 3 areas. The plutonium inventory in Glovebox HC-188-1 is small compared to total inventory in all the gloveboxes in the plant.	
9.1.9	Glovebox Glove Breach	**No effect.** Glovebox glove breach analysis is representative of potential glove breach accident in HC-188-1.	

Table 4. Effect of the Laboratory Prototype Calciner Operations on Prior PFP Accident Analysis. (2 sheets)

PFP FSAR Section	PFP Accident Analysis	Effect on Current Analysis Posed by Calciner Operations	Comments
9.2.1A	Product Concentrator	**No effect.** The Product Concentrator is not currently in use at PFP.	
9.2.1B	Filtrate Evaporator	**No effect.** The Filtrate Evaporator is not currently in use at PFP.	
9.2.1C	Deflagration in Gloveboxes MT-5/HC-21C	**No effect.** There is no impact on the Glovebox MT-5/HC-21C deflagration analysis due to calciner operations in Glovebox 188-1. They are totally independent operations.	
9.2.1D	Laboratory Waste Concentrator	**No effect.** The Laboratory Waste Concentrator is not currently in use at PFP.	
9.2.1E	Explosion, Hydrogen in Fluorinator	**No effect.** The Fluorinator is not currently in use at PFP.	
9.2.1F	Flammable Gas Explosion	**No effect.** The risk associated with flammable gases in PFP is determined to be acceptable in Section 9.2.1F based on the implementation of specific controls on gas cylinder purchase, storage and use. Compressed flammable gases are not used in calciner operations.	
9.2.1G	Explosion, Slag and Crucible System Deentrainer	**No effect.** The slag and crucible process is not currently in use at PFP.	
9.2.2A	Remote Mechanical C Line Fire	**No effect.** Glovebox HC-188-1 is not located in the same area as the RMC line.	
9.2.2B	Roof Fire, 234-5Z	**No effect.** Laboratory Prototype Calciner operations do not affect the likelihood or consequences of a roof fire at PFP.	
9.2.2C	Glovebox MT-5/HC-21C Fire	**No effect.** Laboratory Prototype Calciner operations do not affect the likelihood or consequences of a fire in these gloveboxes.	
9.2.2D	Waste Drum Events	**No effect.** Calciner operations not relevant to waste drum accidents.	

Table 4. Effect of the Laboratory Prototype Calciner Operations on Prior PFP Accident Analysis. (2 sheets)

PFP FSAR Section	PFP Accident Analysis	Effect on Current Analysis Posed by Calciner Operations	Comments
9.2.3	Criticality	**No effect.** Although glovebox HC-188-1 will handle greater than a critical mass of Pu at any given time, the glovebox design features and controls from the CSERs minimize the likelihood of criticalities in the glovebox. In the unlikely event a criticality occurs in Glovebox HC-188-1, the criticality analysis in Section 9.2.3 is adequately representative. No changes are required to Section 9.2.3 as a result of calciner operations.	
9.2.4	Seismic Event	**Additional source term potential.** The radiological inventory in Glovebox HC-188-1 adds to the potential source term in the seismic event due to the potential for calciner pressurization and vessel upsets.	The seismic analysis in Chapter 4 presents an analysis on the increase in dose due to a seismic event considering the effects from calciner operations.
9.2.5	Strong Wind	**No effect.** The 234-5Z Building is shown in the analysis to survive the design basis wind. No releases from the laboratory prototype calciner area is postulated. Calciner operations do not affect the Strong Wind accident analysis.	
9.2.6	Hydrogen Fluoride – Induced Plutonium Release	**No effect.** The fluorinator is not currently in use at PFP.	
9.2.7	Aircraft Accident	**No effect.** Aircraft impacts into the PFP facility are shown in the analysis to be incredible given flight restrictions prohibiting helicopter operation in proximity to the PFP.	
9.2.8	Toxic Chemical Release	**No effect.** The postulated accident in Section 9.2.8 (failure of the 7000 gal outside HNO_3 storage tank) bounds potential NO_x or nitric acid vapor releases through the plant vacuum system caused by calciner or scrubber upsets within Glovebox HC-188-1. The accident in Section 9.2.8 also bounds potential accidents involving the nitric acid or NaOH supplies to the calciner process.	

Table 5. High Temperature Airborne Release Fractions for Thermally Stressed Material.

Material	Air flow rate, m/s	ARF
PuO_2	0.1	5.3E-6
	1.17	2.5E-4
Air-dried Pu $(NO_3)_4$	0.01	6E-5
	0.05	1.5E-3
	0.1	1.9E-4

ARF = Airborne Release Fraction

Table 6. Laboratory Prototype Calciner Equipment Safety Designations

System, Structure, Component (SSC)	Support Systems	Functional Requirements	Criteria from HNF-PRO-704
SAFETY CLASS SSCs			
E-3 and E-4 Ventilation Exhaust System HEPA Filters and Ductwork	See HN F-SD-CP-SDD-005	Filters radionuclide particulate released from Glovebox 188-1 to E-3 or E-4 ventilation exhaust system before discharge to the environment. The filters were previously evaluated as being Safety Class in the PFP FSAR.	1
Calciner Equipment Interconnection to PFP Ventilation Seismic Shutdown System	PFP ventilation seismic shutdown system (see HNF-SD-CP-SDD-004)	The connection to the seismic shutdown system is designed to rapidly terminate calciner operations by deenergizing the following components: • calciner heaters including dome heater • process air supply solenoids to close valves A and B shown in Figure 7.[1] • agitator motor • feed pump motor Deenergizing these components places the calciner process in a safe shutdown mode. Failure to shut down could lead to a continuous release of radiological materials that could result in unacceptable on-site or off-site doses. In addition to the seismic shutdown system deenergizing the above components, two check valves (identified as valves H and I in Figure 7) are provided in the air supply line to the accumulator to prevent backflow of air from the accumulator to the feed nozzle which could pressurize the calciner.	1
Process Air Supply Solenoid Operated Isolation Valves (Valves A & B on Figure 7)	Interconnection to PFP ventilation seismic shutdown system	The connection to the seismic shutdown system isolates the air supply from the calciner process equipment by deenergizing the two solenoids resulting in closure of the valves. This prevents a continuous release of radiological materials due to pressurization of the calciner.	4
Criticality Drain (see HNF-SD-CP-SDD-008)	None	The drain limits the amount of plutonium-bearing solution that can accumulate which prevents a potential criticality.	4
SAFETY SIGNIFICANT SSCs			
Glovebox Structure	None	The glovebox structure (including gloves, bag-out ports, sphincter seals and pie plates) provides the primary confinement for material that may be airborne inside the glovebox and, therefore, protects the worker from potential uptake. (Refer to PFP SEL [FDH 1998b] for definition of glovebox safety boundary)	11
Room 188 CAM and Fixed Head Air Sampler (HNF-SD-CP-SDD-011)	Backup power system	The Room CAM alerts operators to the presence of contaminants in the room that may have been released from the glovebox. The fixed head air sampler provides a permanent record of the levels of airborne contamination in the room.	11

Note : Valves C through G shown in Figure 7 are also deenergized by the seismic shutdown system to isolate the air accumulator tank discharge line which could continue to supply air to the calciner until the air tank is empty. However, only valves A and B are designated safety class since the additional material potentially released from accumulator tank air injection has been determined to be acceptable. In addition, two check valves (identified as valves H and I in Figure 7) are provided in the air supply line to the accumulator to prevent backflow of air from the accumulator to the feed nozzle which could pressurize the calciner. These valves are also not designated as safety class since the additional material potentially released has been determined to be acceptable.

Table 7. Applicability of Existing PFP Operational Safety Requirements to the Laboratory Prototype Calciner Operations. (3 sheets)

OSR Number *	OSR	Applicable to Addendum	Impacted By Addendum	Comments
LCO 3.1.1.1	The 26-Inch Process Vacuum Liquid Detection Interlock System shall be operable whenever the 26-Inch Process Vacuum System is operating	Yes	No	Although the 26-Inch Process Vacuum System does provide ventilation of the calciner offgas system, calciner operations do involve liquids that could potentially be drawn into the vacuum system.
LCO 3.1.1.2	Glovebox Criticality Drains shall be operable (unobstructed) in the following locations: 234-5Z Gloveboxes: HC-4 HC-9B HC-227T HC-6 HC-227S HC-7 HA-23S Pu Process Support Laboratories Gloveboxes: 188-1 179-10 179-12 Analytical Laboratory Glovebox: 522 (Room 152) 236-Z Gloveboxes: MT-5 1st Floor East Cell Access MT-6 1st Floor West Cell Access 4th Floor column 2nd Floor East Cell Access 5th Floor column 2nd Floor West Cell Access 6th Floor column	Yes	No	Glovebox 188-1 houses the Laboratory Prototype Calciner. This requirement is independent of whether or not calciner operations are conducted.
LCO 3.1.1.3	The following criticality safety features shall be in place: • Glovebox Sump Discs in gloveboxes HC-7, HC-9B • Glovebox Floor Filler Plates in glovebox HC-6 • Raschig Rings in Room 166 Sump.	No	No	Calciner operations do not utilize the specified gloveboxes or sump.
LCO 3.1.2	The Criticality Alarm System (CAS) shall be operable.	Yes	No	Calciner operations involve kg quantities of fissile material. Criticality identified as a potential accident.
LCO 3.2.1.1	Before release to the environment, ventilation exhaust from Zone 4 areas shall pass through two operable HEPA filter stages.	Yes	No	Calciner accident analyses do credit the E-4 ventilation system with reducing doses.
LCO 3.2.1.2	Before release to the environment, ventilation exhaust from Zone 3 areas shall pass through one operable HEPA filter stage.	Yes	No	Calciner accident analyses credit the E-3 system with providing one stage of HEPA filtration.

Table 7. Applicability of Existing PFP Operational Safety Requirements to the Laboratory Prototype Calciner Operations. (3 sheets)

OSR Number *	OSR	Applicable to Addendum	Impacted By Addendum	Comments
LCO 3.2.2	The alpha continuous air monitors (CAMs) for the 291-Z-1, 296-Z-3, 296-Z-14, 295-Z-5, and 296-Z-6 stacks shall be operable.	Yes	No	Exhaust air from the rooms and gloveboxes used in support of calciner operations is released from stack 291-Z-1.
LCO 3.2.3	The accelerometer activated 234-5Z supply ventilation system seismic shutdown shall be operable and set to shut down building supply and dry air process fans (supply fans) and the GB 188-1 Calciner in the event of a greater than 0.07 g seismic event.	Yes	Yes	Glovebox 188-1 contributes to the seismic analysis dose consequences for the plant. Select calciner systems are interconnected with the ventilation system seismic shutdown system. This LCO will require modification to reflect this new safety function.
LCO 3.3.1	The dispersible plutonium inventory within PFP shall not exceed the following limits: • 234-5Z Building excluding Analytical Laboratory, Plutonium Process Support Laboratory, and Standards Laboratory: 274,310 g • 236-Z Building excluding canyon and seismically qualified access gloveboxes: 33,400 g • 2736-ZB Repackaging Glovebox: 20,000 g • Analytical Laboratory, Plutonium Process Support Laboratories, and Standards Laboratory: combined total of 12,450 g of which not more than 5,250 may be greater than 10% ^{240}Pu.	Yes	Yes	Dispersible inventory in gloveboxes used in support of calciner operations must be included in Building 234-5Z total. Glovebox 188-1 analysis has been based on 7000 grams and below 10% material.
AC 5.2	Contractor Responsibility	Yes	No	Generic requirement applicable to all PFP operations
AC 5.3	Compliance	Yes	No	Calciner operations must be conducted in compliance with applicable OSRs
AC 5.4	Operational Safety Requirement Violations	Yes	No	Generic requirement applicable to all operations with associated OSRs
AC 5.5	Occurrence Reporting	Yes	No	Generic requirement for all PFP operations. Calciner operations may result in events and conditions which may involve safety, health, quality, safeguards, security, or environmental implications.
AC 5.6	Revisions to the Operational Safety Requirements	Yes	No	Generic requirement applicable to all OSR revisions
AC 5.7	Operational Safety Requirement Basis Control	Yes	No	Generic requirement applicable to all OSR bases
AC 5.8	Minimum Operations Shift Compliment	Yes	No	Generic requirement for PFP main facility and other process areas.
AC 5.9	Procedures	Yes	No	Generic requirement for all PFP operations.

Table 7. Applicability of Existing PFP Operational Safety Requirements to the Laboratory Prototype Calciner Operations. (3 sheets)

OSR Number *	OSR	Applicable to Addendum	Impacted By Addendum	Comments
AC 5.10	Facility Change Control	Yes	No	Generic requirement for all facility equipment, design features, engineering configuration, and operation documentation.
AC 5.11	Unreviewed Safety Questions	Yes	No	Generic requirement for all nuclear facilities.
AC 5.12	Personnel Qualifications and Training	Yes	No	Generic requirement to qualify and certify personnel performing or supporting PFP operations
AC 5.13	Facility Reviews and Audits	Yes	No	Generic facility requirement
AC 5.14	Audit Records Requirements	Yes	No	Generic facility requirement
AC 5.15	Nuclear Criticality Safety	Yes	No	Calciner operations involve kg quantities of fissile material. Criticality identified as a potential accident.
AC 5.16	Radiation Protection	Yes	No	Calciner operations involve kg quantities of radioactive material.
AC 5.17	Effluent Monitoring and Sampling	Yes	No	Generic facility requirement
AC 5.18	MODE Changes	Yes	No	Generic facility requirement
AC 5.19	OSR Interfaces with Other Facilities	No	No	Calciner operations do not include material transfers to interfacing facilities.
AC 5.20	Fire Protection	Yes	No	Calciner accident analyses credit minimization of combustible loading and fire protection equipment.
AC 5.21	Flammable Gas Inventory	No	No	Calciner operations do not use flammable gas cylinders (e.g., propane, acetylene).
AC 5.22	Plutonium Inventory	Yes	Yes	Total dispersible inventories of plutonium contained in gloveboxes operated in support of calciner operations must not exceed the values listed in Table 5.22.1 and Table 5.22.2 of WHC-SD-CP-OSR-010. . Glovebox 188-1 analysis has been based on 7000 grams and below 10% material.
AC 5.23	OSR Compliance Program	Yes	No	Generic requirement applicable to OSRs.

*The OSR numbering scheme is based on the format of WHC-SD-CP-OSR-010. The document sections are as follows: 1.0 Use and Application, 2.0 Safety Limits (no safety limits have been identified for PFP), 3.0 Limiting Conditions for Operations, 4.0 Surveillance Requirements (these are integral with the LCOs presented in Section 3.0), 5.0 Administrative Controls.

Table 8. Operational Safety Requirements

CONDITION	REQUIREMENT	SAFETY FUNCTION
1. Mitigation of seismic event releases.	Prior to calciner operations, the interconnection to the PFP ventilation seismic shutdown system shall be verified to be operable.	This control deenergizes calciner process equipment to limit the quantity of material that may be released as a result of a seismic event which is analyzed in Section 4.2.5.
2. Isotopic distribution of plutonium in feed solution.	Limited to <10% ^{240}Pu content.	Limiting the quantity of higher dose rate isotopes allowed in the glovebox minimizes the consequences in the seismic accident analysis in Section 4.2.5.
3. Glovebox inventory control.	≤ 7000 g of plutonium	Limiting the maximum inventory allowed in the glovebox minimizes the consequences in the seismic accident analysis in Section 4.2.5.

Table 9. Operational Controls for the Laboratory Prototype Calciner
(3 sheets)

CONDITION	REQUIREMENT	SAFETY FUNCTION
1. Accumulation of flammable gas in feed solution transport containers.	Transportation of Pu feed solution shall be in polybottles in vented PR can containers or ITCs. Unvented containers shall not be accepted by the laboratory for use in calciner operations.	The vents in the container and the lids on the ITCs preclude accumulation of flammable gas that could be released or burned during opening of the transfer container. Refer to Section 4.2.1, Hydrogen Deflagration in Room 188 from Opening Drum (PR Container), for a discussion of this scenario and its consequences.
2. Worker exposure to ionizing radiation.	A Radiation Protection program shall be established, implemented and maintained. A key element of the program in Calciner Operations is the use of respiratory protection when unloading PR containers and ITCs in Room 188, when loading solution bottles into Glovebox 188-1, and when bagging out material from Glovebox 188-1	The radiation protection program protects workers from exposure to ionizing radiation through training, dosimetry, shielding, posting, contamination controls and other elements. The hazards analysis notes in numerous entries that a potential exists for worker uptake if a release of material occurs.
3. Confinement of Plutonium in Glovebox 188-1.	The glovebox shall be verified to be at negative pressure relative to the room prior to initiation of any operations at the calciner.	All airflow is to be towards the more contaminated area and away from the worker occupied area to prevent worker contamination or uptake. The hazards analysis notes in numerous entries that a potential exists for worker uptake if a release of material occurs.
4. Excessive heating of Glovebox 188-1 from process operations.	Proper ventilation airflow for heat removal shall be verified prior to operation of the calciner.	Removal of glovebox heat load with the ventilation airflow prevents damage to the process equipment in the glovebox as well as protects as the integrity of the confinement function of the glovebox. Note that glovebox high temperature indication alerts operators of excessive temperature. Refer to Section 4.2.4, Glovebox 188-1 Fire, for additional information on one of the hazards of inadequate heat removal from the glovebox (fire).
5. Calciner over-temperature protection	The calciner over-temperature protection system shall be operable while the calciner is operating.	The over-temperature protection system notifies operators that calciner temperatures are high and automatically shuts power off to the heaters. This prevents calciner failure and potential fire.

Table 9. Operational Controls for the Laboratory Prototype Calciner
(3 sheets)

CONDITION	REQUIREMENT	SAFETY FUNCTION
6. Airborne room contamination monitoring.	A Continuous Air Monitor (CAM) in Room 188, with an audible alarm for alerting the operators, shall be verified to be operable prior to initiation of operation of the calciner.	Long term exposure to airborne plutonium contamination is prevented by the use of the room CAM. The CAM ensures that operators are alerted to contamination releases into the room. The hazards analysis notes in numerous entries that a potential exists for worker uptake if a release of material occurs.
7. Fire prevention and mitigation for calciner operations.	A fire protection program shall be established, implemented, and maintained. Key elements of the program as implemented for calciner operations shall include: minimizing combustible loadings in the glovebox, operability of the glovebox temperature monitoring system and availability of a dry chemical, bayonet-equipped, portable fire extinguisher.	The Fire Protection Program minimizes the potential for and magnitude of any possible fires. Protection of the facility and loss prevention are provided by the program. Refer to Section 4.2.4, Glovebox 188-1 Fire, for additional information on fire scenarios and possible combustible loadings in the glovebox.
8. Control of oil in compressed air supply.	The compressed air oil trap on the process airline in Room 188 shall be operational and continuously drained during calciner operation.	In order to prevent injection of oil from air compressor operation into the calciner with a resultant organic burn, it is necessary to remove oil from the air supply and to drain the oil from the trap. Refer to Section 4.2.3, Flammable Gas Deflagration in the Laboratory Prototype Calciner, for a representative accident scenario involving the injection and burn of organic material in the calciner.
9. Prevention of incompatible chemicals introduced to the feed tank or the calciner.	Controls shall be established addressing chemical compatibility for calciner operations. The controls as applied to calciner operation shall include: control of chemicals brought to and used in calciner operations, evaluation of any new chemicals proposed for calciner operations, and continuous awareness of chemicals in use, or stored in the calciner or feed tanks.	Incompatible chemicals can generate flammable gas, heat, and combustible reactants. To prevent a fire or deflagration in the calciner the use of chemicals must be controlled. Refer to Section 4.2.3, Flammable Gas Deflagration in the Laboratory Prototype Calciner, for a representative accident that could result from the reactions of incompatible chemicals.

Table 9. Operational Controls for the Laboratory Prototype Calciner
(3 sheets)

CONDITION	REQUIREMENT	SAFETY FUNCTION
10. Worker exposure to hazardous chemicals.	An Industrial Hygiene Program shall be established, implemented, and maintained to provide worker protection from chemical hazards.	The Industrial Hygiene program provides appropriate controls for worker protection from chemical hazards. The program provides training and procedures that ensure safe use and transfer of caustic solution used in calciner operations and minimize chemical hazards to workers. The hazards analysis notes in numerous entries that a potential exists for worker injury from the use and proximity of hazardous chemicals.

Table 10. Controls Required to Implement Key Analytical Assumptions

CONDITION	REQUIREMENT	SAFETY FUNCTION
1. Feed solution transfer polybottles.	≤ 3 L maximum capacity ≤ 2.5 L feed solution	This control limits the hydrogen generation rate during transfers to that assumed in the analysis. Larger containers or larger headspaces could invalidate the conclusions of analyses in Sections 4.2.1, 4.2.2, and 4.2.3.
2. Feed solution plutonium concentration	≤ 450 g-Pu/L.	For criticality control purposes, to limit hydrogen generation from radiolysis, and to remain within the bounds of the dose consequence analysis, material brought to the calciner for processing must be controlled. The dose consequences of each accident scenario in Section 4.2 are based on this limit.
3. Feed solution nitric acid concentration	> 4 M.	This control limits the hydrogen generation rate during container transfers and interim storage, if necessary. Lower nitric acid concentration could invalidate the conclusions of analyses in Sections 4.2.1, 4.2.2, and 4.2.3
4. Feed solution control	Feed solutions shall be limited to plutonium nitrate.	Other materials have not been evaluated for processing in the calciner and, therefore, are not supported by the accident analysis of Section 4.2.
5. Feed solution organic content	≤ 1 % organic content with no visible, separable layer of organic.	Limiting the organic concentration to 1% and no visible, separable layer of organic limits the potential for a significant organic burn in the calciner. The deflagration analysis in Section 4.2.3 provides additional information on the consequences of organic burns within the calciner.

Table 11. Required OSR Revisions to Incorporate Calciner Interconnection with PFP Ventilation Seismic Shutdown System.

Surveillance Requirement	Surveillance	Required Frequency	Surveillance Function
SR 3.2.3.1	Perform FUNCTIONAL TEST of the accelerometer activated seismic shutdown system.	Annually	Surveillance 3.2.3.1 ensures the accelerometer activated seismic shutdown system is tested annually to VERIFY functionality. The surveillance verifies that in response to an accelerometer signal indicating a 0.07-g earthquake, supply fans shut down as required, and when the calciner seismic shutdown is required to be operational, power to the Glovebox 188-1 calciner equipment is shut down. The annual frequency is based on the reliable nature of the components (relays, contacts, undervoltage coils) and their limited usage. The components are subjected more to the effects of aging than wear.
SR 3.2.3.2	CALIBRATE each accelerometer channel.	Annually	Surveillance 3.2.3.2 ensures a CALIBRATION of each accelerometer channel is conducted annually to VERIFY each channel is capable of responding properly to a 0.07-g earthquake.
SR 3.2.3.3	VERIFY both seismic shutdown system accelerometers are on line and in service.	Once within 24 hours prior to Glovebox 188-1 calciner startup AND Daily thereafter while the Glovebox 188-1 calciner is operating	Surveillance 3.2.3.3 ensures that a visual inspection of supply ventilation system seismic shutdown accelerometers has been performed to verify both accelerometers are on line and in service prior to initial startup of the Glovebox 188-1 calciner and once every 24 hours thereafter when the calciner is in operation. This surveillance frequency ensures that an accelerometer malfunction not detected by the seismic shutdown alarm system would be detected by plant personnel and calciner operations suspended within a time frame in which a DBE is considered to be an incredible event.

FIGURES

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Figure 1. Laboratory Prototype Calciner – Process Flow Diagram.

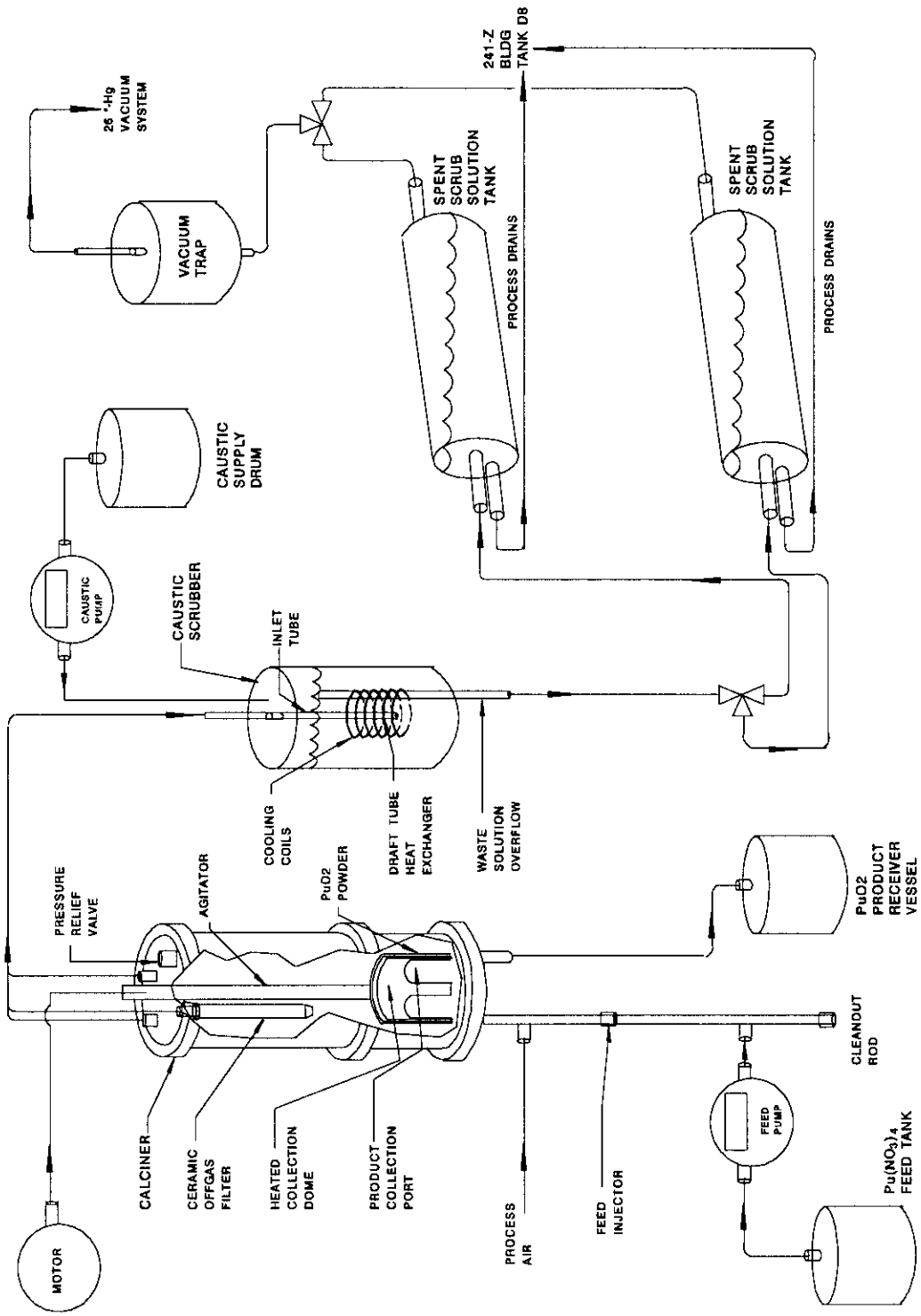


Figure 2. Partial Plan View – Building 234-5Z First Floor Showing Location of Room 227.

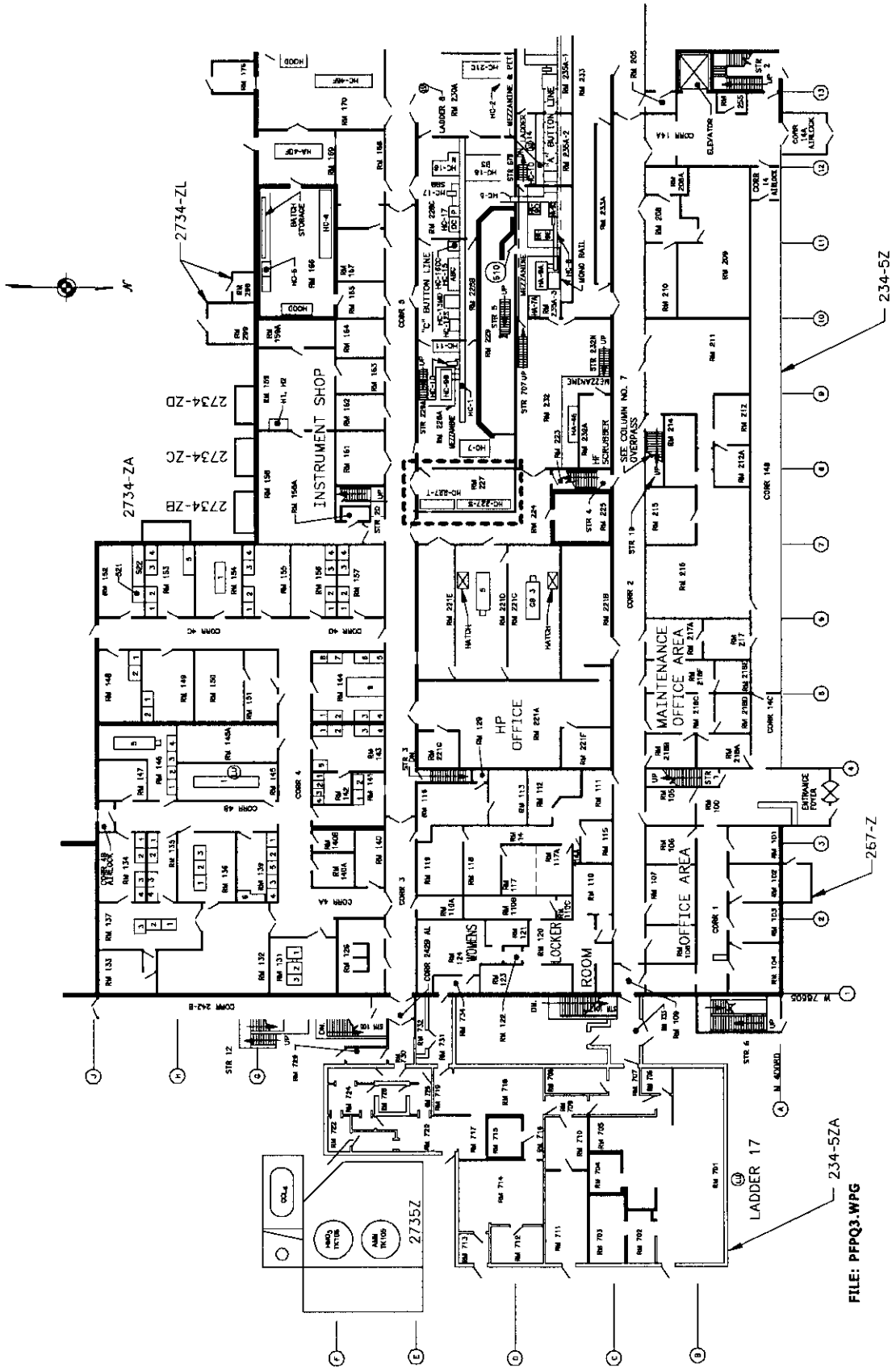


Figure 3. Glovebox HC-227S & Hood HC-227T.
(Ref. Dwg. H-2-26100, Sheet 1)

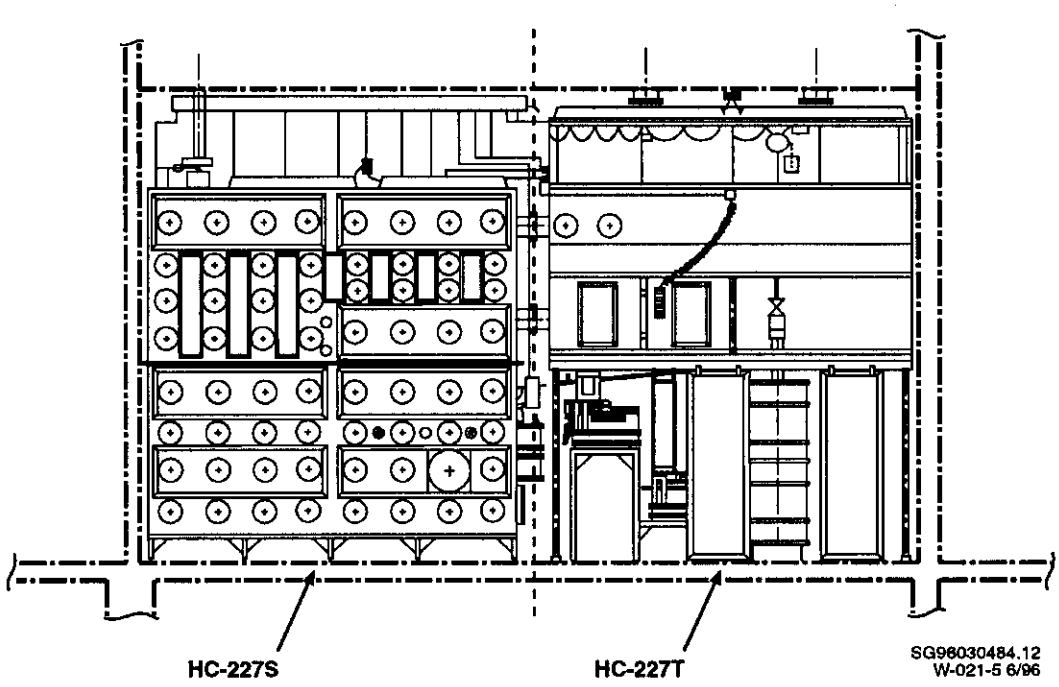


Figure 4. Schematic Showing PR Container (Drum) and PR Can.

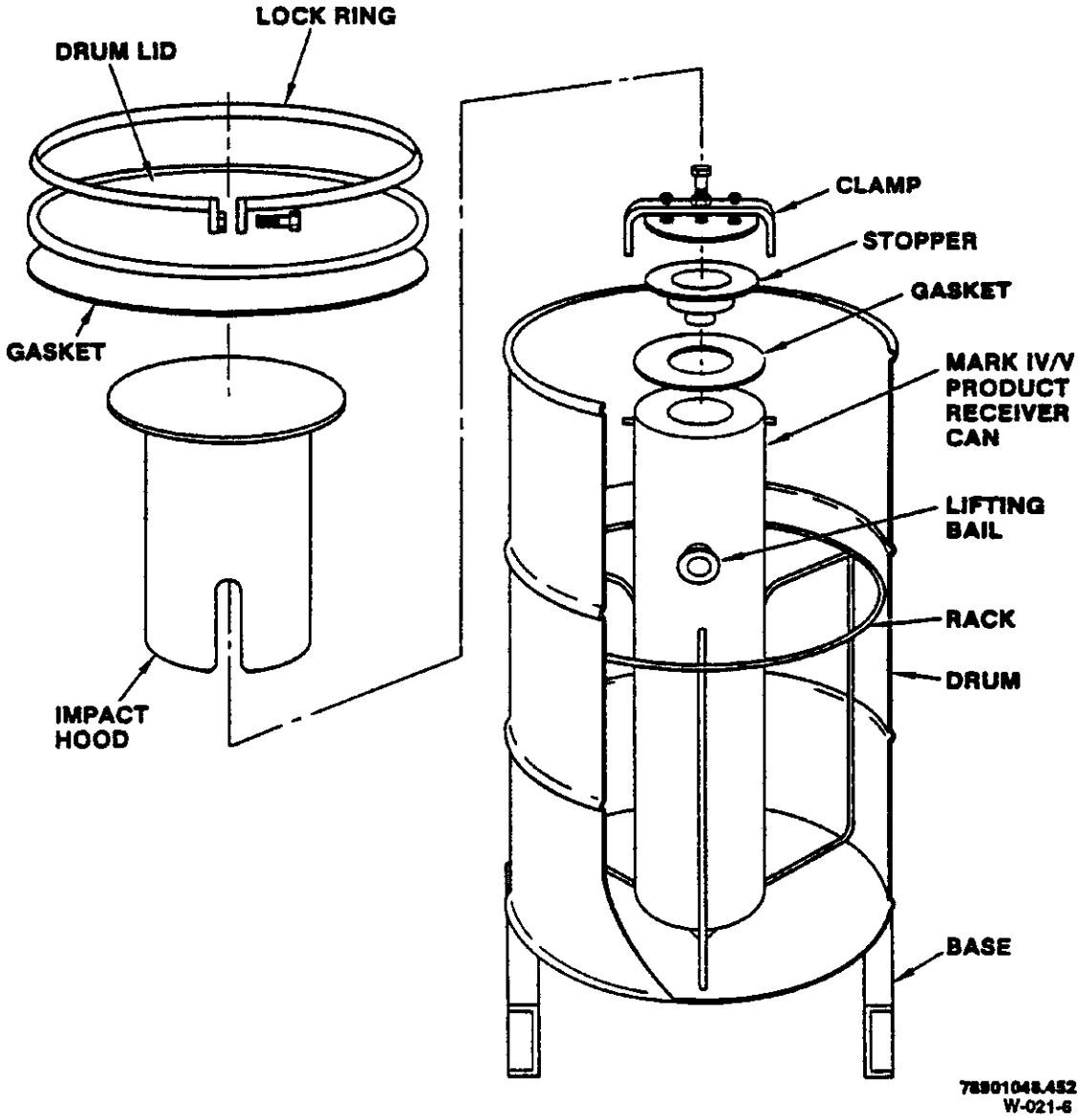


Figure 5. Partial Plan – Building 234-5Z First Floor Showing Room 188 and Related Operations Areas

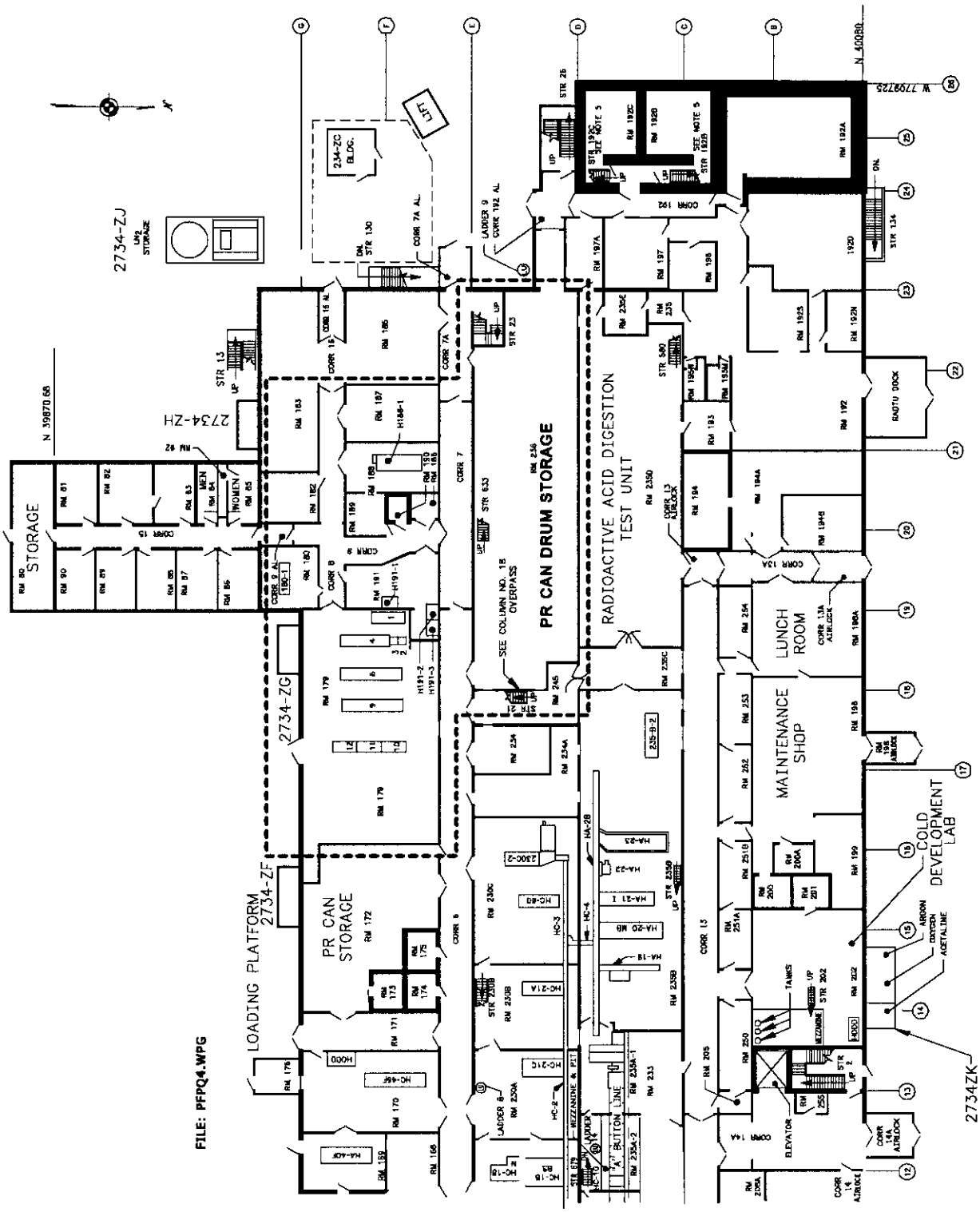


Figure 6. Glovebox 188-1 Schematic

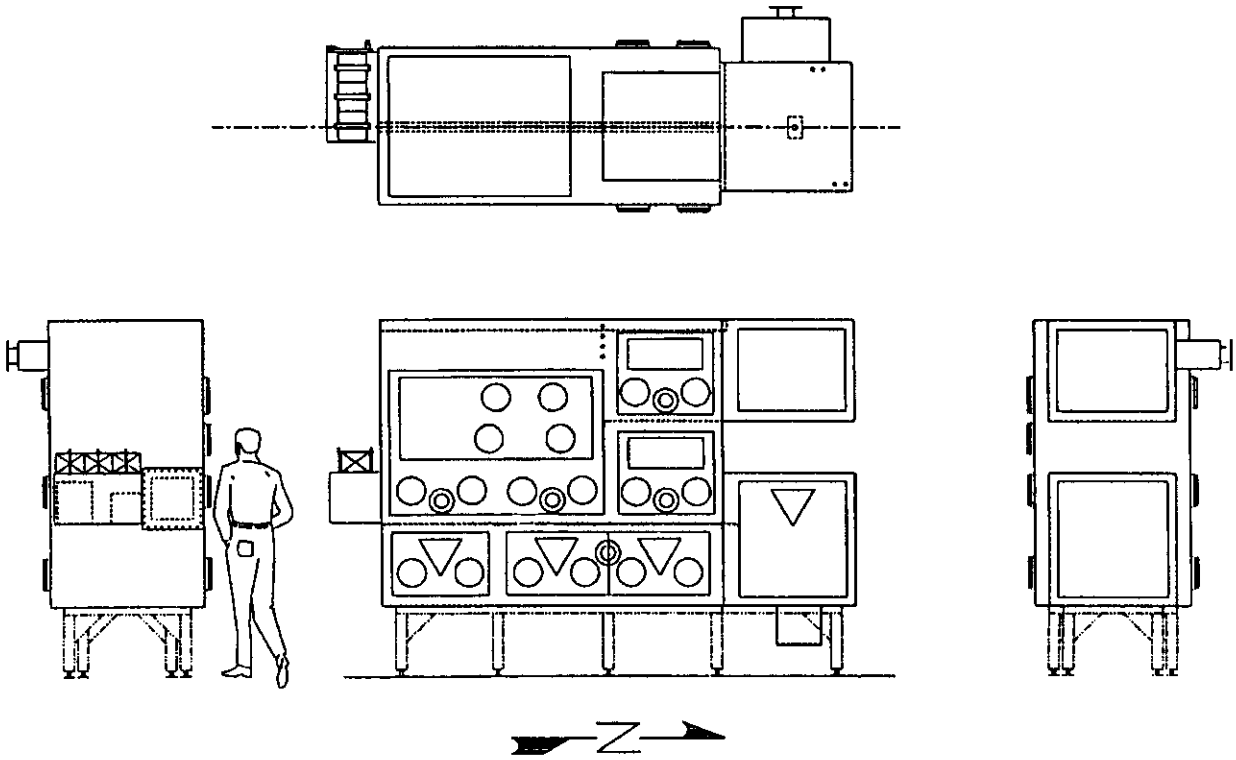


Figure 7. Laboratory Prototype Calciner – Simplified Piping and Instrumentation Diagram.

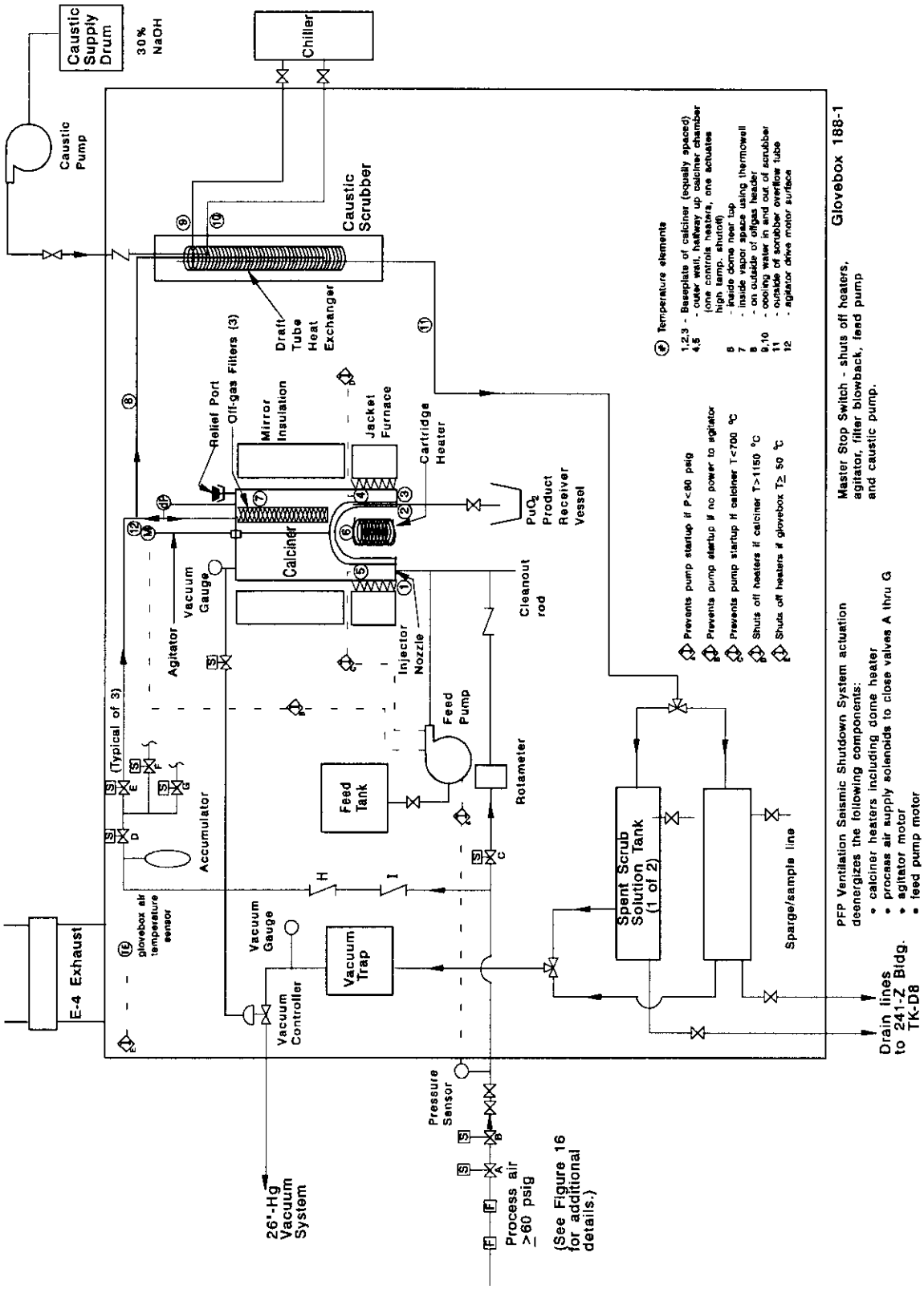


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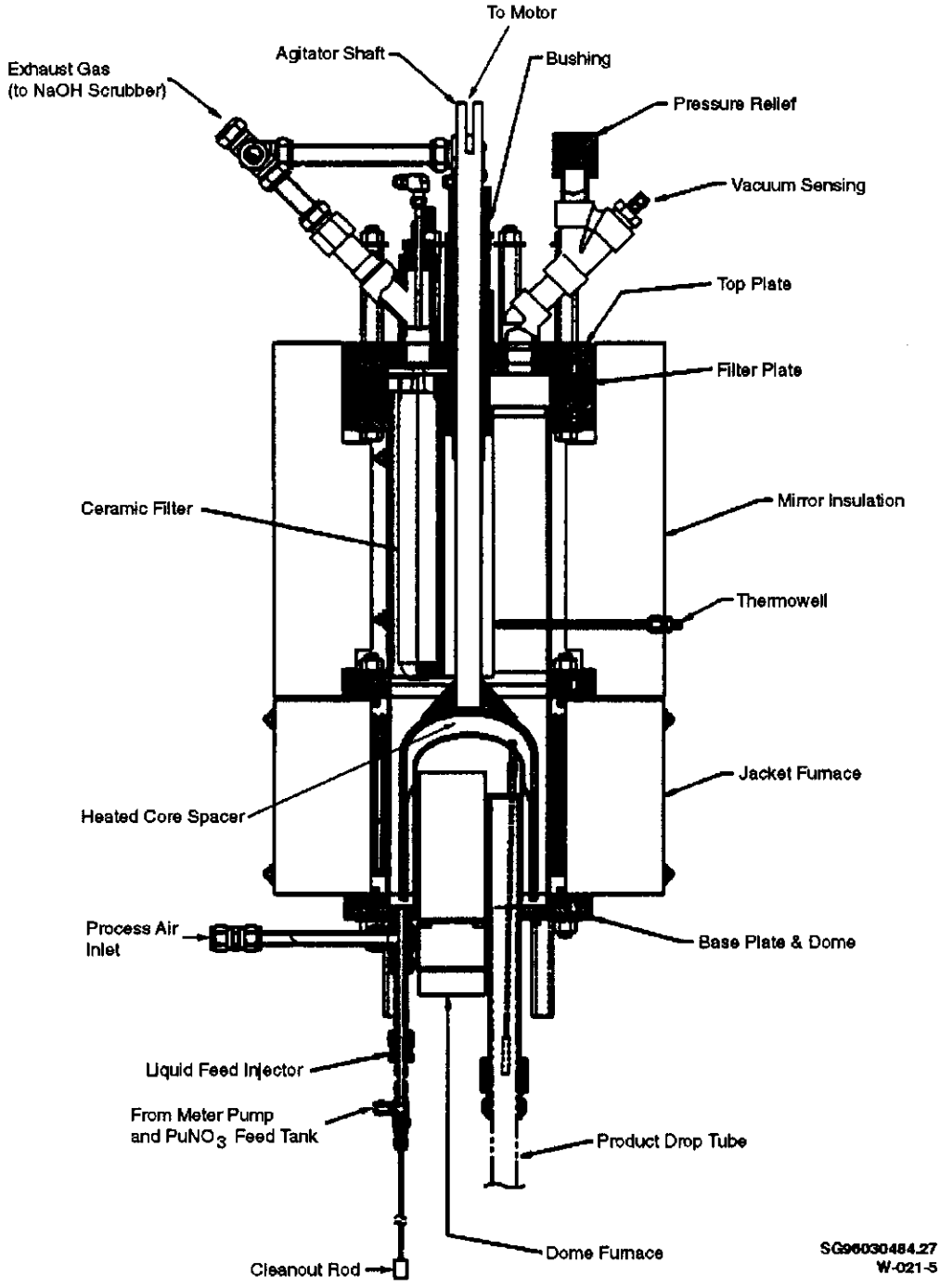


Figure 9. Laboratory Prototype Calciner - Dome and Baseplate Assembly.

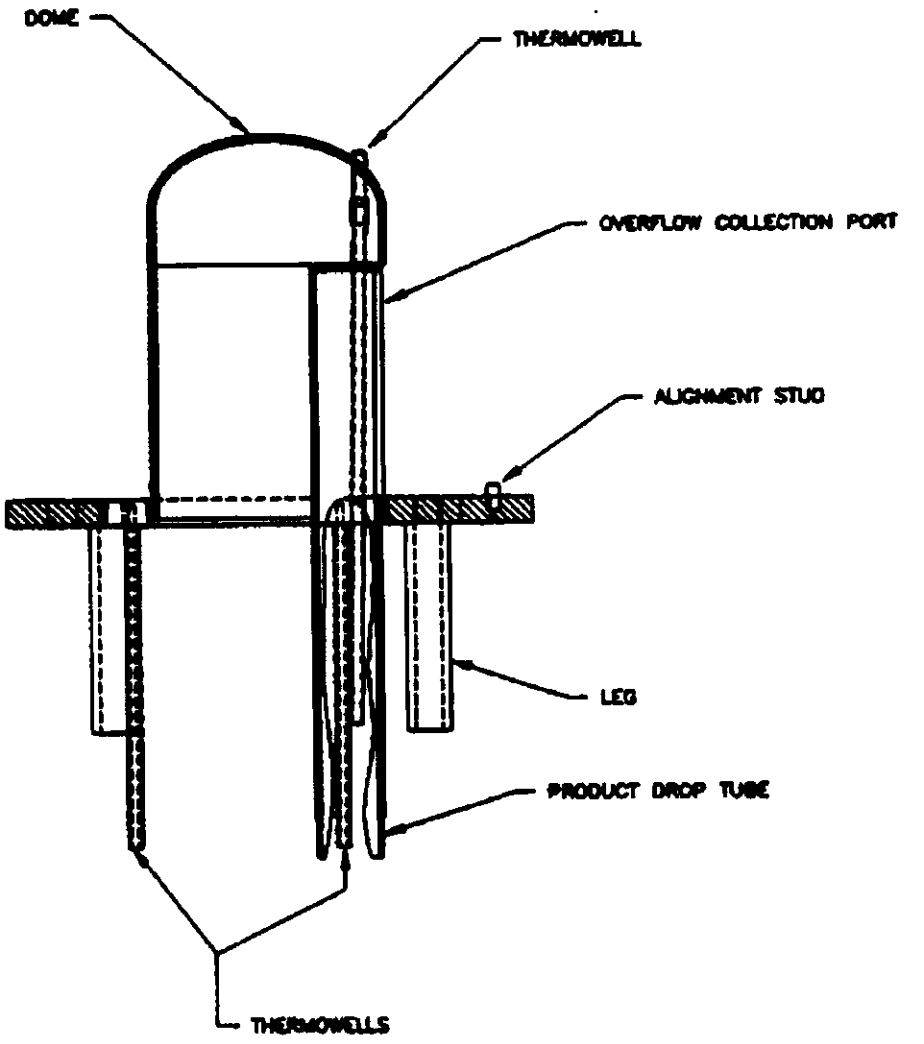


Figure 10. Laboratory Prototype Calciner - Liquid Feed Injector.

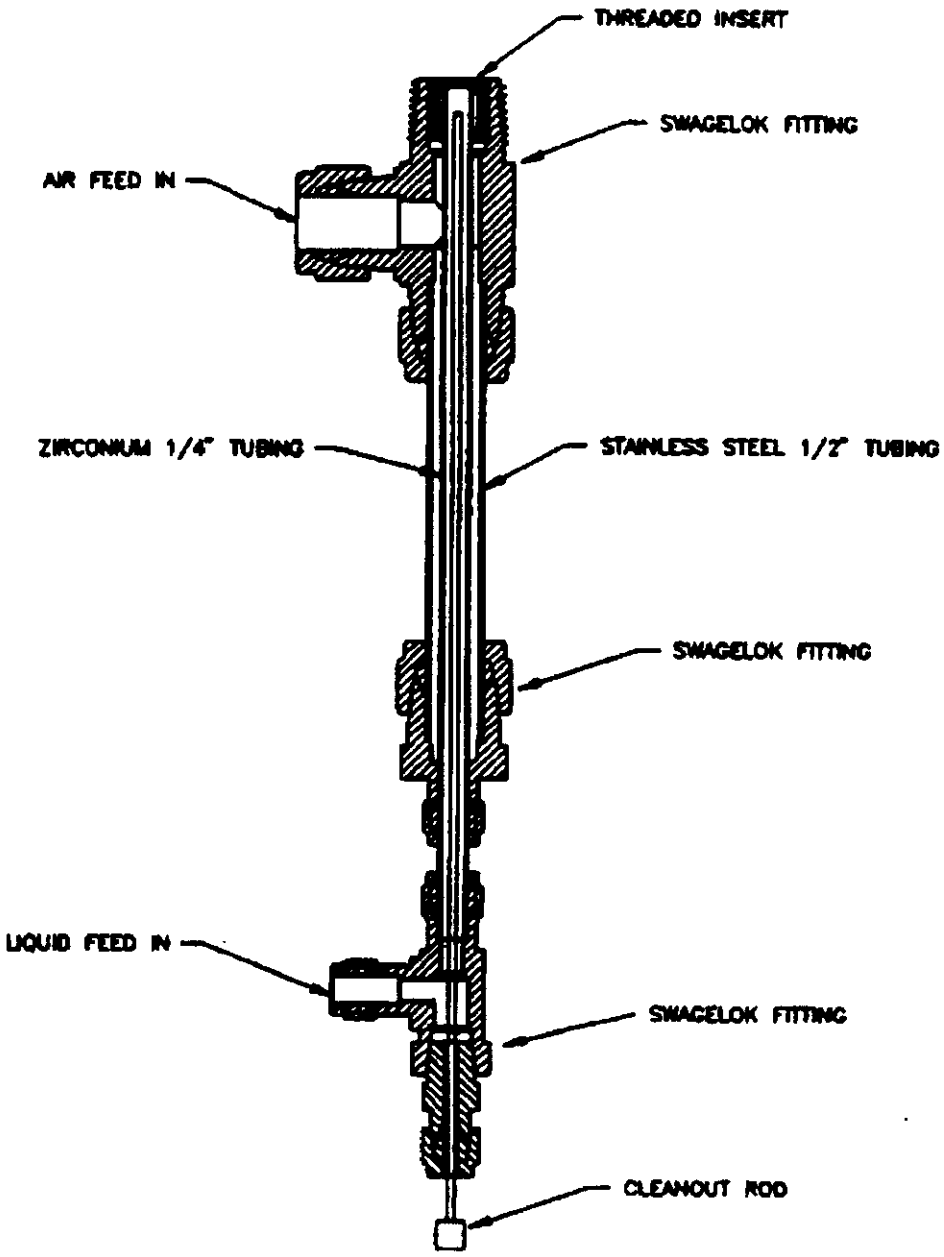


Figure 11. Laboratory Prototype Calciner - Agitator.

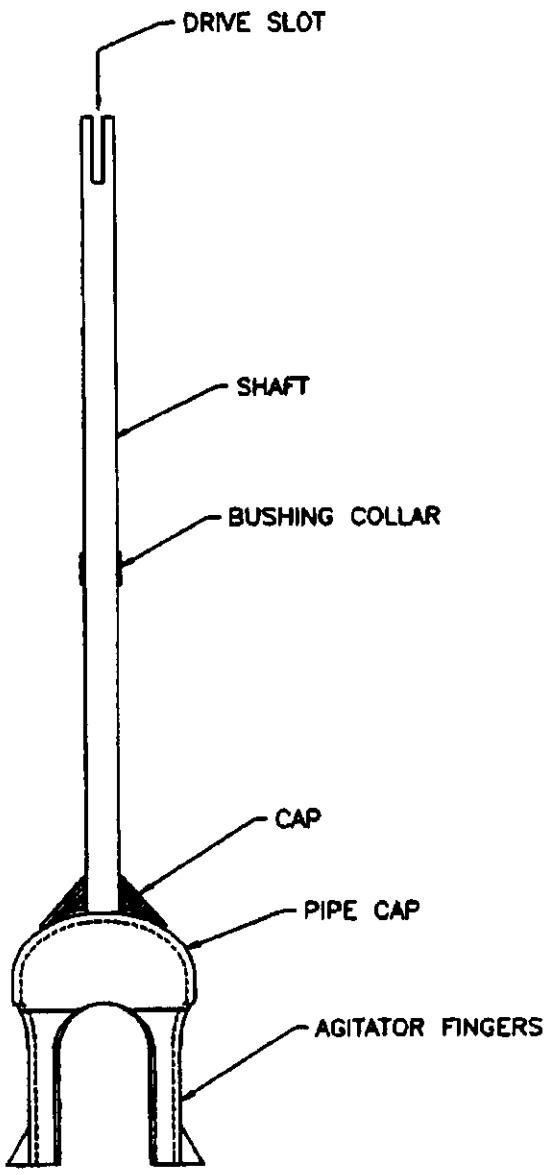


Figure 12. Laboratory Prototype Calciner - Caustic Scrubber.

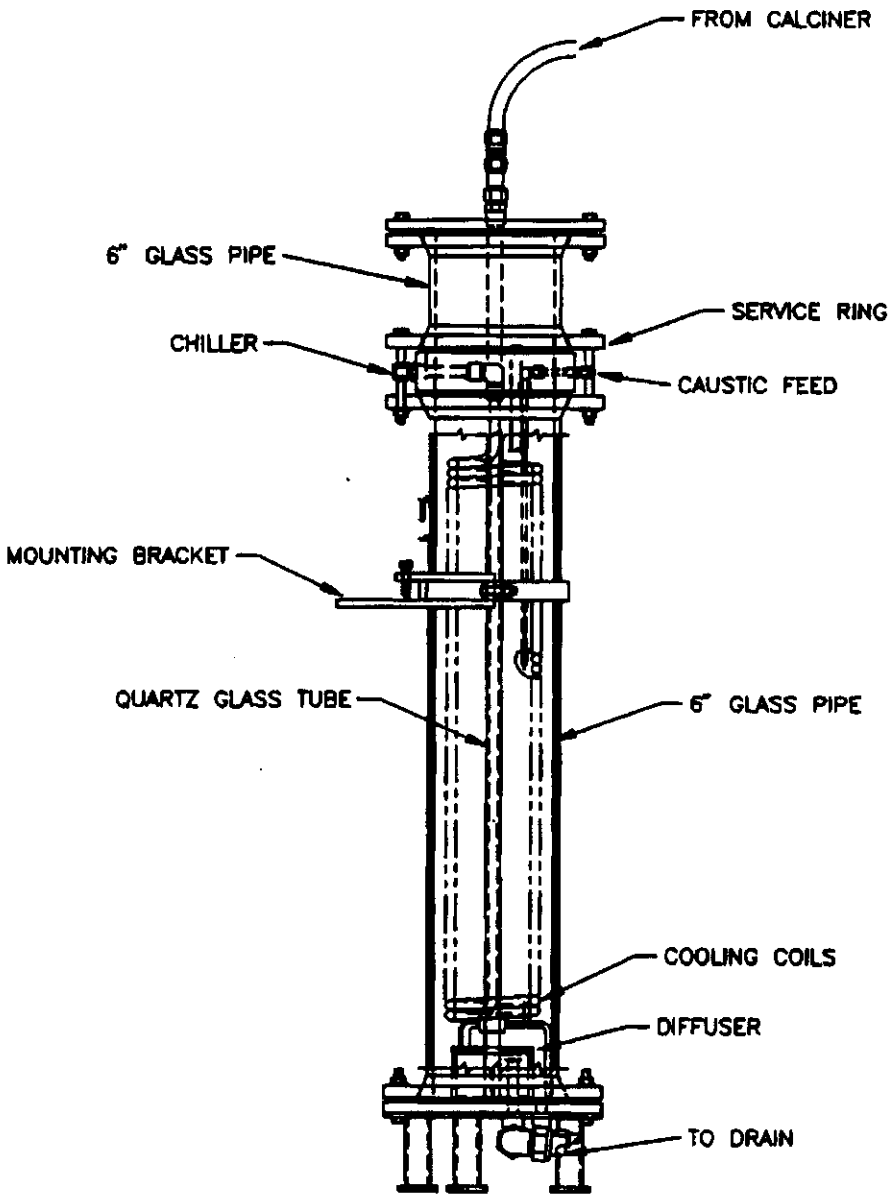


Figure 13. Laboratory Prototype Calciner - Spent Scrub Solution Tank.

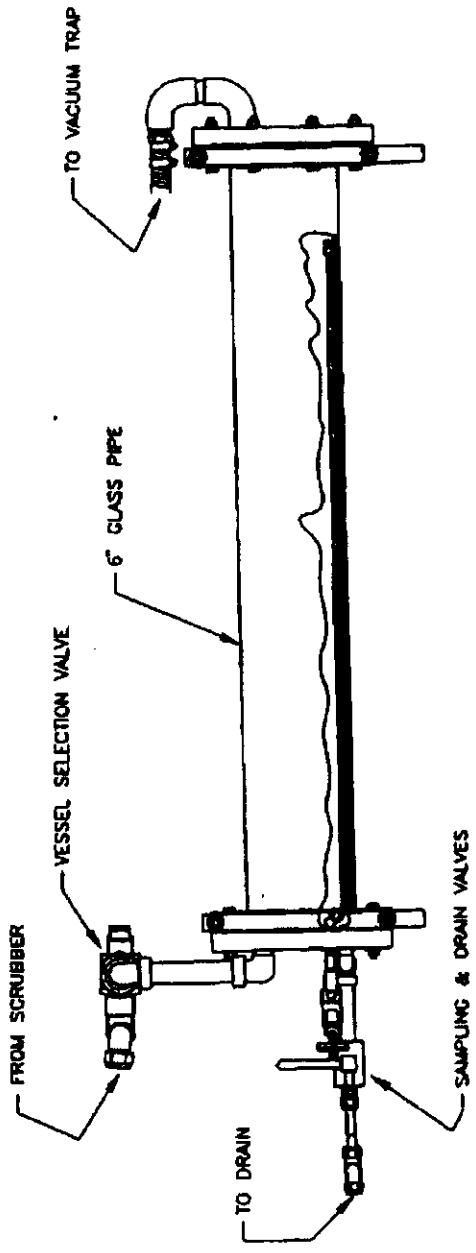


Figure 14. Laboratory Prototype Calciner – Summary Material Balance

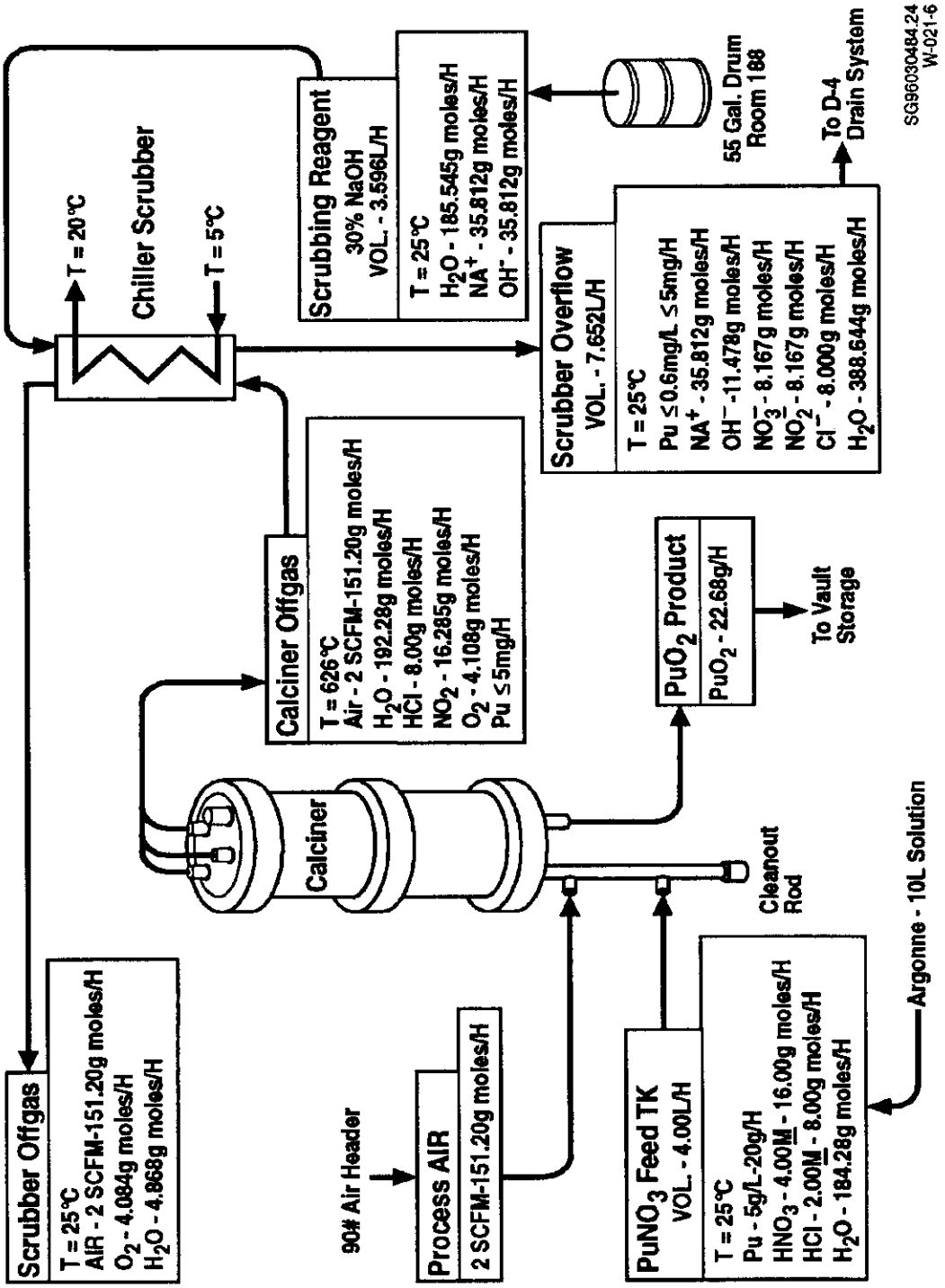


Figure 15. Control Diagram – Calciner Interconnection with PFP Ventilation Seismic Shutdown System

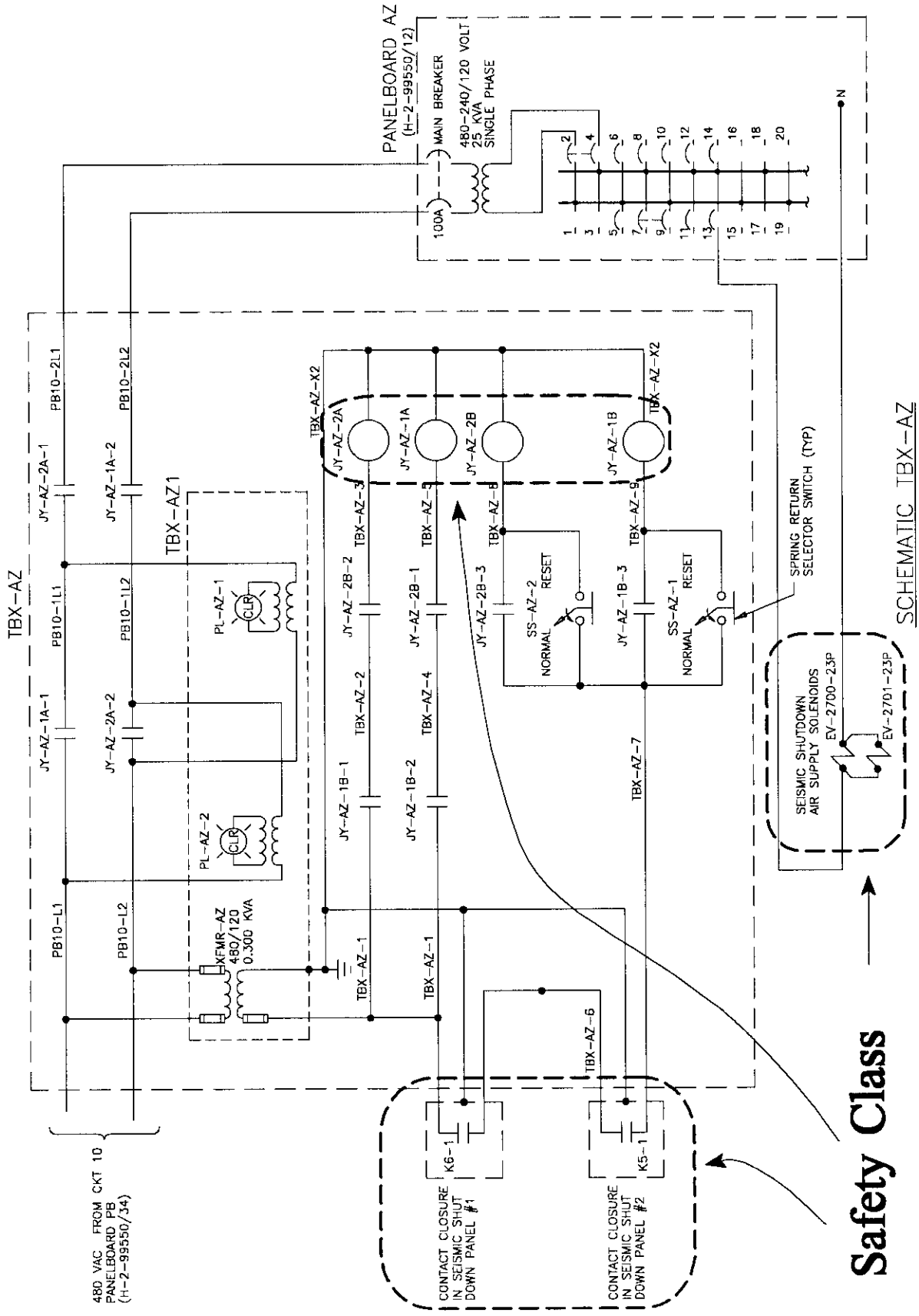
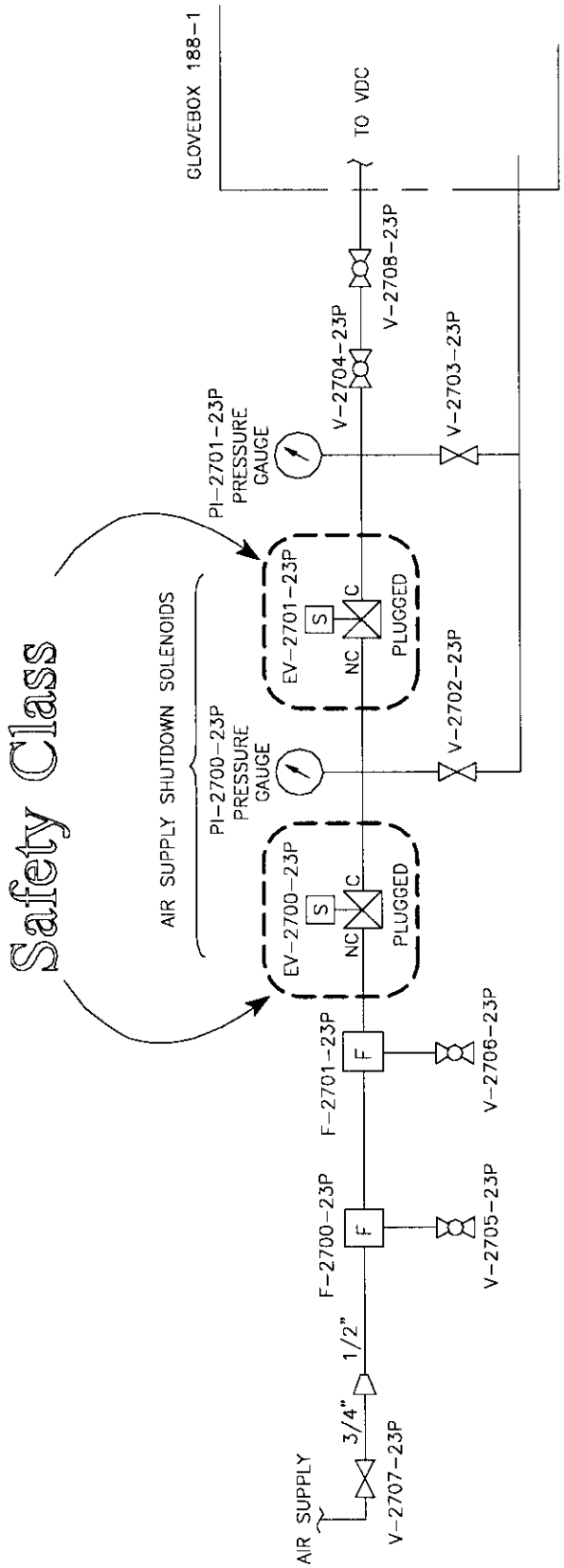


Figure 16. Calciner Air Supply System Seismic Shutdown Valve Configuration.



APPENDIX A

HAZARDS ANALYSIS FOR THE PLUTONIUM FINISHING PLANT LABORATORY PROTOTYPE CALCINER

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1.0 INTRODUCTION

A hazards analysis was performed to identify and evaluate hazards associated with the stabilization of plutonium nitrate solutions using the PFP Laboratory Prototype Calciner. This appendix describes the methodology and presents the results of the hazard analysis performed. The techniques used in identifying the hazards associated with the operation of the calciner were a Preliminary Hazards Analysis (PHA) and a Hazards and Operability Study (HAZOP).

The scope of the PHA and HAZOP included activities from the transport of the PR can drum into Room 188 to the transport of the over-packed product can into a storage vault.

2.0 HAZARD ANALYSIS

The methodology and results of the PFP Laboratory Prototype Calciner hazard analysis and evaluation are presented in this section. The hazard analysis is a structured, systematic examination of the calciner system, and pre- and post-processing activities of the plutonium nitrate solutions. The resulting identified hazards were then evaluated and placed into Accident Groups based on the initiating event and the resulting consequences of the hazard.

2.1 Hazard Identification Methodology

This section describes the methodologies used to identify and characterize hazards associated with the calciner pre- and post-processing activities and the calciner operations. Two techniques were used in identifying the hazards associated with the activities performed before and after the calciner and the operation of the calciner. These techniques are described in Sections 2.1.1 (PHA) and 2.1.2 (HAZOP).

2.1.1 Laboratory Prototype Calciner Hazard Identification Methodology

The activities associated with the movement of the plutonium nitrate solutions into Glovebox 188-1 and the removal of the over-packed can of plutonium oxide from Glovebox 188-1 for transfer to a storage vault were evaluated via a PHA. The PHA process is a systematic approach whereby a system, process, or activities are divided into basic elements and the hazards associated with elemental system, process operations, or activities are identified. Then potential causes of the hazards are determined, potential consequences of the hazards are evaluated, and possible or existing engineered and administrative safety features are identified.

A detailed discussion of the PHA technique can be found in *Guidelines for Hazard Evaluation Procedures* (AIChE 1992).

The PHA was developed using a table to guide and record the results of the hazard identification and evaluation process. The PHA form is provided in Table A-1. The purpose and contents of each column in the PHA table are described in detail in the following paragraphs.

Column 1, Item ID: Provides an alpha-numeric identifier for each postulated hazard in the table. The identifier is primarily used for cross referencing within the table.

Column 2, Acc Group: Provides an alpha-numeric identifier of the accident group the hazard has been assigned to.

Column 3, Activity Operation: Lists the activities or operations performed before and after the calciner operation. For general activity or operation, a description is listed in this column. Safety functions for the activity were identified, and failure of the safety functions was postulated to identify the hazards.

Column 4, Hazardous Event: Hardware failures or operational faults of concern are identified in this column. Hazards are identified by asking "what-if" type questions, such as, "what if the operation is not performed," "what if the operation is performed out of order," "what if the operation is performed too fast". Guide word deviations such as are used in HAZOP analysis (AIChE 1992) were also utilized to identify hazardous conditions. Guide words are process parameters such as pressure, temperature, flow, concentration, etc. Relevant deviations include "low/no," "high," "other than."

Column 5, Causes: Identifies the causes for the failures/hazardous conditions postulated in Column 3. Identifying causes is important to identifying potential preventative controls for significant hazards. In many cases, multiple hardware or operational faults are required to produce a hazardous event. This column identifies the sequence of hardware and operational faults required to produce the postulated hazardous event.

Column 6, Consequences: Describes the potential consequences that could result from the postulated hazards identified in Column 3. The focus of this column is to identify effects to the glovebox confinement system and to facility workers.

Column 7, Engineered Safety Features: Identifies the engineered safety features (hardware items) available to prevent or mitigate the consequences identified in Column 5. The engineered features in this column are candidates for designation as Safety Significant items for hazards that pose a significant threat to the health of facility workers.

Column 8, Administrative Safety Features: Identifies the administrative requirements that reduce the likelihood of the hazardous event identified in Column 3, or that help minimize the potential consequences of the hazardous event. The controls listed in this column are candidates for operational safety requirement (OSR) designation for hazardous events with the potential to significantly harm facility workers.

Column 9, Consequence Category: Used to capture a code designator for the level of consequence associated with a hazardous event. The consequence ranking is a "first cut," qualitative estimate of the safety severity of the consequences. An alphanumeric system has been used at the PFP to designate the severity of hazardous events. The system has the following "S" rankings characterizing safety consequences:

S0 No effect outside the facility confinement systems, and no safety concerns for the facility worker, the onsite worker, or members of the general public.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker. An example of such a hazard would be an operator injury where glovebox gloves are penetrated by the can punch causing worker injury and possible skin/wound contamination.

S1* Potential severe harm or potential death from industrial injury, radiological dose or chemical exposure to the facility worker. Hazards of this severity level may warrant safety significant controls.

S2 Potentially significant radiological dose consequence or chemical exposure to the maximum onsite worker outside the facility, or discharge of hazardous material to the environment within the Hanford Site boundary. This is conservative as such events will not necessarily cause severe harm to facility workers.

S3 Potentially significant radiological dose consequence or chemical exposure to the offsite population, or discharges of hazardous material to the environment outside the Hanford Site boundary or to the groundwater.

Engineered safety features and controls specific to the processing of plutonium oxides are not credited in assigning the above consequence rankings. This is to allow determination of whether the controls warrant designations as safety significant or safety class.

The mitigative effects of features previously designated as safety significant or safety class are credited in assigning the consequence rankings. The effects of energetic events on the glovebox structure, however, are assessed to determine if the hazardous event can compromise the Safety Significant Confinement function provided by the glovebox structure and ventilation system. Similarly, the Building 234-5Z Safety Class Structure and E-3 and E-4 Ventilation Exhaust Systems are credited with protecting onsite workers and the offsite public outside the PFP from accidents that breach glovebox confinement.

Column 10, Frequency Category: Used to capture a code designator for the estimated frequency of occurrence of a hazardous event. The ranking is a "first cut," qualitative estimate of the frequency of the hazardous event. The following ranking system is used.

F0 Events categorized as "beyond extremely unlikely" with a frequency less than 1×10^{-6}/yr.

F1 Events not expected to occur within the lifetime of a typical facility, categorized as "extremely unlikely". The frequency range associated with this category is 1×10^{-6}/yr to less than 1×10^{-4}/yr.

F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1×10^{-4}/yr to less than 1×10^{-2}/yr.

F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is equal to or greater than 1×10^{-2}/yr

The frequency estimate, like the consequence ranking, is assigned taking no credit for active engineered features. The frequency ranges shown above are based on the risk acceptance criteria for the onsite receptor from the PFP FSAR (FDH 1999).

Column 11, Remarks: Contains miscellaneous observations or clarifying comments for a given hazard. The comments column can be used to identify hazards that are adequately addressed in other documentation.

2.1.2 Laboratory Prototype Calciner Operations Hazard Identification

A Hazards and Operability Study (HAZOP) was selected as the method by which to identify the hazardous conditions associated with the operation of the calciner. A HAZOP is a systematic approach in which the basic elements of the system and the hazardous conditions of interest are identified, potential causes and effects are evaluated, and possible corrective and/or preventive measures are proposed. HAZOP findings are documented on a HAZOP Form, which is shown in Table A-2. Guide words and column headings in a HAZOP form are used to aid in ensuring completeness. The columns of the HAZOP Form contain the following data:

Column 1, Node ID: Alphanumeric identifier. Each hazardous condition is assigned a unique identification number which permits cross-referencing information contained in the HAZOP with the accident tables that are generated later in the hazard evaluation process.

Column 2, Acc Group: Provides an alpha-numeric identifier of the accident group the hazard has been assigned to.

Column 3, Node Description: Defines the system node that is being evaluated.

Column 4, Design Function: Contains a description of the operation(s) being performed in the operational area, or a description of the system functions in the case of a system being evaluated.

Column 5, Parameter Guide Word: Contains a description of the operation(s) being performed in the operational area, or a description of the system functions in the case of a system being evaluated.

Column 6, Cause: Lists the potential cause or causes of the hazardous event or failure.

Column 7, Consequence: Lists the potential consequences of the hazardous event.

Column 8, Engineered Safety Features : Lists existing hardware design features that could mitigate or prevent the event being considered.

Column 9, Administrative Safety Features: Lists administrative controls that could mitigate or prevent the event being considered.

Column 10, Cons Cat: Consequence Category contains a qualitative estimate of the result of the event, assuming that no controls, engineered or administrative, are present. However, naturally occurring phenomena that limit the consequences of an event are assumed to take place ("rules of the universe"). This consequence ranking is a "first cut," qualitative, consensus estimate of the safety severity of the consequences. The following "S" rankings are used to characterize the severity of the safety consequences:

S0 No effect outside the facility confinement systems, and no safety concerns for the facility worker, the onsite worker, or members of the general public.

S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker; limited discharge of hazardous material to the environment outside the facility. An example of such a hazard would be an operator injury where glovebox gloves are penetrated by the can punch causing worker injury and possible skin/wound contamination.

S1* Potential severe harm or potential death from industrial injury, radiological dose or chemical exposure to the facility worker. Hazardous conditions sufficient to cause severe harm or death to facility workers are typically associated with events which may result in significant pressurization of or damage to the glovebox structure with potential release of radiological material. Therefore, events with sufficient energy to impact the glovebox in a manner which may cause a release of radiological material are assigned an S1* consequence rank. This is a conservative approach since such events will not necessarily result in harm to or death of facility workers.

S2 Potentially significant radiological dose consequence or chemical exposure to the maximum onsite worker outside the facility, or discharge of hazardous material to the environment within the Hanford Site boundary.

S3 Potentially significant radiological dose consequence or chemical exposure to the offsite population, or discharges of hazardous material to the environment outside the Hanford Site boundary or to the groundwater.

Column 11, Freq Cat: Frequency Category is a "first cut," qualitative, consensus estimate of the frequency of the hazardous condition (also referred to as "event"), assuming that no engineered or administrative safety features are present. The following "F" rankings are used to characterize the frequency of the hazardous condition:

F0 Events categorized as "beyond extremely unlikely" with a frequency less than 1×10^{-6}/year.

F1 Events not expected to occur within the lifetime of a typical facility, categorized as "extremely unlikely". The frequency range associated with this category is 1×10^{-6}/year to less than 1×10^{-4}/year.

F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1×10^{-4}/year to less than 1×10^{-2}/year.

F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is equal to or greater than 1×10^{-2}/year.

Column 12, Remarks: Remarks contains information that the team judges to require documentation. This can include, but is not limited to, assumptions about facility operation or recommendations for changes in the planned design or operation.

The HAZOP table is structured to ensure a systematic and thorough review of potential hazards associated with the operation of the calciner.

2.2 Hazard Analysis Results

2.2.1 PHA Hazardous Condition Evaluation Results

A PHA was performed to identify the hazards associated with calciner operations, including the activities before and after the calciner operations which involve the movement of the plutonium nitrate solutions into Glovebox 188-1 and the removal of the plutonium oxide over-packed can from Glovebox 188-1 into a storage vault. The PHA was performed by a multi-disciplinary team comprised of PFP laboratory personnel with a detailed knowledge of the pre- and post-processing activities associated with the calciner operations, and safety analysis subject-matter experts. The work experience of each of the team members is provided in Section 2.2.3.

The PHA table in the analysis is specially structured to ensure a systematic and thorough review of potential hazards associated with the pre- and post-processing activities of the calciner.

The operational steps covered by the PHA were identified from applicable operating procedures, verbal descriptions provided by the cognizant engineer, and available design media. The groups of operations performed and evaluated in the PHA are:

1. Move PR can drum into Room 188
2. Move replacement drum of caustic into Room 188
3. Open plutonium nitrate drum
4. Remove bags from bottle and load solution into feed tank
5. Start up calciner system in the following sequence: (1) turn on vacuum, (2) turn on pressurized air, and (3) activate agitator and heaters
6. Bag-out empty bottle and waste
7. Load empty bottles back into drum from laboratory, move drum out of laboratory
8. Glovebox 188-1 Laboratory Prototype Calciner- Oxidize plutonium nitrate
9. Load flush solution into glovebox and flush calciner feed line
10. Transfer collection jar contents to slip-lid can
11. LOI sampling
12. Weigh can, tape lid on, and reweigh can
13. Bag-out filled slip-lid can
14. Canning of bagged slip-lid can into overpack (large tomato can)
15. Second overpack (7 in. can) applied in hallway
16. Transfer overpacked can to vault

"What if" questions were asked at each of the activities that are provided above. Hazardous Event, Causes, and Consequences were then identified for each activity and recorded in tabular format (Table A-1). The resulting hazards of this process are recorded in a PHA tabular format and is provided in Table A-5.

2.2.2 HAZOP Hazardous Condition Evaluation Results

The hazards associated with calcining the plutonium nitrate in the calciner were identified via the HAZOP technique. The HAZOP was conducted by a safety analysis expert facilitating a team of knowledgeable contributors with PFP and calciner system experience. That team consisted of safety analysts, accident analysts, and an engineer who has operated this calciner. The work experience of each of the team members is provided in Section 2.2.3.

A HAZOP was performed to identify the hazards associated with operation of the Production Vertical Denitration Calciner (VDC) system but the results were not issued. The results of the previous VDC HAZOP (node id, node description, design function parameter/guide word, cause, consequence) were used as a starting point for the identification of hazardous conditions for the operation of the laboratory calciner.

The calciner system was subdivided into 15 hardware nodes. These nodes are shown in Figure A-1. Each of the nodes were evaluated for relevant design parameters: pressure, temperature, flow rates, pH, composition, mixing, etc. The following guide words are examples of those that were used in determining parametric deviations to the above parameters: no, less, more, part of, as well as, reverse, and other than. All guide words are included in Table A-6. These deviations were applied to each parameter at each of the following nodes:

1. Feed Tank
2. Feed Pump
3. Calciner Injector Nozzle
4. Calciner Vessel
5. Off-gas line between calciner and scrubber
6. Scrubber
7. Spent Scrubber Solution Tank
8. Spent Scrub Solution Drain Line
9. Vacuum Trap
10. Filter Pulsing Supply Air
11. Sodium Hydroxide Feed Supply Line
12. Scrubber Chiller
13. Glovebox 188-1
14. E-4 Exhaust Duct at Outlet of glovebox
15. Product Collection Jars and Slip Lid Cans

"What if" questions were asked at each of the nodes for each of parametric deviations that were identified. Causes and consequences were then identified for each hazard and recorded. The results of this process are recorded in the HAZOP provided in Table A-6.

2.2.3 Laboratory Prototype Calciner PHA/HAZOP Participant Biographies

This section contains the professional biographies of the participants of the PFP Laboratory Prototype Calciner PHA/HAZOP conducted during February 2 – 5, 1999.

David J. Braun - Fluor Daniel Northwest Inc, Engineer, Safety Analysis and Risk Assessment PE

Mr. Braun has over 21 years experience at Hanford working primarily in Safety Analysis. His experience includes Probabilistic Risk Analysis of nuclear reactors, tank farm activities, and hazards identification and evaluation of various Hanford site operations and facilities. He was one of the lead engineers on the hazards identification and evaluation team for the current TWRS BIO and draft FSAR. He has facilitated numerous PHA and HAZOP studies for projects at the Hanford site. Mr. Braun has a Master of Science Degree in Mechanical Engineering from the University of California at Davis. He is a registered Professional Engineer in Mechanical Engineering (Washington State).

Jim Compton - B&W Hanford Company, Engineer

Mr. Compton is the cognizant engineer for the PFP laboratory prototype calciner. He has a Bachelor of Science degree in Chemical Engineering from the University of Kansas. He has worked in the Plutonium Process Support Laboratories for 22 years. He has worked with the design, installation, and testing of this calciner since 1994.

Brett Hall - Fluor Daniel Northwest Inc, Engineer, Safety, Analysis and Risk Assessment

B. S., Chemical Engineering, Process Engineer, FDNW Safety Analysis and Risk Assessment Group. Over nine years experience at Hanford. Eight years of experience in performing and documenting safety analyses for various Hanford facilities, including the TWRS tank farms and the Plutonium Finishing Plant (PFP). One year of experience in Tank Waste Characterization.

Don Porten - Fluor Daniel Northwest Inc, Engineer, Safety, Analysis and Risk Assessment

Mr. Porten is a Nuclear Engineer with 25 years of experience with the safety aspects of nuclear reactors and nuclear facilities in the Hanford area and in commercial power production. He has worked as a safety analysis engineer performing hazard and accident analysis for nuclear facility Safety Analysis Reports and Assessments. He performed hazard and accident analysis for the entire series of safety documents, (Hazard Classification, PSE, PSAR, FSAR) that accompanied WRAP 1 from conceptual design through construction to completion and startup. As a nuclear fuel management engineer, he prepared and used reactor simulation computer models for reload core design, operation, and safety margin evaluation of the Pallisades Nuclear Plant. He worked as a nuclear fuels testing engineer performing transient irradiation experiments of mixed oxide fuel elements which contributed to the safety basis for the Fast Flux Test Facility. Mr. Porten has Master of Science degree in Nuclear Engineering from the University of Washington in Seattle.

Martin Prisc - B&W Hanford Company, Engineer

Mr. Prisc has 30 years experience working at the Mound Facility in the process development and analytical sections. For over 15 years his experience includes involvement with Safety Analysis and Risk Assessments, USQ and FSAR documentation, and as a member of the Safety Overview Committee. Mr. Prisc has a Master of Science degree in Inorganic Chemistry from the University of Cincinnati located in Cincinnati, Ohio.

Jim Shapley - Fluor Daniel Northwest Inc, Engineer,

Mr. Shapley is a Senior Principal Engineer with Fluor Daniel Northwest. He received his B.S. Engineering Degree from the University of California in Los Angeles. He is a systems and project engineer with 30 years of experience in systems design, engineering and analysis. Currently he is the lead engineer responsible for preparation, review and approval of the annual updates and overall maintenance of the PFP SAR.

2.3 Accident Group Selection

The hazardous events identified by the PHA and HAZOP process are segregated into accident groups. This process of grouping the hazards is the starting point for the quantitative accident analysis process. The results of that type of analysis are compared to applicable regulations and requirements for systems, structures, and components. The comparison is made to determine the necessary safety class and safety significant components and to define Operational Safety Requirements (OSRs). The accident selection methodology is provided in Section 2.3.1 and the results of application of this process to the calciner are provided in Section 2.3.2.

2.3.1 Accident Selection Methodology

The selection of accidents that will subsequently be used for quantitative analysis was performed by a grouping process designed to comply with the requirements of Section 3.3.2.3.5 of DOE-STD-3009-94 (DOE 1994) and the requirements of HNF-PRO-704 (HNF 1997). DOE-STD-3009-94 suggests a matrix approach in which only "unacceptable accidents" (moderate to high consequences, and unlikely to anticipated frequency) should be identified. The initial accident screening criteria used in this process were based on qualitative consequence rankings that were developed in the PHA/HAZOP. Any accident appearing in the S2 or S3 consequence category was a potential candidate for quantitative analysis. Thus a broader spectrum of candidate accidents was considered for quantitative analysis than is required by DOE-STD-3009-94. This approach does not omit any accident that the standard would consider and provides for consideration of a broader spectrum of representative and unique accidents to furnish adequate technical justification for the choice of safety class equipment and OSRs.

The selection process is represented in the flowsheet of Figure A-2. All accidents developed in the HAZOP were classified by "Type" and placed into accident groups. The type classification of each accident relates to the initiating phenomena such as canister failures, fire, pressurization, etc. For each accident group with an S1*, S2, or S3 consequence, a representative accident was developed for further quantitative analysis. This representative accident bounds the consequences of similar accidents/hazards in the accident group it represents. Similar accidents/hazards challenge analogous barriers. Analogous barriers reflect the same design philosophy for prevention and mitigation as the representative accident, even though the similar accidents may be in different locations. If there is only one accident/hazard of a given type, it is analyzed as a unique representative accident. The "Category" of an accident was used to help identify initiating events that, for accidents of a common type, could result in significantly different challenges to the analogous barriers.

The results of the accident grouping process are presented in tabular format for each accident group. This information is provided in Table A-5 and Table A-6 under the column Acc. Group. Accidents that would not have effects of concern outside Glovebox 188 (S0 category consequences) are grouped together. Accidents that result in increased worker exposures (direct dose) or minor air contamination releases, but not above exposure limits (S1 category consequences) are grouped together. Accidents that could result in severe worker injury, or

radiological or toxicological exposure to facility workers above established exposure limits (S1* category consequences) are grouped together. (S1* accidents do not have significant consequences outside the facility confinement boundary). Accidents that could potentially have effects of concern to either the maximum onsite individual or the maximum offsite individual (S2 and S3 category consequences) are also grouped together.

2.3.2 Accident Selection Results

The accident groups that were chosen for consideration are provided in Table A-3. An appropriate representative (bounding) accident was chosen for each selected accident group. If a group contained a single accident, that accident was identified as unique and representative. The representative accidents were otherwise chosen as the accident having the highest consequence with the highest frequency ranking in a specific accident group.

Table A-4 contains a list of accidents that were derived from the hazardous conditions generated by the Laboratory Prototype Calciner PHA and HAZOP. The accidents were derived using the "Cause" and "Consequence" columns of the hazardous condition definition. The hazardous conditions were selected on the basis that there was impact on the facility worker (life threatening - S1*) and onsite worker (S2). These resulting accidents are sorted according to the accident groups provided in Table 3. A total of 10 of the 15 accident groups of Table A-3 had S1* and/or S2 defined accidents.

A representative accident was selected for each of the 10 accident groups. A representative accident having the highest consequence and frequency ranking was selected from the accidents in a particular accident group. The selected representative accident is at the top of the list of each accident group and its identifying number ends with an "R".

One event in Table A-4 falls in the consequence category of S2 and frequency category F2. The event is in Accident Group NPH: Release of plutonium to room through failed glovebox, windows, seals, and penetrations due to seismic event resulting in exposure to site personnel.

The other hazardous conditions listed in Table A-4 for Accident Groups C through K are in the Consequence Category S1* and Frequency Categories F1, F2, and F3. There are a total of 57 hazardous condition identifiers listed in Table A-4, which are represented by 42 accidents.

2.4 Abnormal Occurrences and Negligible Consequence Events

Within the 10 accident groups that have S1* and/or S2 consequence defined events, there are four groups that also have S1 and/or S0 consequence defined events. From Section 2.1.2, S1 events are defined as potential industrial injury, low radiological or chemical exposure consequences to the facility worker, and limited discharge of hazardous material to the

environment. Events with an S0 designation have no effect outside the facility and negligible safety concerns for the facility worker.

For each of the 10 groups, all S1* and S2 events are sorted out and collected into a subgroup for evaluation as accidents. All S1 events in each group are collected into a second subgroup for evaluation as abnormal operations. Finally, all S0 events in each group are collected into a third subgroup with the S0 negligible safety concerns.

Of the 15 accident groups of Table A-3, six of them (A2, B, C, G, I, and J) have events with a consequence category of S1, designating abnormal occurrences. There were no representative abnormal occurrence events identified in any of the groups. The rationale for not developing abnormal occurrences is presented in Section 3.2.2 in this addendum.

4.0 REFERENCES

AIChE, 1992, *Guidelines For Hazard Evaluation*, Second Edition, American Institute of Chemical Engineers, Center for Chemical Process Safety of the American Institute of Chemical Engineers, New York, New York.

DOE, 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, DOE-STD-3009-94, U.S. Department of Energy, Washington, D.C.

FDH, 1999, *Plutonium Finishing Plant Final Safety Analysis Report*, HNF-SD-CP-SAR-021, Rev. 1A, September 1999, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF, 1997, *Hazard and Accident Analysis Process*, HNF-PRO-704, Rev. 0, Project Hanford Policy and Procedure System.

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Figure A-1. Hazard and Operability Study Node Schematic

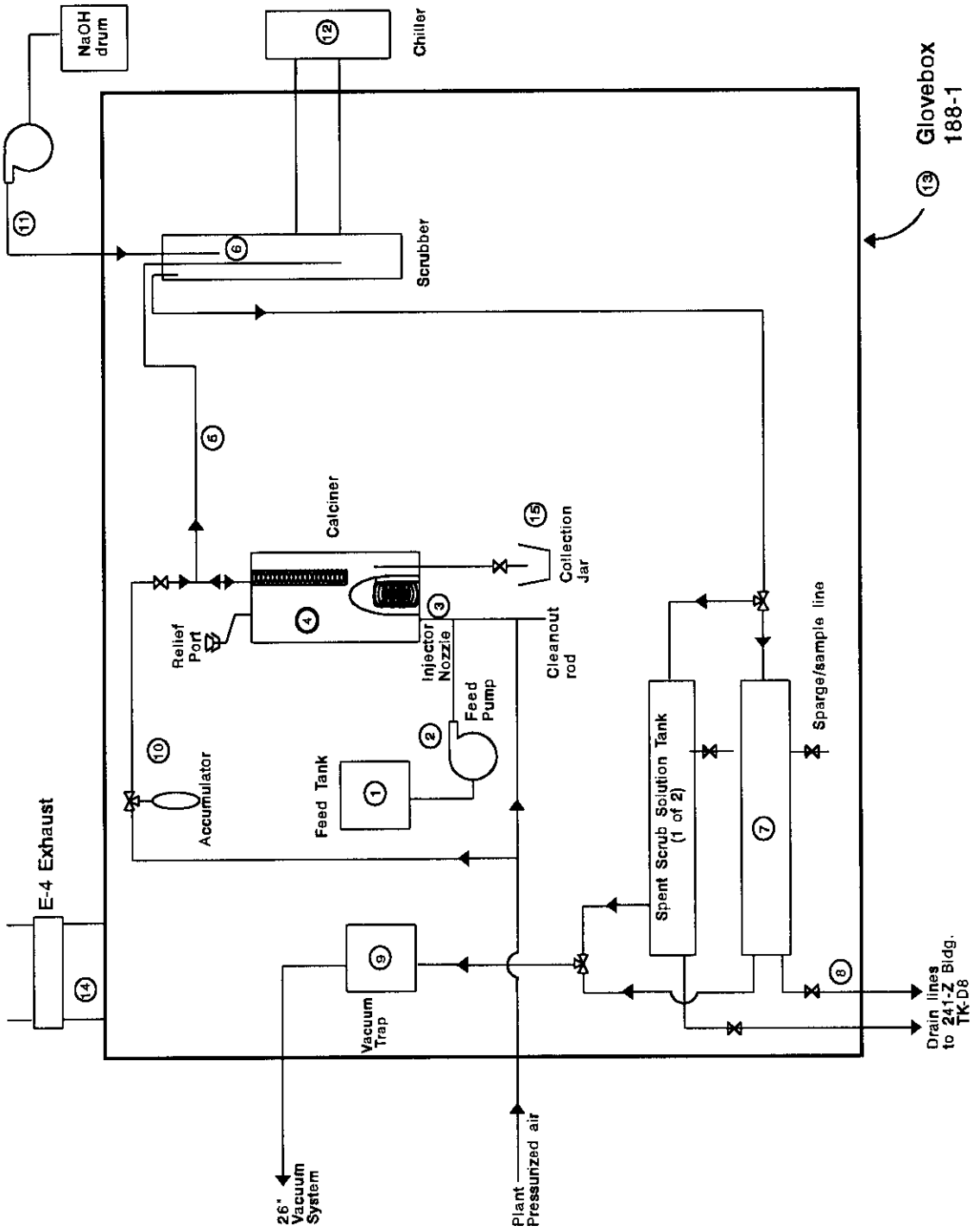


Figure A-2. Accident Selection Process Flowsheet.

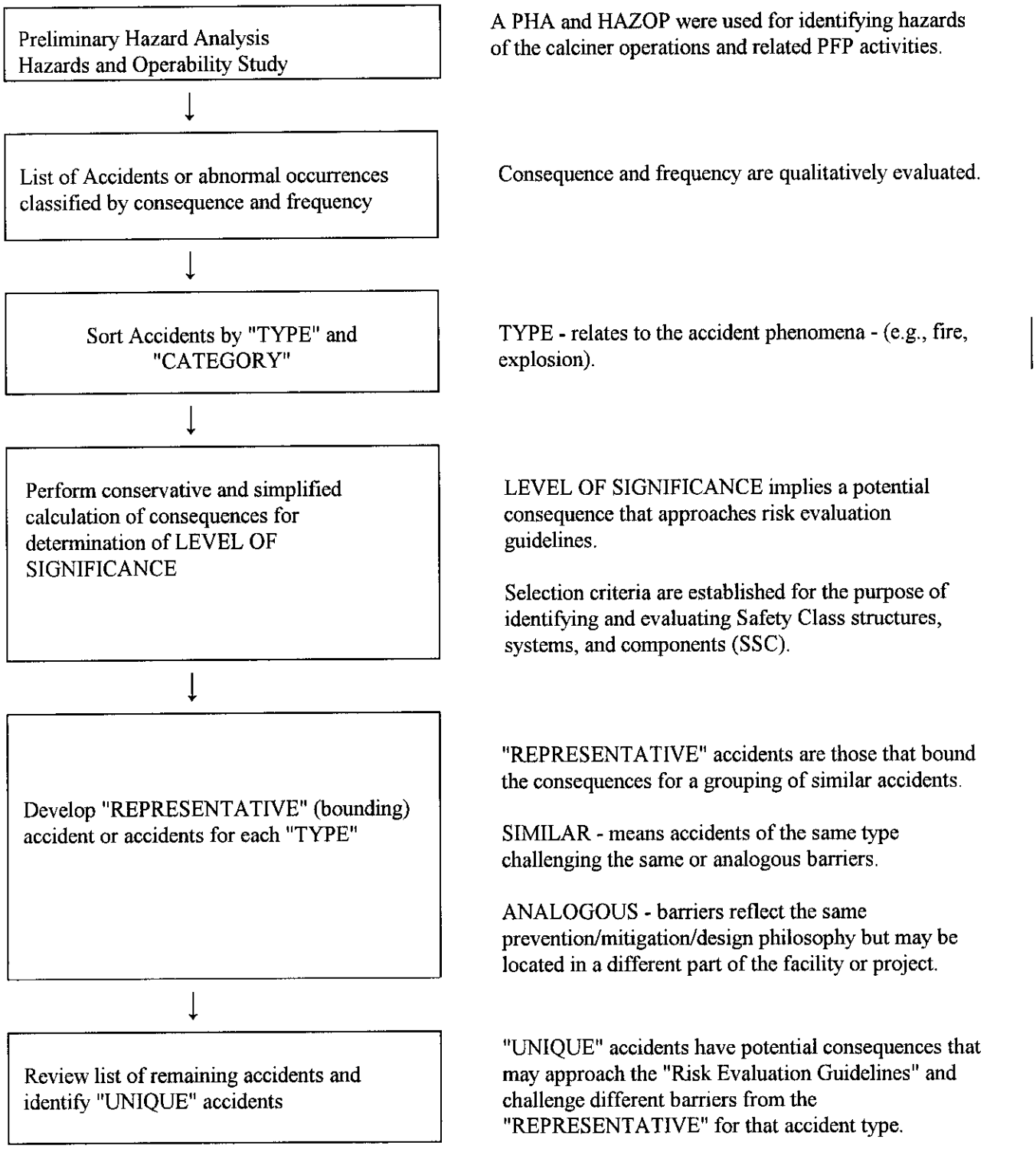


Table A-1. Preliminary Hazards Analysis Form

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat	Freq Cat	Remarks

Table A-2. Hazard and Operability Study Form

Node ID	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat	Freq Cat	Remarks

Table A-3. Accident Groupings

No.	Accident Group Title
A1	Process Upset - no worker impacts
A2	Process Upset - worker ALARA concern
B	Radiological Release Inside Glovebox
C	Radiological Release from Glovebox
D1	Deflagration in Glovebox
D2	Deflagration Outside of Glovebox
E	Criticality
F1	Fire Inside of Glovebox
F2	Fire Outside of Glovebox
G	Industrial Hazards - not resulting in severe worker injury
H	Release to Vacuum System
I	Toxic Chemical Release Inside Facility
J	Radiological Release Inside Facility
K	Inadequate Stabilization of Product
NPH	Natural Phenomena Initiator (Seismic Event)

Table A-4. Plutonium Finishing Plant Laboratory Prototype Calciner S1*, S2 Hazards by Accident Groups

Acc Group	Node /Item ID	General Hazardous Event Considered	Cons Cat	Freq Cat
Radiological Release From Glovebox				
C	01.03 02.01	Pull or tear glove off glovebox due to movement of bottle drum, or caustic drum too close to glovebox, resulting in worker contamination	S1*	F3
	03.05	Glove breach during transfer of bottle from airlock into glovebox due to airlock door, resulting in worker contamination	S1*	F3
	08.04.10/1 08.04.10/2	1. Structural failure of calciner (partially melts) with spill of hot plutonium oxide to floor of glovebox due to control failure of calciner heater power supply (full on) caused by controller or thermocouple failure, software set point, or human error... 2. Pressurization of glovebox due to heat released and flashed liquid, damage to glovebox and loss of confinement due to control failure of calciner heater power supply (full on) caused by controller or thermocouple failure, software set point or human error... 3. Plutonium oxide and nitric oxides released to room due to control failure of calciner heater power supply (full on) caused by controller or thermocouple failure software set point or human error... 4. Structural degradation of calciner due to control failure of calciner heater power supply (full on) caused by controller or thermocouple failure, software set point or human error... Resulting in to Room 188 and worker contamination	S1*	F2
	03.03	Loss of glovebox confinement due to inner & outer airlock doors open at same time (human error), resulting in Room 188 and worker contamination	S1*	F2
	08.13.04	Blown out gloves or glovebox seal/penetration failures due to plant pressurized air leak into glovebox (catastrophic line failure to calciner ceramic filters or air regulator failures), resulting in contamination spread to Room 188 and worker contamination	S1*	F2
	09.01/1	Blown out gloves due to pressurized air leak inside of Glovebox 188-1, results in contamination release to Room 188 and worker contamination	S1*	F2
	09.03/1	Breach of glovebox confinement due to bottle pushed all the way through sphincter port without bottle or carton trailing, resulting in contamination spread to Room 188 and worker inhalation	S1*	F2
	09.03/2	Breach of glovebox confinement boundary due to both airlock doors opened at the same time during load in/load out of item or waste, resulting in worker inhalation	S1*	F2
	11.00	Breach in glovebox confinement boundary due to port bag torn during bagout of LOI sample, resulting in worker inhalation	S1*	F2
	13.00	Breach in glovebox confinement boundary due to port bag torn during bagout of slip lid can, resulting in worker inhalation	S1*	F2

Table A-4. Plutonium Finishing Plant Laboratory Prototype Calciner S1*, S2 Hazards by Accident Groups

Acc Group	Node /Item ID	General Hazardous Event Considered	Cons Cat	Freq Cat
Deflagration Inside of Glovebox				
D1	08.04.05	Deflagration in calciner vessel due to injection of feed containing organics into calciner resulting from sampling errors causing pressurization of glovebox and release of radiological material to Room 188 air and worker inhalation	S1*	F3
	08.03.17 04.02	Acetone or other organic solution loaded into glovebox and poured into feed tank by mistake resulting in flammable gas burn in calciner, pressurization of glovebox, and release of radiological material from glovebox	S1*	F2
	08.03.18	Organic present in plant pressurized air supply resulting in flammable gas burn in calciner, pressurization of glovebox, and release of radiological material from glovebox	S1*	F2
	04.01	Ignition of hydrogen emission from bag or bottle when opened during loading of calciner feed tank of plutonium nitrate resulting in pressurization of glovebox and release of radiological material to room air	S1*	F2
	08.01.07b/2	Flammable gas production due to mixing of organic (methanol) with highly acidic HNO_3 in feed tank	S1*	F1
Deflagration Outside of Glovebox				
D2	03.01/1	Hydrogen release and potential burn due to opening of drum having hydrogen accumulation from radiolysis, resulting in worker injury	S1*	F2
Criticality				
E	08.12.02/2	Criticality in chiller due to chiller line leak in scrubber, resulting in ionizing radiation dose to worker	S1*	F1
	08.07.04	Buildup of plutonium oxide sludge in spent scrubber solution tank due to ceramic filter failure in calciner, resulting in ionizing radiation dose to worker	S1*	F1
	08.04.14/2 08.04.14/4	Flooding of calciner with plutonium nitrate due to incorrect settings on calciner heaters (component failures, human error) resulting in ionizing radiation dose to worker	S1*	F1
	06.00	Criticality violation due to excess plutonium nitrate bottles left in glovebox, resulting in ionizing radiation dose to worker	S1*	F1
	08.01.05b 08.01.05c	Criticality in feed tank due to polymerization/precipitation of plutonium (pH greater than 2), resulting in ionizing radiation dose to worker	S1*	F1
	08.01.08/2	Criticality in feed tank due to make up error of plutonium nitrate, resulting in ionizing radiation dose to worker	S1*	F1
	08.13.20	Buildup of plutonium oxide sludge on floor of glovebox due to spills during operation of calciner, resulting in a criticality	S1*	F1
	08.13.22	Potential criticality in glovebox 188-1 due to activation of room fire suppression system	S1*	F1
	16.01	Criticality during transport of canister to vault due to CPS mass violation	S1*	F1

Table A-4. Plutonium Finishing Plant Laboratory Prototype Calciner S1*, S2 Hazards by Accident Groups

Acc Group	Node /Item ID	General Hazardous Event Considered	Cons Cat	Freq Cat
Fire in Glovebox (Ignition of combustible materials present in Glovebox 188-1)				
F1	08.02.04/2	Fire in glovebox due to electric motor burnout from deadhead conditions or wiring failure, resulting in failure of glovebox and worker inhalation of contamination	S1*	F3
	06.01 08.13.07	Fire in glovebox due to accumulation of waste bags, ice cream cartons, and other flammable waste in proximity to hot surfaces of calciner or ignition due to electrical short, resulting in failure of glovebox and worker inhalation of contamination	S1*	F2
	09.01/2	Incompatible chemical reaction in feed pump tank due to methanol being added by mistake, resulting in a fire and glovebox failure	S1*	F2
Fire Outside of Glovebox (Ignition of flammable materials in Room 188)				
F2	03.02/2	Hydrogen release and burn due to bag breach during handling outside of glovebox, resulting in worker contamination	S1*	F1
Toxic Chemical Release Inside Facility				
I	01.04b	Spray leak into Room 188 and contact with worker due to contact of bottle drum with caustic drum or transfer line during transfer, resulting in worker exposure to caustic spray	S1*	F3
	08.11.03/1	Spray leak into Room 188 due to corrosion of caustic transfer line, resulting in worker injury	S1*	F3
	08.11.03/2 1.04a 02.00	Spill of caustic solution to Room 188 floor due to mechanical contact with line outside of Glovebox 188-1, resulting in injury to worker	S1*	F3
	08.11.04	Spray leak from pump seals or relief valve due to caustic supply line to Glovebox 188-1 shut off, resulting in worker injury	S1*	F3
	03.01/2 09.02	Nitric oxides release when opening drum due to human error or incorrect bottle (drum stored long term) brought into lab, resulting in worker exposure to nitric oxides	S1*	F2
Radiological Release Outside Glovebox				
J	13.01	Release of radiological material to room after bagout of slip lid can due to human error, can dropped, resulting in worker exposure	S1*	F2
	01.02	Bottle drum toppled due to human error, resulting in bottle failure and contamination of worker	S1*	F2
Storage Canister Rupture				
K	08.02.03/1	Release of radiological material to vaults due to improperly set feed pump stroke, resulting in inadequately stabilized plutonium oxide and pressurized can (rupture in vault)	S1*	F3
	08.04.01	Release of radiological material to vaults due to improperly set overflow tube height, resulting in inadequately stabilized plutonium oxide and pressurized can (rupture in vault)	S1*	F3
K (cont'd)	08.04.12/1 08.04.12/2	Release of radiological material to vaults due to improperly set heater controller or failure, resulting in inadequately stabilized plutonium oxide and pressurized can (rupture in vault)	S1*	F3

Table A-4. Plutonium Finishing Plant Laboratory Prototype Calciner S1*, S2 Hazards by Accident Groups

Acc Group	Node /Item ID	General Hazardous Event Considered	Cons Cat	Freq Cat
	11.02/1	Rupture of overpack container in storage vault due to overpressurization of canister (low temperature or short residence time in calciner, incorrect LOI results), resulting in inadequately stabilized plutonium	S1*	F2
Natural Phenomena Initiator: Seismic Event, Ash Fall, and High Wind				
NPH	08.16.00/01/02 08.16.03/04/05	Release of plutonium to room through failed glovebox, windows, seals, and penetrations due to seismic event, resulting in exposure to onsite personnel	S2	F2
	08.16.06/07	Release of caustic from drum to Room 188 due to seismic event toppling of drum, resulting in burns to workers	S1*	F2

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Table A-5

Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
01.00	G	Move bottle drum into Room 188	Worker injury-trips/falls, pallet lowered onto toes, injury to hands, etc.	Human error	Minor worker injury		Use of leather gloves protect hands Safety inspections eliminate tripping hazards	S1	F3	Safety shoes not required
01.01	J	Move bottle drum into Room 188	Floor paint chipped and contamination exposed with sliding drum or if drum toppled	Human error - Sliding of bottle drum on floor	Potential worker contamination	Drum design minimizes likelihood of toppling	Radiation control program PPE & step off pad procedure prevent spread of contamination from area Yellow paint identifies past contamination areas Drum handled by two people	S1	F2	I beams on bottom of drum make low center of gravity
01.02	J	Move bottle drum into Room 188	Drum toppled during handling resulting in contamination of room air	Human error	Spill of solution from bottle into bag; potential contamination of interior of drum if bag ruptures Potential worker exposure when drum righted and lid opened to remove bottle Damage to equipment bag sealer	Drum design minimizes likelihood of toppling	Worker uses respiratory protection when drum opened	S1*	F2	Some bottles have bags that are two to three year old Planned/stored materials have been in drums in Room 236 for years and poses hydrogen accumulation hazard Opening drums with potential hydrogen hazard are not covered in this hazard analysis
01.03	C	Move bottle drum into Room 188	Glovebox gloves pulled off or torn during drum movement	Drum moved too close to glovebox with gloves pulled out contacting drum with mounting ring	Glovebox loss of confinement; potential spread of contamination to room air Worker contamination	Room CAM to detect airborne contamination Glovebox ventilation system (E-4) maintains negative pressure and confinement velocity across breached glove E-3 ventilation system and filters mitigate release to the environment	Air sample taken, analyzed, and approved before respiratory protection removal	S1*	F3	Respiratory protection currently not required by procedure but done out of convenience
01.04a	I	Move bottle drum into Room 188	Drum contacts caustic drum or transfer line resulting in caustic spill or leak	Human error	Caustic drum knocked over Spill of caustic solution	Safety shower in room (no eye wash in room)	Goggles used if not using respiratory protection Spill pig around drum Plugged floor drain prevents draining of caustic into waste system	S1*	F2	Respiratory protection currently not required by procedure but done out of convenience Spill pig is a sock of absorbent Plugged floor drain
01.04b	I	Move bottle drum into Room 188	Drum contacts caustic drum or transfer line resulting in spray leak	Human error	Spray leak into room 188 and worker exposure to caustic aerosol Potential damage to transfer line during transfer	Safety shower in room (no eye wash in room) Plastic sleeve around caustic line knocks down spray leak	Goggles used if respiratory protection not available	S1*	F3	Respiratory protection currently not required by procedure but done out of convenience Spill pig is a sock of absorbent Plugged floor drain
02.00	I	Move replacement drum of caustic into Room 188	Handling accident results in breach of drum	Drum punctured by drum hand truck, dropped or run into	Spill of caustic to floor, worker exposure to caustic aerosol and worker burns (see 1.04a/b)	Safety shower in room (no eye wash in room)	Bung closed when drum moved Chemical hygiene program Worker training and procedure Goggles used if respiratory protection not available Safety shoes and shoe covers protect feet	S1*	F2	

Table A-5

Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
02.01	C	Move replacement drum of caustic into Room 188	Pull or tearing of glove off glovebox during down movement	Caustic drum moved too close to glovebox with gloves inverted or contact with drum mounting ring	Glovebox loss of confinement; potential spread of contamination to room air Worker contamination	Room CAM to detect airborne contamination Glovebox ventilation system (E-4) maintains negative pressure and confinement velocity across breached glove E-3 ventilation system and filters mitigate release to the environment	Repiratory protection used during drum handling Air sample taken, analyzed, and approved before respiratory protection removal	S1*	F3	Respiratory protection currently not required by procedure but done out of convenience
02.02	I	Remove/install caustic pump in caustic drum	Worker chemical burn	Spill of residual sodium hydroxide from tubing or pump	Worker injury		Personal protective equipment Chemical hygiene program	S1	F3	
03.00/1	J	Open plutonium nitrate bottle drum	Pinching of finger/gloves when opening drum, radiological aerosol/particulate release when drum opened	Human Error	Breach of protective barrier against radiological contamination Worker injury Worker exposure to radiological material		Leather gloves RCT survey after opening drum Worker uses respiratory protection Air sample taken, analyzed, and approved before respiratory protection removal RCT surveying Visual check for moisture in drum	S1	F3	S1 based on potential minor worker plutonium contamination
03.00/2	J	Open plutonium nitrate bottle drum	Radiological aerosol/particulate release when drum opened	Leak from bag during storage in drum Degradation of bag during long term storage of bottle in drum Bag failure due to gas buildup (radiolytically generated hydrogen, oxygen, & helium)	Breach of protective barrier against rad contamination Worker exposure to radiological material		Leather gloves RCT survey after opening drum Worker uses respiratory protection Air sample taken, analyzed, and approved before respiratory protection removal RCT surveying Visual check for moisture in drum	S1	F3	S1 based on potential minor worker plutonium contamination
03.01/1	D2	Open plutonium nitrate bottle drum	Hydrogen release and potential burn when opening drum	Hydrogen accumulation in plutonium nitrate drum from radiolysis (only applies to bottles stored long term) Hydrogen ignited due to static or mechanical spark	Hydrogen burn and release of radiological material to room air Worker injury	E-3 ventilation system & filters mitigate release to the environment	Grounding strip on drum Nonsparking tools used to open drum Cloth coveralls are static resistant Modesty clothing under whites (to minimize attracting radon and minimize static buildup) Labeling and paperwork to identify drums with potential hydrogen hazard	S1*	F2	Definition of acceptable storage time of drums needed to preclude flammable gas buildup Nitric oxides from radiolysis provides oxidizer in hydrogen burn
03.01/2	I	Open plutonium nitrate bottle drum	Nitric oxide release when opening drum	Radiolysis of nitric acid solution - Incorrect drum containing bottle stored long term brought into lab due to human error	Worker exposure to nitric oxide vapors			S1*	F2	

Table A-5

Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
03.02/1	J	Remove bagged bottle of plutonium nitrate from drum and load into glovebox 188 through airlock	Bag breach during handling	Bottle dropped or bag torn during handling	Release of contamination and worker exposure Chemical burn to operator & potential skin contamination	Vent in bottle is 1/16 in which minimizes release of liquid into bag	Worker uses respiratory protection during load in of bottle into glovebox Air sample taken, analyzed, and approved before respiratory protection removal Personal Protective Equipment No exposed skin Bottle is double bagged minimizing the likelihood of release	S1	F3	S1 based on potential minor worker plutonium contamination
03.02/2	F2	Remove bagged bottle of plutonium nitrate from drum and load into glovebox 188 through airlock	Bag breach during handling	Bottle dropped or bag torn during handling	Hydrogen release & burn	Vent in bottle is 1/16 in which minimizes release of liquid into bag	Worker uses respiratory protection during handling of bottle Air sample taken, analyzed, and approved before respiratory protection removal Personal Protective Equipment No exposed skin Bottle is double bagged minimizing likelihood of release Vent in bottle and horsetail vents in bags allow diffusion of hydrogen out of bag and bottle, limiting hydrogen accumulation	S1*	F1	Highly unlikely event due to diffusivity of hydrogen in air No obvious ignition source in this accident Worker contamination
03.03	C	Remove bagged bottle of plutonium nitrate from drum and load into glovebox 188 through airlock	Loss of glovebox confinement due to open airlock	Inner & outer airlock doors open at same time due to human error	Spread of Glovebox contamination to room air with potential worker uptake	Glovebox ventilation system (E-4) sized to maintain negative pressure and confinement velocity across open doors E-3 ventilation systems and filters mitigates release to environment Room CAM to detect airborne contamination	Worker uses respiratory protection during load in of bottles into glovebox Air sample taken, analyzed, and approved before respiratory protection removal Procedure ensures only one door open at a time	S1*	F2	S1* based on potential worker exposure to airborne plutonium
03.04	J	Remove bagged bottle of plutonium nitrate from drum and load into glovebox 188 through airlock	Breach of bags encasing bottle during insertion into airlock resulting in contamination spread	Bags torn on corner of door during load into airlock	Increased contamination of airlock Potential contamination of worker	Glovebox ventilation system maintains confinement velocity across airlock door	Worker uses respiratory protection Air sample taken, analyzed, and approved before respiratory protection removal Training and procedures	S1	F3	S1 based on potential minor worker plutonium contamination
03.05	C	Remove bagged bottle of plutonium nitrate from drum and load into glovebox 188 through airlock	Glove breach during transfer of bottle from airlock into glovebox	Glove torn on inner airlock door	Worker injury and contamination of workers Airborne release through breached glove with workers uptake	E-4 ventilation maintains confinement velocity across breach in glove Airlock door corners are rounded Room CAM E-3 ventilation system	Worker uses respiratory protection Air sample taken, analyzed, and approved before respiratory protection removal Personal protective equipment	S1*	F3	S1* based on potential operator plutonium contamination
04.00/1	A2	Remove bags from bottle and load solution into feed tank	Breach of glove	Glove cut by scissors (see above 3.05)	Increased contamination levels in glovebox Increased exposure to workers during cleanup and operations	6" open top on feed tank Glovebox and E-4 ventilation system confines aerosols generated due to splatter in the spill		S1	F3	S1 based on ALARA concerns in recovering from event

Table A-5

Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
04.00/2	B	Remove bags from bottle and load solution into feed tank	Solution spilled inside glovebox	Bottle dropped or feed pump tank missed during fill process Lid left on tank during fill process	Increased contamination levels in glovebox Increased exposure to workers during cleanup and operations	6" open top on feed tank Glovebox and E-4 ventilation system confines aerosols generated due to splatter in the spill		S1	F3	S1 based on ALARA concerns in recovering from event
04.01	D1	Remove bags from bottle and load solution into feed tank	Hydrogen release from bag or bottle when opened	Radiolysis of nitric acid solution in bottle Radiolysis of plastic bottle & bags	Potential ignition of hydrogen from static or mechanical spark Rupture of bag Minor pressurization of glovebox	Glovebox confinement boundary and E-4ventilation system confine release Glovebox ventilation system dilutes hydrogen concentration		S1*	F2	Failure of glovebox not expected due to small quantity of hydrogen expected in bottle or bag Need acceptance criteria for bottles with respect to storage length
04.02	D1	Remove bags from bottle and load solution into feed tank	Incompatible chemical (organic) added to feed tank	Methonol or other organic solution loaded into glovebox and poured into feed tank by mistake - cleaning or drying solution vs plutonium-bearing solution poured into tank	Violent reaction in feed tank and potential fire Flammable gas burn in the calciner Pressurization of glovebox & potential damage to glovebox confinement boundary	E-3 ventilation system and HEPA filters mitigate release to environment Glovebox contamination boundary and E-4 ventilation system confine release Limited flow rate of calciner feed pump limits consequences of burned in calciner Room CAM	Light color of solution indicates wrong material Labeling of containers and lab results to identify compatible solutions Test plan: chemical safety program	S1*	F2	S1* based on potential operator plutonium contamination
04.03	B	Remove bags from bottle and load solution into feed tank	Incompatible chemical (caustic) added to feed tank	Caustic plutonium bearing solutions loaded into glovebox and poured into feed tank	Splatter and boiling of solution in feed tank increasing contamination level of glovebox Formation of mastic in calciner causing plugging of calciner Seizing up of agitator Increased worker dose in cleaning out calciner	E-3 ventilation system and HEPA filters mitigate release to environment Glovebox Confinement boundary and E-4 ventilation system	Labeling of containers and lab results to identify compatible solutions Test plan: chemical safety program	S1	F2	Caustic salts melt before they decompose
05.00	B	Startup calciner system, turn on vacuum before pressurized air then agitator and heaters	Pressurized calciner	Vacuum not turned on before pressurized air or not turned on at all	Release of plutonium dust into glovebox through relief cap Increased worker exposure due to increased contamination level in glovebox	Pressure relief cap prevents failure of calciner Glovebox and E-4 ventilation system confine release	Training and procedures Vacuum system gauges indicate operating vacuum By procedure vacuum gauges are checked before turning on pressurized air	S1	F3	S1 based on ALARA concerns in recovering from event
05.01/1	A2	Startup calciner system turn on vacuum before pressurized air then agitator and heat	Flooding of calciner	Feed inadvertently turned on early (before calciner ready at operating pump)	Plugging of nozzle & calciner, seizing of agitator (process delay) Overflow of solution, plutonium oxide, and plutonium nitrate salts into collection jar	Glovebox confinement boundary & E-4 ventilation system confine release Interlock prevents turning on feed pump before calciner wall is at 700 C	Procedure outlines general sequence for starting up calciner	S1	F3	
05.01/2	A2	Startup calciner system turn on vacuum before pressurized air then agitator and heat	Flooding of calciner	Feed inadvertently turned on early (before calciner ready at operating pump)	Overflow of solution, plutonium oxide, and plutonium nitrate salts into collection jar	Glovebox confinement boundary & E-4 ventilation system confine release Interlock prevents turning on feed pump before calciner wall is at 700 C	Procedure outlines general sequence for starting up calciner	S1	F3	S1 based on ALARA concerns in recovering from event
06.00	E	Bag out empty bottle or waste	Criticality violation	First bottle not bagged out before second bottle loaded in Waste bags not made into noncontainers (cut up and rolled up) due to human error	Potential criticality		Procedures & training Criticality posting Criticality specifications	S1*	F1	No criticality controls for frequency estimates See criticality hazards analysis and CSER for glovebox 188-1

Table A-5

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Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
06.01	F1	Bag out empty bottles, bags or waste	Fire in glovebox	Accumulation of waste bags, ice cream cartons, and other flammable waste in proximity to hot surfaces of calciner or ignition of accumulated combustibles due to electrical short	Damage to glovebox confinement boundary (burn through of bag out ports melting of plastic panels) Release of radiological material to room 188 air; worker inhalation of rad particles	Heat shields around calciner prevent ignition of combustibles Glovebox high temperature indicator and alarm	Combustible loading limit for glovebox Bayonet equipped, portable, dry chemical fire extinguisher available Waste bags are staged at end of glovebox away from calciner Housekeeping procedures	S1*	F2	Worker contamination
06.02	C	Bag out empty bottle or waste	Loss of glovebox confinement	Bag torn or pulled off glovebox during bag out Bag not properly sealed	Worker uptake of airborne contamination	E-3 ventilation system and filters mitigate release to the environment CAM alerts workers to presence of airborne contamination in room 188	Workers use respiratory protection during bag outs	S1	F3	Contamination spread outside of glovebox
06.03	C	Bag out empty bottle or waste	Contamination release into room	Bagged bottle dropped to floor and ruptured Bag not properly horse tailed Bag torn during handling	Worker uptake of airborne contamination	E-3 ventilation system and filters mitigate release to the environment CAM alerts workers to presence of airborne contamination in room 188	Workers use respiratory protection during bag outs Air sample taken, analyzed, and approved before respiratory protection removal Bottle is double bagged before placing in drum RCT survey of first bag	S1	F3	
07.00	J	Load empty bottle back into drum, move drum out of lab	Contamination of drum exterior	Bag ruptured during handling	Spread of contamination from room 188	E-3 ventilation system filters mitigate release to environment	Double bag on bottle minimizes potential for spread of contamination to drum surfaces RCT survey of first bag RCT survey of drum before moving drum out of room Institutional rad con program Additional RCT survey in hallway	S1	F3	S1 based on potential minor worker plutonium contamination
08.00		Glovebox 188-1 Laboratory Prototype Calciner covered by Hazard and Operability Study						See Hazard and Operability Study in Table A-6 for hazards associated with laboratory calciner operations		
09.00/1	A2	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Pluggage of feed nozzle causes shutdown of process and feed pump damage on subsequent calciner run	Failure to flush feed line due to human error allows solids to build up in nozzle.	Feed pump damage due to deadheading Increased worker direct dose to clear plug and replace/repair pump	Glovebox and glovebox ventilation system confines release from cacliner and filters release before discharge to the environment	Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event
09.00/2	A2	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Pluggage of feed nozzle causes shutdown of process and feed pump damage on subsequent calciner run	Failure to flush feed line due to human error allows solids to build up in nozzle.	Pressurization of calciner during subsequent operation due to liquid surge when pluggage breaks loose, leading to release of plutonium particulate, nitric oxide gases and nitric acid vapor to the glovebox atmosphere	Glovebox and glovebox ventilation system confines release from cacliner and filters release before discharge to the environment	Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event

Table A-5

Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
09.01/1	C	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Incompatible chemical reaction in feed tank (e.g., methanol or caustic added by mistake)	Organic solvent (e.g., methanol) or caustic solution added to feed tank by mistake (human error)	Violent reaction in feed tank causing steam and gas releases to glovebox atmosphere resulting in pressurization of glovebox Worker contamination	Glovebox and glovebox ventilation system confine aerosols released from feed tank Glovebox ventilation system removes heat of reaction Three glovebox inlet HEPA filters allow overpressure to vent from glovebox without causing damage to the glovebox confinement boundary	Visual observation of incompatible reaction or polymer formation Labelling of chemical bottles and chemical safety program minimize likelihood of organic or caustic being substituted for plutonium nitrate solution Combustible loading limit and housekeeping practices limit fire to feed tank only	S1*	F2	S1* based on potential worker plutonium contamination
09.01/2	F1	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Incompatible chemical reaction in feed tank (e.g., methanol added by mistake)	Organic solvent (e.g., methanol) solution added to feed tank by mistake (human error)	Potential fire in feed tank when methanol added	Glovebox and glovebox ventilation system confine aerosols released from feed tank Glovebox ventilation system removes heat of reaction Three glovebox inlet HEPA filters allow overpressure to vent from glovebox without causing damage to the glovebox confinement boundary Glovebox limited supply water bottle fire suppression system Building fire suppression system to limit fire spread should glovebox be breached	Visual observation of incompatible reaction or polymer formation Labelling of chemical bottles and chemical safety program minimize likelihood of organic or caustic being substituted for plutonium nitrate solution Bayonet equipped, dry chemical fire extinguisher in hallway outside room 188 for extinguishing small fire Combustible loading limit and housekeeping practices limit fire to feed tank only	S1*	F2	S1* assumes breach of glovebox with worker contamination
09.01/3	B	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Incompatible chemical reaction in feed tank (e.g., caustic added by mistake)	Caustic solution added to feed tank by mistake (human error)	Spattering of radioactive aerosols into the glovebox atmosphere	Glovebox and glovebox ventilation system confine aerosols released from feed tank Glovebox ventilation system removes heat of reaction Three glovebox inlet HEPA filters allow overpressure to vent from glovebox without causing damage to the glovebox confinement boundary	Visual observation of incompatible reaction or polymer formation Labelling of chemical bottles and chemical safety program minimize likelihood of organic or caustic being substituted for plutonium nitrate solution	S1	F2	S1 based on ALARA concerns in recovering from event
09.01/4	E	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Incompatible chemical reaction in feed tank (e.g., caustic added by mistake)	Organic solvent (e.g., methanol) or caustic solution added to feed tank by mistake (human error)	Plutonium polymer formation in feed tank, if caustic added, causing potential criticality specification violation	Feed tank designed as critically safe geometry	Visual observation of incompatible reaction or polymer formation Labelling of chemical bottles and chemical safety program minimize likelihood of organic or caustic being substituted for plutonium nitrate solution	S1	F2	See CSER for prototype calciner operation for controls to prevent criticality from polymer formation) S1 based on ALARA concerns in recovering from event
09.02	I	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Acid bottle dropped outside glovebox during load in	Human error	Worker chemical burns and exposure to nitric oxide gases or nitric acid fumes		Personal protective equipment Worker training and procedures Test plan (chemical safety)	S1*	F3	S1* based on potential worker exposure to toxic chemical
09.03/1	C	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Breach of Glovebox confinement boundary	Bottle pushed all the way through sphincter port without bottle or carton trailing	Contamination spread from glovebox to room air Inhalation uptake by workers	Room CAM Sphincter seal design Glovebox ventilation system maintains negative pressure in glovebox and confinement velocity across open sphincter port or open airlock door	Worker training and procedures Workers use respiratory protection during load in/load out operations	S1*	F2	S1* based on potential worker plutonium contamination

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Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
09.03/2	C	Load flush solution into glovebox and flush calciner feed line (after completion of previous calciner run)	Breach of Glovebox confinement boundary	Both airlock doors opened at the same time during load in of bottle (if airlock used instead of sphincter seal)	Contamination spread from glovebox to room air Inhalation uptake by workers	Room CAM Spinster seal design Glovebox ventilation system maintains negative pressure in glovebox and confinement velocity across open sphincter port or open airlock door	Worker training and procedures Workers use respiratory protection during load in/load out operations through air lock	S1*	F2	S1* based on potential worker plutonium contamination
10.00	B	Transfer collection jar contents to slip lid can	Spill of plutonium oxide to glovebox floor	Jar or can dropped or spilled Can overfilled	Entrainment of plutonium oxide particulate into glovebox air Increased contamination level of glovebox causing increased direct dose to workers	Glovebox and Glovebox ventilation system confine particulate release E-4 ventilation system HEPA filters mitigate release to environment	Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event
11.00	C	LOI sampling (includes taking sample, bagging out sample vial, and performing LOI test)	Breach in glovebox confinement boundary	Port bag torn during bagout Port bag not properly heat sealed or horsetailed	Contamination spread from glovebox to room air Inhalation uptake by workers	Room CAM Glovebox ventilation system maintains negative pressure in glovebox and confinement velocity across open bag port	Worker training and procedures Workers use respiratory protection during load in/load out operations	S1*	F2	S1* based on potential worker plutonium contamination
11.01	J	LOI sampling (includes taking sample, bagging out sample vial, and performing LOI test)	Sample vial dropped after bagout	Human error	Potential breakage of sample bottle and release of radioactive material from bottle into room 188	Room CAM	Worker training and procedures Two bags applied during load out limit potential contamination spread to room air Workers use respiratory protection during load in/load out operations	S1	F3	S1 based on potential minor worker plutonium contamination
11.02	K	LOI sampling (includes taking sample, bagging out sample vial, and performing LOI test)	Rupture of overpack container in storage vault due to overpressure	Inadequate stabilization of plutonium oxide in calciner due to low temperature or short residence time causes buildup of hydrogen in the storage container - Incorrect LOI results give false low reading of water content in plutonium oxide - LOI test not performed - LOI samples mixed up or wrong can sent to vault	Rupture of container in storage vault (lab vault or 2736-ZB vault) with potential worker inhalation of plutonium particles on entry to storage vault	Vault ventilation system filters release to the environment Vault CAM warns of airborne contamination before entry into vault	Worker training and procedures LOI testing to detect inadequately stabilized material Cans not moved to ZB vaults until LOI test results come back acceptable Overpacked slip lid cans temporarily stored in lab vault pending LOI test results and are periodically monitored for bulging	S1*	F2	S1* based on potential worker plutonium contamination
12.00	A1	Weigh can, tape lid on, and reweigh can	No significant hazards identified for this step							Weighing errors pose plutonium accountability problems only
13.00	C	Bagout filled slip lid can	Breach in glovebox confinement boundary	Port bag torn during bagout Port bag not properly heat sealed or horsetailed	Contamination spread from glovebox to room air Inhalation uptake by workers	Room CAM Glovebox ventilation system maintains negative pressure in glovebox and confinement velocity across open bag port	Worker training and procedures Workers use respiratory protection during load in/load out operations	S1*	F2	S1* based on potential worker plutonium contamination

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Plutonium Finishing Plant
Laboratory Prototype Calciner PHA

Item ID	Acc Group	Activity Operation	Hazardous Event	Causes	Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
13.01	J	Bagout filled slip lid can	Can dropped after bagout	Human error	Potential release of radiological material to room air (if bag breached by drop) Worker contamination	Room CAM	Worker training and procedures Load out bag limits potential contamination spread to room air Workers use respiratory protection during load in/load out operations Slip lid is taped on before bagout Lid is expected to remain on during drop, preventing significant release from can	S1*	F2	S1*/F2 assumes failure of slip lid can and rupture of both bags
14.00/1	J	Canning of bagged slip lid can into overpack (on counter in Room 188)	Contamination spread beyond room 188 due to Inadequate sealed overpack	Overpack inadequately sealed due to human error, canning machine malfunction, or plastic bag caught under lip of seal	Potential spread of contamination to clean area of plant (hallway outside room 188 where secondary overpack applied) Potential skin contamination and minor inhalation uptake of plutonium by workers	Room CAM to detect airborne contamination	Contamination spread from slip lid can unlikely due to double bagging and taped slip lid RCT survey of cans before movement out into hallway RCT survey and self surveys of workers (step off pad procedure)	S1	F3	S1 based on potential minor worker plutonium contamination
14.00/2	A2	Canning of bagged slip lid can into overpack (on counter in Room 188)	Contamination spread beyond room 188 due to Inadequate sealed overpack	Overpack inadequately sealed due to human error, canning machine malfunction, or plastic bag caught under lip of seal	Programmatic Impact - Overpacked can would have to be bagged back into glovebox and reopened increasing likelihood of worker injury and contamination due to puncture hazards during cutting of bag and crushing of overpack cans to make non-containers	Room CAM to detect airborne contamination	Contamination spread from slip lid can unlikely due to double bagging and taped slip lid RCT survey of cans before movement out into hallway RCT survey and self surveys of workers (step off pad procedure)	S1	F3	
15.00	J	Second overpack applied on table in hallway	Contamination of workers transporting package to storage vault	Inadequately sealed inner and outer overpack due to human error or canning machine malfunction (assumes inside of first overpack container is contaminated	Contamination of workers handling transporting package to storage vault		Contamination spread from slip lid can unlikely due to double bagging and taped slip lid RCT survey of cans before movement out into hallway RCT survey and self surveys of workers (step off pad procedure)	S1	F2	S1 based on potential minor worker plutonium contamination
16.00	A1	Transfer overpacked can to vault	Packaged dropped or otherwise impacted during transport to vault	Package dropped during handling prior to placement in transport wagon Transport wagon overturned during transport	No significant consequence expected due to sturdy multiple overpack design and low drop height	Sturdy multiple overpack design will survive credible impacts without failing	Worker training and procedures	S0	F3	
16.01	E	Transfer overpacked can to vault	Criticality specification violation during transport to vault	Too many cans placed in transport wagon Transport wagon not used in violation Wagon pulled too close to other sources of fissile material	Potential criticality with worker exposure to ionizing radiation and fission product gases	Wagon design ensures adequate spacing of containers and minimizes likelihood of containers being spilled together in unsafe geometry	Worker training and procedures Criticality specification requirements	S1*	F1	See appropriate CSER for hazards associated with transportation of plutonium oxide containers.

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table A-6

Plutonium Finishing Plant
Laboratory Prototype Calciner HazOp

Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.01		Feed Tank									
08.01 00	B	Feed Tank	Lag storage to support continuous calciner operation Safely contain plutonium nitrate solution	Level/low	Feed tank rupture (spurious tank failures, seal failures, etc)	Splatter release of aerosols to glovebox atmosphere Contamination of glovebox equipment	Glovebox criticality drain Glovebox structure E-4 ventilation system and filters maintain confinement in event of spill	Operator surveillance of level in glass tank	S1	F3	S1 ranking for contamination of glovebox equipment and increased worker exposures Criticality requires several tank failures (criticality assumed to be extremely unlikely)
08.01.01	B-XREF	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/low	Tank leak or rupture	See node for feed pump tank for Level/low (Node 8.01.00)			S1	F3	
08.01.02	A2	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/low	Human error by not refilling tank when required	Programmatic upsed Pump Damage			S1	F3	S1 based on increased work inside of glovebox by worker
08.01.03	B	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/high	Human error by overfilling from feed pump tank (transfer at wrong time while tank has material present - 4 L tank supplying into partially full 10 L tank)	Vent overflows to floor of glovebox	Glass tank permits visual surveillance of level	Operator surveillance of feed tank level Procedures for filling and draining feed receipt tank and feed pump tank	S1	F3	S1 based on splatter release to glovebox atmosphere
08.01.04	A2-XREF	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/other than	Phase separation--presence of separable organic layer	Programmatic impact Operation shut down if organic noticed See Calciner Injector Nozzle (Node 8.03.02 - 8.03.03)			S0	F3	
08.01.05a	A2	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/other than	Phase separation: plutonium polymerization/precipitation due to tank pH greater than 2 (nitric acid solution too dilute)	Programmatic upset		Procedures governing mixing of materials in HC-227S Operator surveillance of feed receipt tank solids level Blending and sampling in glovebox HC-227S	S0	F3	S1/F3 for programmatic upset requiring operator exposure to correct Incorrect pH could be caused by using nitric acid solution that's too dilute or flushing transfer line or tanks with water
08.01.05b	E	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/other than	Phase separation: plutonium polymerization/precipitation due to tank pH greater than 2 (nitric acid solution too dilute)	Potential criticality spec violation due to accumulation of solids in the tank Potential criticality if layer allowed to build up too deep	CAS (criticality alarm system)	Procedures governing mixing of materials in HC-227S Operator surveillance of feed receipt tank solids level Blending and sampling in the HC-227S glovebox Lab Analysis Results	S1*	F1	S1*/F1 for criticality

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Laboratory Prototype Calciner HazOp

Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.01.05c	E-XREF	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Level/other than	Phase separation - plutonium polymerization/precipitation due to incorrect solution pH range.	See phase separation for feed pump tank (Node 8.01.05a & 8.01.05b)			S1*	F1	
08.01.06	A2	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Pressure/high	Off gassing chemical reaction that exceeds vent capacity (caused by accidental mixing of incompatible materials)	Potential for rupture of tank and splatter release to glovebox floor Nitric oxides release to glovebox atmosphere	Glovebox outlet filters and E-4 ventilation system Glovebox sump level alarm Feed Tank Lid will lift off before 20 psi rupture pressure	Solution makeup, sampling, and transfer setup procedures for the HC-227S glovebox Operator surveillance of feed receipt tank	S0	F3	
08.01.07a	B	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Temperature/high	Heat of reaction due to addition of concentrated nitric acid to water from prior flush or water added to concentrated nitric acid during a flush	Potential boiling with steam generation and release of aerosols to vent system and glovebox atmosphere	Tanks made of Pyrex glass which is resistant to temperature shock Glovebox and E-4 ventilation system maintain secondary confinement	Procedures for the makeup and use of flush solutions Blending and sampling procedures in HC-227S	S0	F3	S0 based on release of uncontaminated releases to glovebox atmosphere
08.01.07b/1	B	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Temperature/high	Heat from organic-nitrate reaction (requires organic, e.g. methanol, containing solution to be mixed with highly acidic nitric acid solution)	Production of nitric oxides Possible increase in particulate releases from tank system		Training and procedures	S1	F3	Not expected to result in large temperature increase in glovebox S1 based on increased exposure to workers
08.01.07b/2	D1	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Temperature/high	Heat from organic-nitrate reaction (requires organic, e.g. methanol, containing solution to be mixed with highly acidic nitric acid solution)	Possible production of small quantities of flammable gasses	Sturdy glovebox design (metal walls, glass wire mesh windows)	Training and procedures	S0	F1	Not expected to result in large flammable gas concentration in glovebox
08.01.08/1	A1	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Plutonium concentration/ high	Makeup error at source of plutonium nitrate - Sampling error	Programmatic upset		Blending and sampling procedures in 188-1 Lab Analysis for plutonium content	S0	F3	
08.01.08/2	E	Feed Tank	Lag storage for feed to calciner Safely contain solution Provides net positive suction head for feed pump	Plutonium concentration/ high	Makeup error at source of plutonium nitrate - Sampling error	Potential criticality or CPS violation	Criticality alarm system (CAS) Criticality drains for spills Six inch diameter tank geometrically favorable to criticality prevention	Criticality prevention specifications Blending and sampling procedures in 188-1 Lab Analysis for plutonium content	S1*	F1	Criticality highly unlikely given tank geometry
08.02		Feed Pump									
08.02.01/1	A2	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/no	Supply valve from feed pump tank closed Feed tank empty	Programmatic upset Pump damage Overheating of nozzle Potential boiling of plutonium nitrate solution in material injection nozzle (corrodes and plugs nozzle)	Pressurized air prevents plugging of nozzle	Worker may notice feed tank level not decreasing (visual) or product collection jar level not increasing	S1	F3	S1 due to increased exposure to worker during pump repair

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Plutonium Finishing Plant
Laboratory Prototype Calciner HazOp

Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.02.01/2	A1	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/no	Failed pump	Programmatic upset Pump damage Overheating of nozzle Potential boiling of plutonium nitrate solution in material injection nozzle (corrodes and plugs nozzle)	Pressurized air prevents plugging of nozzle	Worker may notice feed tank level not decreasing (visual) or product collection jar level not increasing	S0	F3	
08.02.01/3	A1	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/no	Loss of power Pump shutdown from various interlocks Loss of Agitation Low calciner wall temperature Loss of air pressure	Programmatic upset Pump damage Overheating of nozzle Potential boiling of plutonium nitrate solution in material injection nozzle (corrodes and plugs nozzle)	Pressurized air prevents plugging of nozzle	Worker may notice feed tank level not decreasing (visual) or product collection jar level not increasing	S0	F3	
08.02.02/1	A1	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/low	Improperly set pump stroke	Programmatic impact Low oxide output from calciner	Air feed to nozzle cools nozzle and prevents plugging via solids	Worker may notice feed tank level not decreasing (visual) or product collection jar level not increasing	S0	F3	
08.02.02/2	A2	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/low	Partial nozzle plugging Pump wear	Pump damage	Air feed to nozzle cools nozzle and prevents plugging via solids	Worker may notice feed tank level not decreasing (visual) or product collection jar level not increasing	S1	F3	S1 due to increased exposure to worker during pump repair
08.02.03/1	K	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/high	Improperly set pump stroke	Inadequate mixing of plutonium nitrate solution fed to calciner Inadequately stabilized plutonium oxide powder due to low residence time in calciner; Potential overpressurization of site convenience cans during handling or in storage	E-3 vent system and filters if can ruptures in Zone 3 area 2736Z vent system and filters if can rupture occurs in vaults Pressure relief cap prevents over pressurization E-4 vent system and filters and glovebox structure maintain confinement Vacuum System Vault CAM	LOI testing of plutonium oxide powder before packaging in product can	S1*	F3	S1*/F3 for rupture in occupied zone 3 area
08.02.03/2	B	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Flow/high	Improperly set pump stroke	Pressurization of calciner release of plutonium oxide to glovebox Plugging of calciner	E-3 vent system and filters if can ruptures in Zone 3 area 2736Z vent system and filters if can rupture occurs in vaults Pressure relief cap prevents over pressurization E-4 vent system and filters and glovebox structure maintain confinement Vacuum System Vault CAM	LOI testing of plutonium oxide powder before packaging in product can	S1	F3	S1/F3 is based on increased exposure to worker during clean up

Table A-6

Plutonium Finishing Plant
Laboratory Prototype Calciner HazOp

Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.02.04/1	A1	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Temperature/high	Electric motor burnout due to deadhead conditions Electric motor spurious failure from wiring fault	Programmatic impact Pump or motor failure	None	Worker training and procedures	S0	F3	
08.02.04/2	F1	Feed Pump	Supply plutonium nitrate to calciner injector nozzle at required flow and pressure	Temperature/high	Electric motor burnout due to deadhead conditions Electric motor spurious failure from wiring fault	Programmatic impact Possible fire in glovebox from overheated electric motor Potential loss of glovebox confinement and spread of contamination to room 188	Glovebox fire suppression system (Limited volume water bottle) E-3 ventilation system and HEPA filters limit release to atmosphere through exhaust stack Sturdy glovebox design (metal walls, glass wire mesh windows)	Worker training and procedures for responding to fire in glovebox Test plan limits loading in glovebox Bayonet Fire Extinguisher	S1*	F3	Postulated fire is small due to glovebox design and limited combustible loading; glovebox is metal with fire resistant windows
08.03		Calciner Injector Nozzle									
08.03.00/1	B	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Nozzle plugging caused by scale buildup, cake formation, etc	Deadheaded feed pump (pump damage) Damage to agitator Potential injector nozzle and line heat up with pressurization of transfer line and liquid slug releases into calciner causing calciner pressurization and plutonium oxide releases through pressure relief cap	Nozzle equipped with clean out rod Pressurized air to nozzle minimizes plugging	Worker monitoring of feed tank level	S1	F3	S1 based on ALARA concerns in increased exposure to workers
08.03.00/2	A1	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Pump stroke set to low	Programmatic impact - reduced production	Nozzle equipped with cleanout rod Pressurized air to nozzle minimizes plugging	Worker monitoring of feed tank level	S0	F3	
08.03.01	B	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Line leak/break between pump and injector	Release to glovebox floor; potential spray release Splatter or spray release of aerosols to glovebox atmosphere Elevated radioactive release through E-4 ventilation system Increased contamination of glovebox with increased dose to worker	Glovebox outlet HEPA filter mitigates potential release to the environment E-4 ventilation system and HEPA filters mitigate potential release to environment	Visual detection	S1	F3	S1 based on ALARA concerns in increased exposure to workers
08.03.02	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Feed line plugging caused by solids accumulation (e.g., plutonium precipitates or polymers if pH too high)	Programmatic impact; increased campaign duration Node 8.03.00		Visual monitoring of feed pump tank level	S0	F3	
08.03.03	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Pump failure due to equipment failure or electrical supply failure	Programmatic impact; increased campaign duration		Visual monitoring of feed pump tank level	S0	F3	
08.03.04	A1	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/low or no	Feed pump supply valve shut due to human error	Programmatic impact Pump damage due to dead heading		Visual monitoring of feed pump tank level Worker training and procedures	S0	F3	
08.03.05	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid flow/high	Feed pump stroke set too high	Node 8.02.02			S1	F3	S1 due to increased exposure to worker during pump repair

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.03.06	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Nozzle plugging	Programmatic impact; shutdown of calciner	Cleanout rod for cleaning out plug	Worker monitoring of critical parameters Worker training and procedures Plugging indicate by lack of pressure fluctuations in calciner	S0	F3	S1 for operator ALARA concerns from repair activities
08.03.07/1	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Loss of plant air supply (60 psi) Plugging of nozzle	Programmatic impact Plugging of feed nozzle due to powder from bed dropping into feed nozzle	Check valve in liquid feed line prevents backflow Interlock shuts off feed pump on loss of pressure in plant air supply (not effective for plugging case w/o loss of plant air) Cleanout rod for cleaning out plug	Rotameter in air line provides opportunity to visually detect backflow PAX announcement on loss of plant air	S0	F3	
08.03.07/2	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Loss of plant air supply (60 psi) Plugging of nozzle	Increased worker doses on recovery from event Backflow of plutonium nitrate solution into clean air supply	Check valve in liquid feed line prevents backflow Interlock shuts off feed pump on loss of pressure in plant air supply (not effective for plugging case w/o loss of plant air) Cleanout rod for cleaning out plug	Rotameter in air line provides opportunity to visually detect backflow PAX announcement on loss of plant air	S1	F3	
08.03.07/3	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Loss of plant air supply (60 psi) Plugging of nozzle	Increased worker doses on recovery from events Backflow of plutonium nitrate solution into air accumulator tank on filter blow back system Rupture of ceramic filters due to thermal shock Accumulator discharges unfiltered release from calciner into scrubber Plutonium contamination of scrubber Leakage of solution through seal nut of clean out rod	Check valve in liquid feed line prevents backflow Interlock shuts off feed pump on loss of pressure in plant air supply (not effective for plugging case w/o loss of plant air) Cleanout rod for cleaning out plug	Rotameter in air line provides opportunity to visually detect backflow PAX announcement on loss of plant air	S1	F3	
08.03.07/4	C	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Loss of plant air supply (60 psi) Plugging of nozzle	Worker contamination in other parts of the plant Potential spread of contamination to clean areas of plant due to leaks in plant air system after back flow	Check valve in liquid feed line prevents backflow Interlock shuts off feed pump on loss of pressure in plant air supply (not effective for plugging case w/o loss of plant air) Cleanout rod for cleaning out plug	Rotameter in air line provides opportunity to visually detect backflow PAX announcement on loss of plant air	S1	F2	S1 based on potential minor worker exposure to airborne plutonium
08.03.08/1	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Incorrectly set flow indicating controller	Plugging of feed due to powder from bed dropping into feed nozzle Backup of solution into feed line or valve not opened before operation	Check valve prevents back flow E-3 ventilation system and HEPA filters Cleanout rod for cleaning out plug	Rotameter in air line provides opportunity to visually detect back flow	S1	F3	
08.03.08/2	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/no	Air supply needle valve plugged or not opened	Plugging of feed due to powder from bed dropping into feed nozzle Backup of solution into air line	Check valve prevents back flow E-3 ventilation system and HEPA filters Cleanout rod for cleaning out plug	Rotameter in air line provides opportunity to visually detect back flow	S1	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.03.09	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/low	Incorrectly set flow via needle valve (human error)	Node 8.03.08	Node 8.03.08	Rotameter indicates proper flow rates Rotameter in air line provides opportunity to visually detect back flow	S0	F3	
08.03.10	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air flow/high	Failed open regulator on plant air supply combined with air system PRV failure	Design intent			S0	F3	Air supply limited by capacity of plant air supply
08.03.11	B-XREF	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid pressure/low	See nozzle liquid flow/low (Nodes 8.03.01 - 8.03.04)				S0	F3	
08.03.12	A2-XREF	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Liquid Pressure/high	See liquid flow/low and liquid flow/high (Node 8.03.05)				S0	F3	
08.03.13	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air pressure/low	Air supply needle valve plugged or not opened	Node 8.03.07			S1	F3	S1 based on ALARA concerns in recovering from event
08.03.14	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Air Pressure/high	Design Intent				S0	F3	
08.03.15	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Temperature/low	Design Intent				S0	F3	
08.03.16	A2	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Temperature/high	Low or no air flow can result in possible boiling in the injector (with cake formation and plugging) Plugging of feed due to powder from bed dropping into feed nozzle	Programmatic impact if disassembly of nozzle required to clear plug Back flow of solution into air supply system Node 3.07	Node 8.03.07	Node 8.03.07	S1	F3	S1 for increased worker exposures in recovering from leak or to clear plug
08.03.17	D1	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Feed composition/other than (other than plutonium nitrate)	Organics present in plutonium nitrate injected into 1000 C plutonium oxide bed	Flammable gas generation and possible ignition inside calciner; potential failure of calciner Release of plutonium oxide powder to glovebox atmosphere Potential pressurization of glovebox due to steam and hot particulates released from calciner vessel Potential glovebox damage due to pressurized release	Calciner pressure relief cap Sturdy glovebox design (metal walls, glass wire mesh windows) E-3 ventilation system and HEPA filters mitigation release to atmosphere	Procedures requires sampling in glovebox HC227S before plutonium nitrate is transferred bottles and brought into laboratory Worker surveillance of feed tank for separable layers	S1*	F2	Consequence related to type of organic and ignition energy release (needs calculation) S1* assumes significant contamination release to room and worker inhalation
08.03.18	D1	Calciner Injector Nozzle	Mix plutonium nitrate with air and feed entrained plutonium nitrate into calciner chamber in controlled manner	Feed composition/other than (other than plutonium nitrate)	Organics (lubrication oil from compressor) present in plant pressurized air injected into 1000 C plutonium oxide bed	Flammable gas generation and possible ignition inside calciner; potential failure of calciner Release of plutonium oxide powder to glovebox atmosphere Potential pressurization of glovebox due to steam and hot particulates released from calciner vessel Potential glovebox damage due to pressurized release	Calciner pressure relief cap Sturdy glovebox design (metal walls, glass wire mesh windows) E-3 ventilation system and HEPA filters mitigation release to atmosphere	Procedures requires sampling in glovebox HC227S before plutonium nitrate is transferred bottles and brought into laboratory Worker surveillance of feed tank for separable layers	S1*	F2	Consequence related to type of organic and ignition energy release (needs calculation) S1* assumes significant contamination release to room and worker inhalation

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04		Calciner Vessel									
08.04.00	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/no	Failure to charge powder bed prior to start of processing	Programmatic upset Cake formation, cement formation, plugging of calciner		Worker procedures for startup of the calciner Visually check overflow tube level collection jar status bed dumped RCT survey suggesting low calciner level	S1	F3	S1 based on ALARA concerns in recovering from event
08.04.01	K	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Powder bed Level/low	Overflow tube set to lowest level in previous run	Inadequate stabilization with potential for eventual rupture of storage container in storage Potential worker inhalation, dose on entry into vault	Vault ventilation and HEPA filters mitigate release to environment	LOI testing Procedures for operating calciner and operator training Vault sample before entry	S1*	F3	S1* based on operator exposure and injury from canister rupture during handling
08.04.02/1	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Product overflow tube set too high (potential for plugging tube) Loss of agitation allows buildup away from overflow tube Initial overcharge of calciner bed (double batching)	Ceramic filter plugging and potential calciner pressurization No product collected in jar Minor increased worker direct dose from additional plutonium in calciner	Calciner pressure relief device prevents catastrophic over pressurization Filter delta pressure monitoring Calciner delta pressure to atmosphere	Worker training and procedures Plutonium mass balances performed during processing Worker training	S0	F3	Calciner critically safe when completely full of plutonium oxide Six batches needed to fill up to the bottom of ceramic filters
08.04.02/2	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Level/high (powder)	Plugging of product over flow tube	Ceramic filter plugging and potential calciner pressurization No product collected in jar Minor increased worker direct dose from additional plutonium in calciner	Calciner pressure relief device prevents catastrophic over pressurization Filter delta pressure monitoring Calciner delta pressure to atmosphere	Worker training and procedures Plutonium mass balances performed during processing Worker training	S0	F3	Calciner critically safe when completely full of plutonium oxide Six batches needed to fill up to the bottom of ceramic filters

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04.03	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Plugged ceramic filters	Release of plutonium oxide into glovebox due to pressure relief cap being displaced	Filter delta pressure monitoring E-4 ventilation system and HEPA filters provide confinement Glove box provides confinement Back pulsing air	Worker training and procedures Worker monitors dP across ceramic filters (light actuates on high dP) Calciner delta pressure to atmosphere monitored by worker	S1	F3	S1 based on ALARA concerns in increased exposure to workers
08.04.04	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Pump stoke too large (large quantity of vapor generated)	Release of plutonium oxide into glovebox due to pressure relief cap being displaced	E-4 ventilation system and HEPA filters provide confinement Glove box provides confinement	Worker training and procedures Visual displacement of pressure relief cap Visual observation of steam release from calciner	S1	F3	S1 based on ALARA concerns for cleanup operations
08.04.05	D1	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Deflagration from injection of feed containing organics due to sampling or pretreatment errors	Release of plutonium oxide into glovebox due to pressure relief cap being displaced Release of plutonium oxide into glovebox Potential calciner damage	E-4 ventilation system and HEPA filters Sturdy glovebox design (metal walls, glass wire mesh windows) Glovebox provides confinement	Worker training and procedures Worker monitoring for separable layers in feed pump tank and feed tank Sampling to detect organics in HC-227S	S1*	F3	S1* based on potential to degrade glovebox confinement with worker contamination
08.04.06	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Filter pulse system failure allowing excess flow to ceramic filters Solenoid valve open to long	Release of plutonium oxide into glovebox due to pressure relief cap being displaced	Node 6.08 E-4 ventilation system and HEPA filters Glove box provides confinement	Worker training and procedures Visual Identification of steam relief from calciner	S1	F3	S1 based on ALARA concerns for cleanup operations

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04.07	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/high (positive or less negative)	Loss of or reduced vacuum due to: Plugging of vacuum line Vacuum line valved shut	Release of plutonium oxide into glovebox due to pressure relief cap being displaced	E-4 ventilation system and HEPA filters Glove box provides confinement Vacuum gauge	Worker training and procedures Visual identification of steam relief from calciner Less activity in scrubber Low system vacuum on system gauges	S1	F3	S1 based on ALARA concerns for cleanup operations
08.04.08	A1	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/low (excessive vacuum)	Pressure variation due to upset in plant vacuum system	No significant consequence identified			S0	F3	Vacuum controller when set to fully open in calciner results in 80" w.g. vacuum
08.04.09	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Pressure/low (excessive vacuum)	Pressure relief cap left on during calciner cool down (human error)	Back flow of scrubber solution into calciner vessel Pressurized release through relief cap due to flashing of scrubber solution Plugging of calciner with long term loss of production	E-4 ventilation system and glovebox maintain confinement Vent system filters minimize release through stack Inleakage through DPTs minimizes potential for draw back of material	Worker training and procedures	S1	F2	Back flow of scrubber solution is unlikely due to in leakage paths; Clean out rod cap seal Product collection jar leakage through seal area
08.04.10/1	C	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of calciner heater power supply (full on) caused by controller or thermocouple failure	Structural failure of calciner (partially melts) with spill of hot plutonium oxide to floor of glovebox Pressurization of glovebox due to heat released and flashed liquid, damage to glovebox and loss of confinement Plutonium oxide and nitric oxides released to room Structural degradation of calciner	Calciner over temperature interlock to heater elements Calciner temperature controller Glovebox and E-4 ventilation system reduces release consequences	Procedures for monitoring calciner temperature Multiple temperature elements located throughout calciner heater system read out on recorders monitored	S1*	F2	S1* due to loss of glovebox confinement (burn hole through bottom of glovebox or over pressurize glovebox) resulting in worker contamination Heater elements may short out and fail before melting of calciner occurs Calciner heaters operated at 80-90% At 100% calciner not expected to fail

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04.10/2	C	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of calciner heater power supply (full on) caused by software set point error, human error	Structural failure of calciner (partially melts) with spill of hot plutonium oxide to floor of glovebox Pressurization of glovebox due to heat released and flashed liquid, damage to glovebox and loss of confinement Plutonium oxide and nitric oxides released to room Structural degradation of calciner	Calciner over temperature interlock to heater elements Calciner temperature controller Glovebox and E-4 ventilation system reduces release consequences	Procedures for monitoring calciner temperature Multiple temperature elements located throughout calciner heater system read out on recorders monitored	S1*	F2	S1* due to loss of glovebox confinement (burn hole through bottom of glovebox or over pressurize glovebox) resulting in worker contamination Heater elements may short out and fail before melting of calciner occurs Calciner heaters operated at 80-90% At 100% calciner not expected to fail
08.04.11/1	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of heater power supply (full on) caused by controller or thermocouple failure	Increased vaporization of scrubber solution due to hotter gasses from overheated calciner resulting in nitric oxides, water vapor, and nitric acid vapor to vacuum system	Glovebox temperature indicator Calciner temperature interlock Calciner temperature controller	Procedures for monitoring calciner temperature Multiple temperature elements located throughout calciner heater system read out on recorders monitored	S0	F3	Postulated elevated nitric oxides release to stack
08.04.11/2	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/high	Control failure of heater power supply (full on) caused by software set point human error	Increased vaporization of scrubber solution due to hotter gasses from overheated calciner resulting in nitric oxides, water vapor, and nitric acid vapor to vacuum system	Glovebox temperature indicator Calciner temperature interlock Calciner temperature controller	Procedures for monitoring calciner temperature Multiple temperature elements located throughout calciner heater system read out on recorders monitored	S0	F3	Postulated elevated nitric oxides released to stack
08.04.12/1	K	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Start processing cycle before calciner up to temperature (human error)	Inadequate stabilization of plutonium oxide (if temperature above boiling point but not close to 1000 C) tential canister rupture in storage vault if inadequate stabilization not detected via LOI testing Worker contamination	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low E-3 ventilation system for mitigating releases inside storage vaults or other areas of PFP	LOI testing of plutonium oxide powder before canning	S1*	F3	S1* for potential storage can rupture in storage vault

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04.12/2	K	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Failure of heater controller Failure of heater elements	Inadequate stabilization of plutonium oxide (if temperature above boiling point but not close to 1000 C) tential canister rupture in storage vault if inadequate stabilization not detected via LOI testing Worker contamination	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low E-3 ventilation system for mitigating releases inside storage vaults or other areas of PFP	LOI testing of plutonium oxide powder before canning	S1*	F3	S1* for potential storage can rupture in storage vault
08.04.13/1	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Start processing cycle before calciner up to temperature (human error)	Programmatic upset Bed buildup in calciner vessel Cake or cement formation in calciner vessel, nozzle plugging, and seizing of calciner agitator	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low	Worker surveillance of feed pump level and product collection jar level	S0	F3	
08.04.13/2	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Failure of heater controller Failure of heater elements	Programmatic upset Bed buildup in calciner vessel Cake or cement formation in calciner vessel, nozzle plugging, and seizing of calciner agitator	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low	Worker surveillance of feed pump level and product collection jar level	S1	F3	S1 based on ALARA concerns in recovering from event
08.04.14/1	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Start processing cycle before calciner up to temperature (human error)	Programmatic impact - Increased worker exposure Flooding the calciner with liquid plutonium nitrate solution (if calciner bed temperature not substantially above solution boiling point) Overflow solution into vacuum sensing line Plugging of ceramic filters with plutonium oxide or precipitates Seized agitator from mud formation Cracked ceramic filters due to thermal shock Entrained plutonium nitrate aerosols carry over to scrubber Possible polymerization of plutonium in scrubber	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low	Worker observation of contaminants in scrubber vessel Worker observation of mud or liquid into collection jar Plugged filter indicated by high dP (light on control panel)	S1	F3	Collection bottle full in as little as 7.5 minutes (bottle assumed to be one half liter) Single batch to feed tank not enough to fill calciner up to vacuum line Increased worker dose involved with clean up

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04.14/2	E	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Incorrect setting of heater controller (human error) Start processing cycle before calciner up to temperature (human error)	Flooding the calciner with liquid plutonium nitrate solution (if calciner bed temperature not substantially above solution boiling point) Seized agitator from mud formation Accumulation of moderated plutonium mass in calciner poses criticality concern	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low	Worker observation of contaminants in scrubber vessel Worker observation of mud or liquid into collection jar Plugged filter indicated by high dP (light on control panel)	S1*	F1	Collection bottle full in as little as 7.5 minutes (bottle assumed to be one half liter) Single batch to feed tank not enough to fill calciner up to vacuum line Increased worker dose involved with worker clean up
08.04.14/3	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Failure of heater controller Failure of heater elements	Programmatic impact - Increased worker exposure Flooding the calciner with liquid plutonium nitrate solution (if calciner bed temperature not substantially above solution boiling point) Overflow solution into vacuum sensing line Plugging of ceramic filters with plutonium oxide or precipitates Seized agitator from mud formation Cracked ceramic filters due to thermal shock Entrained plutonium nitrate aerosols carry over to scrubber Possible polymerization of plutonium in scrubber	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low	Worker observation of contaminants in scrubber vessel Worker observation of mud or liquid into collection jar Plugged filter indicated by high dP (light on control panel)	S1	F3	S1 based on ALARA concerns in recovering from event
08.04.14/4	E	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Temperature/low	Failure of heater controller Failure of heater elements	Flooding the calciner with liquid plutonium nitrate solution (if calciner bed temperature not substantially above solution boiling point) Seized agitator from mud formation Accumulation of moderated plutonium mass in calciner poses criticality concern	Interlock between calciner temperature elements and feed pump shuts off supply if calciner temperature too low	Worker observation of contaminants in scrubber vessel Worker observation of mud or liquid into collection jar Plugged filter indicated by high dP (light on control panel)	S1*	F1	
08.04.15/1	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Agitation/no/low	Agitator motor failure Agitator shaft failure Agitator bearing failure Loss of power to agitator motor	Programmatic upset; extended shutdown of process Inadequate plutonium oxide stabilization Plugging of feed injector nozzle Formation of cake or cement inside calciner vessel	Interlock shuts down agitator upon loss of power to feed pump (interlock does not cover stalling or seizure of agitator)	Worker training and procedures for response to alarms	S1	F3	S1 based on ALARA concerns in recovering from event

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.04.15/2	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Agitation/no/low	Cement formation during shutdown inside vessel due to absorption of liquid in calciner bed	Programmatic upset; extended shutdown of process Inadequate plutonium oxide stabilization Plugging of feed injector nozzle Formation of cake or cement inside calciner vessel	Interlock shuts down agitator upon loss of power to feed pump (interlock does not cover stalling or seizure of agitator)	Worker training and procedures for response to alarms	S1	F3	S1 based on ALARA concerns in recovering from event
08.04.16	A1	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Agitation/excessive	Speed control fails high or set to high	No consequence			S0	F3	Not evaluated
08.04.17	A2	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Time procedure/out of sequence	Feed injected into calciner before it has come up to temperature (See calciner temperature/low nodes 8.04.12, 8.04.14)				S1	F3	S1 based on ALARA concerns in recovering from event
08.04.18	B	Calciner Vessel	Convert plutonium nitrate into dry stable plutonium oxide Confine off gasses and particulates generated in the denitrating process Contain plutonium oxide powder bed Prevent heat of process from threatening integrity of glovebox, starting a fire, or injuring workers	Confinement/low /no	Spurious failure of calciner vessel (corrosion fatigue assembly etc.)	Increased air flow through vacuum system to scrubber Potential nitric oxides, nitric acid vapor, and water vapor release to glovebox atmosphere (during air pulsing of ceramic filters) Spill of hot plutonium oxide to floor, heat up of glovebox	Material of calciner (design of high temperature operation) Glovebox structure and E-4 vent system to maintain confinement in event of release from calciner	Worker monitoring of calciner pressure Monitoring of dP gauges across calciner ceramic filters	S1	F3	Agitator can force plutonium oxide through opening in calciner vessel S1 based on ALARA concerns in recovering from event
08.05		Off Gas Line (Calciner to Scrubber)									
08.05.00	B	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/low	Ceramic filter plugging due to various causes	If all filters plugged, calciner pressurizes releasing plutonium oxide, nitric oxides, and acid vapors to glovebox atmosphere	Filter pulsing air system	Worker training and procedures Filter delta pressure monitoring	S1	F3	S1 based on ALARA concerns in recovering from event

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.05.01	A2	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/low	Inadequate vacuum due to vacuum system failure, closed valves, or incorrect vacuum regulation	Potential calciner pressurization with release of radioactive material to the glovebox	E-4 ventilation system and HEPA filters Glovebox structure provides confinement	Worker training and procedures Monitoring of calciner delta pressure to atmosphere	S1	F3	S1 based on ALARA concerns in recovering from event
08.05.02	A2	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/low	Pipe failure (leak - not catastrophic)	Potential calciner pressurization Hot denitration gas leak into glovebox air	Glovebox structure and E-4 ventilation system maintain confinement		S0	F3	
08.05.03/1	H	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Calciner vessel develops in leakage paths (at flanges, collection jar, seals, agitator bearing, etc.) Broken off gas line (due to thermal stress, improper connection)	Excessive bubbling in scrubber Inadequate scrubbing, elevated nitric oxides released through stack Entrainment of liquid in vacuum system line Release of particulates through relief port	Differential pressure gauges across ceramic filters E-4 ventilation system and HEPA filters Glovebox structure provides confinement	Worker observes that cap is off Worker training and procedures Worker trained to shut down system on visual observation of orange color in scrubber vapor space Differential pressure indicator across ceramic filters	S0	F2	Nitric oxides released through stack not above level of regulatory concern
08.05.03/2	H	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Relief cap off of calciner during processing due to human error	Excessive bubbling in scrubber Inadequate scrubbing, elevated nitric oxides released through stack Entrainment of liquid in vacuum system line Release of particulates through relief port	Differential pressure gauges across ceramic filters E-4 ventilation system and HEPA filters Glovebox structure provides confinement	Worker observes that cap is off Worker training and procedures Worker trained to shut down system on visual observation of orange color in scrubber vapor space Differential pressure indicator across ceramic filters	S0	F3	Nitric oxides release through stack not above level of regulatory concern
08.05.04	A1	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Excessive air feed to feed nozzle	Design intent			S0	F3	
08.05.05	B-XREF	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Flow/high	Excessive liquid flow rate into calciner through feed nozzle (increased off gas causes calciner pressure rise which causes vacuum regulator valve to open up more)	See injector liquid flow/high (Node 8.04.02)			S0	F3	
08.05.06	A2-XREF	Off gas line between calciner to scrubber (downstream of three ceramic filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Temperature/low	See calciner temp/low (Nodes 8.04.13 - 8.04.14)	Condensation in off gas line	Node 8.04.12 - 8.04.14		S0	F3	
08.05.07	B-XREF	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Temperature/low	Broken pipe	See off gas line flow/high (Node 8.05.03)			S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.05.08	B-XREF	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Temperature/high	See calciner Temp/high (Nodes 8.04.10, 8.04.11)				S0	F3	
08.05.09	A1	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/low (excessive vacuum)	See calciner pressure/low (Node 8.04.08)				S0	F3	
08.05.10	H-XREF	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/low (excessive vacuum)	Excessive vacuum due to low scrubber level Evaporation during normal operation (Loss of chiller function, Low caustic flow)	Reduced nitric oxides scrubbing Release of nitric oxides through stack Corrosion damage to vacuum system Low pH vacuum seal water		Observation of liquid level in scrubber	S0	F3	
08.05.11	B-XREF	Off gas line between calciner to scrubber (downstream of three filter legs)	Convey hot denitration gases and vapors from calciner to scrubber	Pressure/high (inadequate vacuum or positive pressure)	See calciner Pressure/high (Nodes 8.04.03 - 8.04.07)	See calciner Pressure/high (Nodes 8.04.03 - 8.04.07)			S0	F3	
08.06		Scrubber									
08.06.00	B	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/low	Scrubber vessel failure Leaking flanges or gaskets	Release of caustic solution to glovebox floor Release of potentially contaminated caustic aerosol to glovebox atmosphere Reduced or increased vacuum at calciner depending on in leakage rate and liquid level Reduced scrubbing of nitric oxides and nitric acid vapor	E-4 ventilation system to maintain negative pressure in the glovebox should vapors and gases be released from system Glovebox 188-1 structure provides containment	Visual observation of scrubber level (glass tank)	S0	F3	
08.06.01/1	A1	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/high	Excessive sodium hydroxide feed rate	Programmatic impact due to shutdown of process to allow draining of spent scrubber solution tanks Excessive use of sodium hydroxide Spent scrub solution receiver tanks filled prematurely	Vacuum trap prevents carryover of caustic into vacuum system	Visual monitoring of liquid levels in spent scrubber solution receiver tanks	S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.06.01/2	A2	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/high	Excessive sodium hydroxide feed rate	Overflow of caustic solution from spent scrubber solution tank into vacuum system	Vacuum trap prevents carryover of caustic into vacuum system	Visual monitoring of liquid levels in spent scrubber solution receiver tanks	S0	F3	
08.06.02/1	B	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/high	Three way valve set to intermediate position (blocked off flow to scrubber solution tank)	Potential calciner pressurization with release of nitric oxides, steam, and nitric acid vapor to glovebox atmosphere due to loss of vacuum flow or flashing of caustic solution Back flow of sodium hydroxide into calciner (formation of mud in calciner) Release of plutonium to glovebox	Glovebox structure E-4 ventilation system and filters mitigate release to atmosphere through stack	Worker observation of scrubber tank level (glass tank) Worker training and procedures Worker observation of steam being released from calciner pressure relief Delta pressure indication across ceramic filters Bubbles not observed in scrubber tank	S1	F2	S1 based on ALARA concerns in recovering from event
08.06.02/2	B	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Level/high	Standpipe plugging	Potential calciner pressurization with release of nitric oxides, steam, and nitric acid vapor to glovebox atmosphere due to loss of vacuum flow or flashing of caustic solution Back flow of sodium hydroxide into calciner (formation of mud in calciner) Release of plutonium to glovebox	Glovebox structure E-4 ventilation system and filters mitigate release to atmosphere through stack	Worker observation of scrubber tank level (glass tank) Worker training and procedures Worker observation of steam being released from calciner pressure relief Delta pressure indication across ceramic filters Bubbles not observed in scrubber tank	S1	F2	S1 based on ALARA concerns in recovering from event
08.06.03	A1	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Temp/low	Chiller temperature set point set too low	No significant effect identified			S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.06.04/1	H	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Temp/high	Loss of power to chiller Chiller failure (general failures of equipment) Loss of chiller fluid from supply or return line failure	Reduced level in scrubber due to increased evaporation Reduced scrubbing of nitric oxides and nitric acid vapor, nitric oxides and nitric acid release to process vacuum system, nitric oxides release through stack Accelerated corrosion of vacuum system components due to nitric oxides and nitric acid vapor Increased condensation in spent scrubber solution tanks and vacuum trap	Vacuum trap limits amount of liquid that can move into vacuum system	Worker observation of scrubber level (glass tank) Monitoring of scrubber temperature	S0	F3	
08.06.04/2	H	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Temp/high	Chiller supply or return valve closed (human error)	Reduced level in scrubber due to increased evaporation Reduced scrubbing of nitric oxides and nitric acid vapor, nitric oxides and nitric acid release to process vacuum system, nitric oxides release through stack Accelerated corrosion of vacuum system components due to nitric oxides and nitric acid vapor Increased condensation in spent scrubber solution tanks and vacuum trap	Vacuum trap limits amount of liquid that can move into vacuum system	Worker observation of scrubber level (glass tank) Monitoring of scrubber temperature	S0	F3	
08.06.05	H	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Pressure/low (excessive vacuum)	Plant vacuum system upset/variation	No adverse effects identified			S0	F3	
08.06.06/1	B	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Pressure/high (inadequate vacuum or positive pressure)	Vacuum regulating valve fails closed or partially closed Path failure on vacuum side of scrubber	Release of plutonium oxide powder, water vapor, nitric oxides, nitric acid vapor to glovebox atmosphere	E-4 ventilation system and filters Glovebox confinement structure	Visual observation of steam release from calciner pressure relief cap or steam in product collection jar Worker training and procedures Worker periodic surveillance of the delta pressure gauges	S1	F3	S1 based on ALARA concerns in recovering from event

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.06.06/2	AI	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	Pressure/high (inadequate vacuum or positive pressure)	Vacuum regulating valve fails closed or partially closed Path failure on vacuum side of scrubber	Pressurization of calciner vessel	E-4 ventilation system and filters Glovebox confinement structure	Visual observation of steam release from calciner pressure relief cap or steam in product collection jar Worker training and procedures Worker periodic surveillance of the delta pressure gauges	S0	F3	
08.06.07	H	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	pH/low (less than 14)	Low sodium hydroxide concentration in feed (e.g. low feed concentration, wrong drum dilute caustic water) Valves in supply line to scrubber closed as continued operation calciner neutralizer scrubber solution Sodium hydroxide supply drum empty (human error)	Nitric oxides scrubbing efficiency reduced (as well as removal of other materials in the calciner off gas) which results in nitric oxides going to 26" vacuum system and creating acidic condition in seal water Possible release of nitric oxides from vacuum system to facility stack		Worker observation of gas stream color - orange (glass tank) Analysis of spent scrubber solution Worker training and procedures	S0	F3	
08.06.08	H	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	pH/low (less than 14)	Acid drum brought into laboratory instead of caustic (mislabeling, human error)	Decreased scrubbing of nitric oxides, increased nitric oxides release to vacuum system Vigorous reaction in scrubber heat production in scrubber	Chiller removes portion of reaction heat Vacuum system removes heat and gases to control pressure	Shipping document and labeling identifies chemical in drum from vendor Hazardous chemical safety program	S0	F2	Not enough to boil solution or to fail scrubber
08.06.09	AI	Scrubber	Condense and neutralize nitric acid vapors Remove nitric oxides from calciner off gas stream by reacting to form soluble salts Cool off gas stream from calciner Protect process vacuum system from nitric acid vapors and heat	pH/high (10 M sodium hydroxide)	High caustic flow rate High concentration of caustic in supply	Excessive consumption of sodium hydroxide solution - programmatic impact Also see scrubber Level/high (Node 8.06.01)		Worker training and procedures	S0	F3	
08.07		Spent Scrubber Solution Tank									

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.07.00	A2	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/high	Human error--spent solution flow not switched to second bank when first tank full Tanks not drained prior to processing campaign Three way valve not switched when tank filled	Spent solution drawn into vacuum system	Vacuum trap prevents liquid to be drawn into vacuum system	Worker surveillance of tank level Worker training and procedures	S0	F3	
08.07.01/1	B	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/low	Ruptured tanks or tank seals	Programmatic impact Spill of solution to glovebox floor		Worker surveillance of tank level Worker training and procedures	S0	F3	
08.07.01/2	B	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/low	Sample valve left open	Programmatic impact Spill of solution to glovebox floor		Worker surveillance of tank level Worker training and procedures	S0	F3	
08.07.02	A2	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/low	Inlet transfer pipe failure	Programmatic impact Spill of solution to glovebox floor		Worker surveillance of tank level Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event
08.07.03	A2	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/low	Evaporation of solution in tanks leaving solids layer (of sodium nitrate, sodium hydroxide, etc.)	Programmatic impact - necessity of cleaning tanks		Worker observation of tanks	S0	F3	Tank can be sparged through sample valve to stir up solids before sampling
08.07.04	E	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Filter failure at calciner	Buildup of plutonium oxide sludge in tanks, criticality or CPS violation	Critically safe geometric design	Sampling of spent scrubber solution for plutonium content before discharge to D8 Monitoring of dP across ceramic filters Worker observation of solution color Worker observation of spent scrubber tanks (glass for visibility of solids layer) Process engineering and building operations approval for transfer	S1*	F1	
08.07.05/1	E	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Ceramic filter failure in calciner	Possible transfer of plutonium material to tank D-8 with potential criticality specification violation	Criticality alarm in 241Z	Sampling of spent scrubber solution for plutonium content before discharge to D8 Monitoring of dP across ceramic filters Worker observation of solution color Worker observation of spent scrubber tanks (glass for visibility of solids layer) Process engineering and building operations approval for transfer	S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.07.05/2	A2	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Level/solids layer	Ceramic filter failure in calciner	Programmatic impact in having to remove and reprocess material from scrubber solution tank	None	Sampling of spent scrubber solution for plutonium content before discharge to D8 Monitoring of dP across ceramic filters Worker observation of solution color Worker observation of spent scrubber tanks (glass for visibility of solids layer) Process engineering and building operations approval for transfer	S1	F1	S1 based on ALARA concerns in recovering from event
08.07.06/1	B	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Pressure/high (less vacuum)	Drain, sample, vent valve not closed during processing Wrong scrubber solution tank valved	Less flow through scrubber Pressurization of calciner Release of steam, nitric oxides, nitric acid vapor and plutonium oxide to glovebox atmosphere	Pressure relief cap on calciner Glovebox and E4 vent system	Visual observation of less bubbling in scrubber Monitoring of vacuum system gauges Visual observation of release through calciner relief cap	S0	F3	
08.07.06/2	B	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Pressure/high (less vacuum)	Leak in scrubber solution tank Loss of plant vacuum system	Less flow through scrubber Pressurization of calciner Release of steam, nitric oxides, nitric acid vapor and plutonium oxide to glovebox atmosphere	Pressure relief cap on calciner Glovebox and E4 vent system	Visual observation of less bubbling in scrubber Monitoring of vacuum system gauges Visual observation of release through calciner relief cap	S0	F3	
08.07.07	A1	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Temperature/high	Chemical reaction in spent scrubber solution tank from incompatible material mixing - Nitric acid instead of sodium hydroxide	Increased heat generation in spent scrubber solution tank	Node 8.06.08		S0	F3	
08.07.08	A1	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Pressure/low (vacuum in "tank")	Both vents blocked and drain opened Vent valve not opened when tank drained	Programmatic impact Inability to drain tanks Increased nitric oxides release to scrubber system Boiling not expected due to buffer supplied by scrubber	Tank vents have no valves		S0	F3	
08.07.09	H	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	pH/low (<13)	pH low at scrubber	Elevated nitric oxides release	Node 8.06.07		S0	F3	
08.07.10	A1	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	pH/low (<13)	pH low at scrubber	No significant impact to spent scrub solution receiver tanks; however pH of tank D-8 could be significantly affected			S0	F3	Potential effect on tank D-8 unknown
08.07.11	A1	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	pH/high	High caustic drum delivered from supplier	Design intent, no significant consequence			S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.07 12/1	A2	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Composition/high plutonium	Ceramic filter failure in calciner	plutonium polymer in spent solution tank Programmatic impact in having to remove and reprocess material		Sparging and sampling for plutonium content Worker observation of solution color Worker observation of tanks (glass for visibility of solids layer) Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event
08.07.12/2	E	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Composition/high plutonium	Ceramic filter failure in calciner	Transfer of plutonium material to tank D8 in excess of limits derived from CPS	Critically safe spent scrubber solution tank design	Sparging and sampling for plutonium content Worker observation of solution color Worker observation of tanks (glass for visibility of solids layer) Worker training and procedures	S0	F3	Covered by CSER
08.07.13/1	A2	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Composition/high plutonium	Flooding of calciner with plutonium nitrate solution - Submerging of ceramic filters and allowing plutonium into vacuum system - Flooding caused by; excessive flow rate from feed pump, low temperature operation of calciner	Plutonium polymer in spent solution tank Programmatic impact in having to remove and reprocess material	Critically safe design Interlock prevents operation of calciner below 700 C	Sparging and sampling for plutonium content Worker observation of solution color Worker observation of tanks (glass for visibility of solids layer) Worker training and procedures Visual observation of solution in product jar	S1	F3	Several batches from feed tank would be required to flood calciner to filter level S1 based on ALARA concerns in recovering from event
08.07.13/2	E	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Composition/high plutonium	Flooding of calciner with plutonium nitrate solution - Submerging of ceramic filters and allowing plutonium into vacuum system - Flooding caused by; excessive flow rate from feed pump, low temperature operation of calciner	Transfer of plutonium material to tank D8 in excess of limits derived from CPS	Critically safe design Interlock prevents operation of calciner below 700 C	Sparging and sampling for plutonium content Worker observation of solution color Worker observation of tanks (glass for visibility of solids layer) Worker training and procedures Visual observation of solution in product jar	S0	F3	Several batches from feed tank would be required to flood calciner to filter level
08.07.14/1	A1	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Sparging/no/low	Sample valve not opened Vacuum system not valved in	Programmatic impact	Lip on drain valve limits solids carry over to tank D8	Worker training and procedures Worker observation of spent solution tank	S0	F3	
08.07.14/2	E	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Sparging/no/low	Sample valve not opened Vacuum system not valved in	Inaccurate plutonium sample results, ultimately could result in excessive quantities of plutonium to tank D-8 with potential CPS infraction	Lip on drain valve limits solids carry over to tank D8	Worker training and procedures Worker observation of spent solution tank	S0	F3	CPS violation

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.07.15	E	Spent scrubber solution tank (one tank representative of both tanks)	Provide lag storage of spent scrub solution for sampling prior to transferring solution to Tank D8 for disposal	Sparging/no	Sampling step skipped due to human error	Inaccurate plutonium sample results, ultimately could result in excessive quantities of plutonium to tank D-8 with potential CPS infraction Potential transfer of plutonium material to tank D8 in excess of CPS limit	Lip on drain valve limits solids carry over to tank D8	Worker training and procedures Worker observation of spent solution tank	S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.08		Spent Scrub Solution Drain Line to Tank D8									
08.08.00	E	Spent Scrub Solution Drain Line to Tank D8	Transfer spent scrub solution to tank D8 to permit eventual transfer to tank farms	Composition/high plutonium concentration	Calciner filter failure permits movement of plutonium into scrubber and failure to detect visually or by sampling	Potential for buildup of plutonium in tank D8 and possible criticality concern	Lip on drain valve limits solids carry over to tank D8	Procedure for sampling spent scrubber solution before being sent to tank D8 Worker observation of scrubber solution color in scrubber	S0	F3	CSER
08.09		Vacuum Trap									
08.09.00	H-XREF	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Level/high	Liquid drawn into vacuum system due to overfilling of the spent scrubber solution tank caused by failure to switch drain tank or failure to shutdown when tank full	Contamination of vacuum system corrosion damage to vacuum system Low pH in vacuum pump seal Liquid accumulation in vacuum header and vacuum traps	Polyethylene float prevents overflow into vacuum system Vacuum trap has critically safe geometry Demisters in main vacuum system collect solution and are critically safe	Observation of liquid level in trap and in spent scrubber solution tanks Observation of calciner pressure after float seals off vacuum flow	S0	F3	
08.09.01	B-XREF	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Pressure/high (lack of vacuum)	Failure of plant vacuum system Vacuum trap flooded, resulting in float sealing off process gases	Node 8.04.07			S0	F3	
08.09.02	H	Vacuum Trap	Prevent liquids from entering the 26" process vacuum system	Pressure/high (lack of vacuum)	Excessive in leakage from various points in the calciner system due to piping and vessel failures	Addressed at various nodes specific to the rest of the system			S0	F3	
08.10		Filter Pulsing Supply Air									
08.10.00	B	Filter pulsing supply air (between accumulator and calciner)	Provide supply of air to prevent filter plugging	Pulse/no/low	Loss or decrease of plant pressurized air Solenoid valves fail to open due to loss of power malfunction Pulse too short due to timing program malfunction or improper programming Pulse too infrequent due to timing program malfunction or improper programming	Plugging of filters due to buildup of solids causing pressurization of calciner and release of nitric oxides, nitric acid, and plutonium oxide to glovebox atmosphere	Glovebox confinement boundary E-4 ventilation system confinement release	Visual observation of steam and particulate release through calciner relief port Visual observation of lack of bubbling through scrubber No audible clicking of solenoid valves	S1	F3	S1 based on ALARA concerns in recovering from event
08.10.01	C	Plant pressurized air supply (line inside glovebox)	Contain and route air to pulse air and atomizing air systems	Containment low/no	Catastrophic failure of air supply line in glovebox (random failure, seismic event, mechanical impact)	Reduced glovebox vacuum or slight pressurization of glovebox Possible resuspension of powder in open can if line fails above base plate Potential contamination spread from glovebox through small leakage paths in glovebox boundary	Line sized such that sonic velocity through catastrophically failed line is insufficient to compromise glovebox confinement Room CAM	Monitoring of pressure gauges Gloves checked for holes prior to use	S1	F2	Maximum potential air flow rate through catastrophically failed line has been shown by analysis to be insufficient to pressurize glovebox to point that inlet HEPA filters fail

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.11		Sodium Hydroxide Feed Supply line									
08.11.00	A1-XREF	Sodium Hydroxide Feed Supply line	Supply sodium hydroxide feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	Flow/high (excessive or continuous)	See scrubber Level/high (Node 8.06.01) Excessive sodium hydroxide flow				S0	F3	
08.11.01	A2	Sodium Hydroxide Feed Supply line	Supply sodium hydroxide feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	Flow/reverse	Siphoning of scrubber contents back into sodium hydroxide after shutting of caustic feed pump and shutting off vacuum	Programmatic impact Contaminated solution in fresh caustic supply Contamination of transfer line and pump	Check valve action in diaphragm pump would prevent back flow Supply tube in scrubber doesn't reach bottom of scrubber limiting amount of back flow into drum Room CAM Check valve in line inside glovebox prevents siphoning	Valve on supply closed before vacuum shutoff Vacuum sufficient to prevent siphoning when on Periodic RCT surveys of room	S1	F2	Vapor space of full drum sufficient to accommodate potential drain back from scrubber Supply line in drum is submerged when installed ensuring contamination not released into vapor space of drum Bung hole size limits potential release to room 188 S1 based on ALARA concerns in recovering from event
08.11.02	I-XREF	Sodium Hydroxide Feed Supply line	Supply sodium hydroxade feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	Flow/low/no (inadequate to meet process requirements)	See scrubber pH/low (Node 8.06.07)				S0	F3	
08.11.03/1	I	Sodium Hydroxide Feed Supply line	Supply sodium hydroxide feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	Flow/low/no (inadequate to meet process requirements)	Breach of transfer line due to corrosion, aging, etc.	Spill of caustic solution to room 188 floor and potential spray leak	Plastic sheath around line	Worker training and procedures Personnel protective equipment - goggles and protective gloves Safety Shower	S1*	F3	S1*/F3 for potential spray leak
08.11.03/2	I	Sodium Hydroxide Feed Supply line	Supply sodium hydroxide feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	Flow/low/no (inadequate to meet process requirements)	Breach of transfer line due to mechanical contact outside of glovebox 188-1 (human error).	Spill of caustic solution to room 188 floor and potential spray leak	Plastic sheath around line	Worker training and procedures Personnel protective equipment - goggles and protective gloves Safety Shower	S1*	F3	S1*/F3 for potential spray leak
08.11.04	I	Sodium Hydroxide Feed Supply line	Supply sodium hydroxide feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	Pressure/high	Caustic supply line to glovebox 188-1 shut off	Line rupture with potential spray leak into room 188 (sodium hydroxide aerosols) Potential spray leak from pump seals and relief valve	Supply pump has deadhead relief line back into caustic drum Plastic sheath around line	Worker training and procedures Personnel protective equipment - goggles and protective gloves Safety Shower	S1*	F3	There is a deadhead relief line going back into the caustic supply drum. The relief back pressure is adjustable. The maximum pressure provided by the caustic pump is 85 psig.
08.11.05	H-XREF	Sodium Hydroxide Feed Supply line	Supply sodium hydroxide feed to scrubber for removal of acids and nitric oxides from the calciner off gas Contain sodium hydroxide solution thereby preventing worker exposure	pH/low	Wrong drum used to supply feed pump (low concentration of sodium hydroxide) or acid drum	See scrubber pH/low (Node 8.06.07 & 8.06.08)			S0	F2	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.12		Scrubber Chiller									
08.12.00	A1	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Insufficient cooling	Leak in chiller recirculation loop outside glovebox (random failures)	Spill of water to floor		Worker training and procedures	S0	F3	
08.12.01	A1	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense offgas water vapor and acid vapor	Insufficient cooling	Leak in chiller line in scrubber	Programmatic impact Addition of water to scrubber resulting in high level and reduced pH Elevated nitric oxides release to vacuum system Excess solution to spent scrubber solution tank	Recirculation system has limited volume of liquid available for leakage into unintended areas	Scrubber temperature monitoring Chiller temperature monitoring	S0	F3	
08.12.02/1	C	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense off gas water vapor and acid vapor	Insufficient cooling	Leak in chiller line in scrubber	Cross contamination of chilled water system Solution condensation of the vapors in spent solution waste tank Loss of cooling to scrubber resulting in decreased removal of water and acid vapor allowing vapors to enter plant vacuum system	Chiller line pressure is higher than scrubber solution pressure limiting leakage of sodium hydroxide into chiller systemScrubber solution should have very dilute plutonium, reducing criticality concerns	Scrubber temperature monitoring Chiller temperature monitoring	S1	F3	Chiller reservoir not critically safe S1 rank for ALARA concerns during repair of chiller
08.12.02/2	E	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense off gas water vapor and acid vapor	Insufficient cooling	Leak in chiller line in scrubber	Potential criticality or CPS violation	Chiller line pressure is higher than scrubber solution pressure limiting leakage of sodium hydroxide into chiller systemScrubber solution should have very dilute plutonium, reducing criticality concerns	Scrubber temperature monitoring Chiller temperature monitoring	S1*	F1	Chiller reservoir not critically safe Scrubber solution should have very dilute plutonium resulting in reduced criticality concerns
08.12.03/1	H	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense off gas water vapor and acid vapor	Insufficient cooling	Leak in chiller line in glovebox outside scrubber	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) Increased scrubber temperature results in increased evaporation No scrubbing of nitric oxides and nitric acid vapor, nitric oxides and nitric acid release to process vacuum system, nitric oxides release through stack Accelerated corrosion of vacuum system components due to nitric oxides and nitric acid vapor	Recirculation loop has limited volume to minimize criticality concerns	Scrubber temperature monitoring Chiller temperature monitoring	S0	F3	
08.12.03/2	H	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense off gas water vapor and acid vapor	Insufficient cooling	Isolation valves in recirculation loop closed (human error)	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) Increased scrubber temperature results in increased evaporation No scrubbing of nitric oxides and nitric acid vapor, nitric oxides and nitric acid release to process vacuum system, nitric oxides release through stack Accelerated corrosion of vacuum system components due to nitric oxides and nitric acid vapor	Recirculation loop has limited volume to minimize criticality concerns	Scrubber temperature monitoring Chiller temperature monitoring	S0	F3	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.12.04	H	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense off gas water vapor and acid vapor	Insufficient cooling	Failure of refrigeration unit (random failures associated with mechanical and electrical equipment) Loss of refrigeration unit working fluid (Freon leak)	Increased vacuum at calciner due to reduced scrubber head (not expected to fail calciner) Increased scrubber temperature results in increased evaporation No scrubbing of nitric oxides and nitric acid vapor, nitric oxides and nitric acid release to process vacuum system, nitric oxides release through stack Accelerated corrosion of vacuum system components due to nitric oxides and nitric acid vapor	Recirculation loop has limited volume to minimize criticality concerns	Scrubber temperature monitoring Chiller temperature monitoring	S0	F3	
08.12.05	I	Scrubber Chiller	Provide cooling to scrubber to maintain scrubber temperature sufficiently low to condense off gas water vapor and acid vapor	Insufficient cooling	Loss of refrigeration unit working fluid (Freon leak)	Exposure of personnel to refrigeration gas (probably not a health issue unless creates lack of oxygen condition which is of very low likelihood)	E-3 ventilation system 5 fume hoods in Room 187 Louvers in door to Room 187		S0	F3	Working fluid leak not a significant safety or health hazard
08.13		Glovebox 188-1									
08.13.00	A1	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/low (excessive vacuum)	E-4 exhaust system imbalance (dampers in E-4 system set Incorrectly or dampers fail open)	No significant consequence--glovebox not expected to fail at credible vacuums	Glovebox to room dP gauge	Procedure requires worker to verify glovebox to room dP prior to initiating glovebox operations	S0	F3	
08.13.01	A1	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/low (excessive vacuum)	Damper control failures in E-3 reduce pressure in both E-4 and E-3 areas	NO significant consequences as relative pressure difference maintained			S0	F3	
08.13.02	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--dP between room and glovebox >-0.5 in W.G)	Ventilation imbalance between Zone 3 and Zone 4 (dampers in E-4 and/or E-3 ventilation set or modulated incorrectly)	Potential for reverse flow through glovebox penetrations to room 188, minor contamination spread to room 188	Glovebox 188-1 exhaust minimizes potential for glovebox to go more positive than Zone 3 Glovebox structure and penetration design minimizes potential contamination spread should room pressure drop below glovebox pressure	Procedure requires worker to verify glovebox to room DP prior to initiating glovebox operations (procedures Z0-190-502 and Z0-190-506)	S1	F3	S1 based on minor operator plutonium contamination

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.13.03	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--dP between room and glovebox >-0.5 in W.G)	Damper control failure in E-3 increase pressure in both E-4 and E-3 areas	No contamination spread--relative pressure in glovebox still more negative than room pressure			S0	F3	
08.13.04	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--dP between room and glovebox >-0.5 in W.G)	Pressurized air leak inside glovebox (catastrophic line failure and possibly air regulator failures)	Contamination spread to room 188 through glovebox seals and penetrations Gloves blown out	Glovebox 188-1 provides large volume for compressed gases to expand into Pressure gauges on plant compressed air lines Glovebox to room dP gauge	Worker/audio detection of catastrophic leak	S1*	F2	S1* based on potential worker plutonium contamination
08.13.05	B-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--dP between room and glovebox >-0.5 in W.G)	Pressurized releases from calciner due to various causes	See calciner Pressure/high (Nodes 8.04.03 - 8.04.07)			S0	F3	
08.13.06	B-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Pressure/high (less vacuum--dP between room and glovebox >-0.5 in W.G)	Releases from glovebox tanks due to chemical reactions	See calciner Pressure/high (Nodes 8.04.03 - 8.04.07)			S0	F3	Total volume of 188-1 glovebox minimizes potential for pressurization as does E-4 ventilation system capacity
08.13.07	F1	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Fire in room 188 due to ignition of combustibles in the room	Potential loss of confinement of glovebox due to failure of seals, windows, gloves, etc.	Room fire suppression system Glovebox constructed primarily of metal and has fire resistant glass wire mesh windows	Housekeeping procedures limit combustible loading Dry chemical portable fire extinguisher available.	S1*	F2	Plastic viewing ports S1*/F2 ranking for fire that engulfs glovebox

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.13.08	F1-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Fire in glovebox (due to loss of control of calciner heaters, or combustibles in contact with hot equipment)	See calciner Temperature/high (Node 8.04.10/11) See feed pump Temperature/high (Node 8.02.04)		Housekeeping procedures limit combustible loading	S1*	F2	
08.13.09	D1-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Butene explosion in calciner causes release of hot gases, steam, and very hot plutonium oxide to glovebox atmosphere	See calciner temperature/high (Node 8.04.10/11)			S1*	F3	
08.13.10	F1-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Overheated calciner due to temperature control failures on calciner heaters	See calciner Temperature/high (Nodes 8 04.10/11)			S1	F3	
08.13.11/1	G	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Thermal degradation of materials and components inside glovebox such as flexible hose, electrical wiring insulation, elastomer gloves, elastomeric seals, etc.	Electrical shock hazard to operator during manual operations inside glovebox	Glovebox temperature elements and recorders E-4 ventilation system instrumentation Glovebox gloves act as insulator Electrical equipment has protective shielding and is grounded	Worker training and procedures Procurement specifications require materials placed in glovebox be able to survive the glovebox environment	S1	F3	S1 based on possibility of electrocution Industrial hazard
08.13.11/2	B	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Thermal degradation of materials and components inside glovebox such as flexible hose, electrical wiring insulation, elastomer gloves, elastomeric seals, etc.	Possible failure of pump seals allowing sprays and leaks of material being pumped	Glovebox temperature elements and recorders E-4 ventilation system instrumentation Procurement specifications requiring materials placed in glovebox be able to survive the environment Glovebox gloves act as insulator Electrical equipment has protective shielding and is grounded	Worker training and procedures	S1	F3	S1 based on possibility of electrocution Industrial hazard

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.13.12	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Temperature/high	Loss of glovebox ventilation (loss of E-4 exhaust fans or exhaust path valved closed)	Heat given off by calciner and piping surfaces increases temperature in the glovebox Glovebox confinement boundary potentially compromised due to thermal expansion of structural components and effect on heat on glovebox seals	Glovebox temperature elements and recorders Room CAMs to detect spread of contamination from glovebox Glovebox pressure gauges, indicators and annunciators E-4 ventilation system instrumentation Glovebox HEPA filters allow pressure and heat to vent from glovebox	Worker training and procedures regarding glovebox and ventilation system instrument readings	S0	F1	Significant pressurization of glovebox not expected due to expansion volume of glovebox
08.13.13	A1	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Liquid level/low/no	Intended condition				S0	F3	
08.13.14	B-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Level/high	Spills of plutonium nitrate solution, caustic makeup solution, scrubber solution, spent scrubber solution, flush solution, or plutonium oxide due to various vessel failure modes	See prior nodes relating to solution spills			S0	F3	
08.13.15	F1-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Glovebox fire	See calciner Temp/high (Node 8.04.10/11) See feed pump Temp/high (Node 8.02.04)			S1	F2	
08.13.16	D1-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Calciner butene explosion	See calciner pressure/high (Node 8.04.05)			S1*	F1	

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.13.17	C-XREF	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Accumulator rupture damages containment	See pulse air system pressure/high (Node 8.10.00)			S1	F2	Contamination spread
08.13.18	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	Bag in /bag out operation allows spread of contamination to room 188	Minor spread of contamination to room and possible worker exposure	CAMs in room E-4 ventilation maintains sufficient negative pressure and face velocity to prevent contamination migration	Worker training and procedures	S1	F3	S1 based on potential minor worker exposure to airborne plutonium
08.13.19	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Glovebox confinement/ structural integrity/ compromised	External impact on glovebox by moving object (hand truck, tool, etc.)	Potential loss of glovebox confinement (due to breach of glove or window) with release of contamination to room	Sturdy metal glovebox design Glovebox has seismically qualified tie down to the room floor preventing toppling Glovebox structure is seismically qualified to withstand design basis earthquake	Procedures governing use of material handling equipment Personnel training and procedures regarding the use of items that could cause glovebox breach	S1	F3	S1/F3 ranking for minor contamination spread to room Glovebox is assumed to remain upright due to support structure being bolted to floor
08.13.20	E	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Fissile material/Excess accumulation	Spills of fissile material not cleaned up or not completely cleaned up resulting in accumulation of fissile material Plutonium accountability errors Accumulation of plutonium nitrate bottles with continued processing of plutonium nitrate	Potential for criticality		Worker training and procedures regarding the cleanliness of the glovebox Observation of material buildup Criticality prevention specifications	S1*	F1	S1* based on potential worker exposure to ionizing radiation
08.13.21	A2	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Radioactive material/excess accumulation	Spills of radioactive material not completely cleaned up resulting in accumulation of radioactive material in glovebox	Potential for significant ionizing radiation fields around glovebox and increased operator exposure	Glovebox has built-in lead shielding	Worker training and procedures regarding glovebox housekeeping Periodic radiation surveys	S1	F3	S1 based on ALARA concerns

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.13.22	E	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Confinement integrity/water intrusion	Flood in room 188 due to activation of room fire suppression system	Potential initiator for criticality	Glovebox support structure elevates glovebox above floor Glovebox top is sealed No open paths in top of glovebox for water intrusion Vessels in glovebox are designed to be geometrically unfavorable to criticalities even if fully moderated	Mass of fissile material controlled by criticality specifications and procedures Specifications require use of movable vessels with shapes and volumes that are criticality unfavorable	S1*	F1	If large ingress of fire water occurs criticality drain may not keep up with flow rate Water flows under the room doors out into corridor
08.13.24	C	Glovebox 188-1	Provide confinement of gases and particulates for calciner process Contain spilled fluids Provide structure to support equipment within glovebox Provide shielding to minimize operator exposure	Confinement integrity/water intrusion	Flood in room 188 due to activation of room fire suppression system	Potential for spread of plutonium oxide to room 188	Glovebox support structure elevates glovebox 1.5 feet above floor Glovebox top is sealed Room CAMs alert workers to airborne hazard	Worker training	S1	F3	S1/F3 ranking for minor contamination spread to room
08.14		E-4 Exhaust Duct									
08.14.00/1	C	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/low/no	Loss of E-4 exhaust fans Loss of power Plugged glovebox E-4 exhaust filter Plugged inlet HEPA filters	Stagnation of glovebox with possible contamination release to room 188 (assumes that some contamination exists in the glovebox at all times) Overheating glovebox due to no air movement in box resulting in migration of contamination to room	CAMs in room Ventilation system failure alarm Glovebox temperature detection elements and recorders Glovebox pressure indication	Worker training and alarm response procedures Procedure requires checking dP before working in glovebox Plant vacuum system helps maintain vacuum until shut down By procedure, process is shut down and room is evacuated upon loss of ventilation	S1	F3	S1 based on simple migration of contamination
08.14.00/2	C	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/low/no	E-3 or E-4 flow dampers closed or set incorrectly	Stagnation of glovebox with possible contamination release to room 188 (assumes that some contamination exists in the glovebox at all times) Overheating glovebox due to no air movement in box resulting in migration of contamination to room	CAMs in room Ventilation system failure alarm Glovebox temperature detection elements and recorders Glovebox pressure indication	Worker training and alarm response procedures Procedure requires checking dP before working in glovebox Plant vacuum system helps maintain vacuum until shut down By procedure, process is shut down and room is evacuated upon loss of ventilation	S1	F3	S1 based on simple migration of contamination
08.14.01	A1	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	E-4 ventilation system exhaust dampers open fully	No significant effect		Worker training and procedures Procedure requires checking dP before working in glovebox	S0	F3	Inlet HEPA filters not plugged

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Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.14.02/1	A1	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	Failure of glovebox gloves or windows	Programmatic impact Loss of glovebox integrity	E-4 ventilation maintains negative pressure and confinement velocity across holes in gloves	Worker training and procedures Periodic glovebox and glove inspections	S0	F3	E4 ventilation system provides enough negative pressure to overcome loss of confinement
08.14.02/2	C	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	Failure of glovebox gloves or windows	Potential spread of contamination from glovebox	E-4 ventilation maintains negative pressure and confinement velocity across holes in gloves	Worker training and procedures Periodic glovebox and glove inspections	S1	F3	S1 based on simple migration of contamination
08.14.03	C	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Air flow/high	Gross failure of compressed air piping or gross failure of plant compressed air system	Node 8.10.01	Node 8.10.01	Node 8.10.01	S1	F3	Pressurization of glovebox is not expected S1 rank for ALARA concern based on increased exposure of worker
08.14.04	B	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Filtration/lack of	Glovebox exhaust filter failure	Elevated contamination release to E-4 system (normal operation) Elevated plutonium oxide, plutonium nitrate aerosol release to E-4 system if failed filter in place at time of process upsets identified elsewhere in this table	E-4 stage 1 HEPA filters (in duct level) Final E-4 ventilation system filters to limit release to environment Stack exhaust CAM	Periodic aerosol testing of E-4 exhaust filters	S0	F3	S0 based on no significant release through stack due to safety class E-4 filters
08.14.05	C	E-4 exhaust duct at outlet of Glovebox 188-1	Prevents movement of contamination from glovebox to room 188 by maintaining a negative pressure in glovebox Provides removal of heat produced by calciner through movement of air through glovebox	Pressure/low/high vacuum	Glovebox inlet HEPA filters plugged by some obstruction and E-4 exhaust dampers fully opened	Possible failure of inlet HEPA filters loss of glovebox confinement	E-4 ventilation system helps maintain confinement across failed filters room CAM	Training procedures	S1	F1	Glovebox vacuum may be adjusted by partially obstructing inlet HEPAs Maximum dP produced by E-4 fans believed to be insufficient to fail HEPA filters S1 rank for ALARA concern based on increased exposure of worker

Table A-6

Plutonium Finishing Plant
Laboratory Prototype Calciner HazOp

Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.15		Product Collection Jars									
08.15.00	B	Product collection jars and slip lid cans (handling within glovebox)	Contain plutonium oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Containment/lack of	Spill during transfer of collection jar contents to slip lid can	Release of plutonium oxide particulate to glovebox atmosphere	Glovebox exhaust filter E-4 exhaust system filters (2 stages) Glovebox structure, seals, and E-4 exhaust to maintain confinement	Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event
08.15.01	B	Product collection jars and slip lid cans (handling within glovebox)	Contain plutonium oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Containment/lack of	Drop or topple slip lid can during movement	Release of plutonium oxide particulate to glovebox atmosphere	Glovebox exhaust filter E-4 exhaust system filters (2 stages) Glovebox structure, seals, and E-4 exhaust to maintain confinement	Worker training and procedures	S1	F3	S1 based on ALARA concerns in recovering from event
08.15.02	B-XREF	Product collection jars and slip lid cans (handling within glovebox)	Contain plutonium oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Confinement/lack of	Product collection jar breaks while connected to calciner downcomer port - Thermal stress - Mechanical contact	Spill of plutonium oxide to glovebox atmosphere Inrush of air into calciner	Glovebox exhaust filter E-4 exhaust system filters (2 stages) Glovebox structure, seals, and E-4 exhaust to maintain confinement	Worker training and procedures	S1	F2	S1 based on ALARA concerns in recovering from event
08.15.03	B-XREF	Product collection jars and slip lid cans (handling within glovebox)	Contain plutonium oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Confinement/lack of	Improperly attached product collection jar while process is occurring in calciner	Inrush of air into calciner	Glovebox exhaust filter E-4 exhaust system filters (2 stages) Glovebox structure, seals, and E-4 exhaust to maintain confinement	Worker training and procedures	S0	F2	
08.15.04	A2	Product collection jars and slip lid cans (handling within glovebox)	Contain plutonium oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Temperature/high	Normal condition of the product collection jar while collecting plutonium oxide from calciner process	None		Worker training and procedures Temperature of jar taken before handling	S0	F3	
08.15.05	G	Product collection jars and slip lid cans (handling within glovebox)	Contain plutonium oxide Product collection jar maintains confinement for calciner while connected to product collection down pipe	Temperature/high	Inadequate time allowed for cooling prior to transferring plutonium oxide to convenience can	Worker burns		Worker training and procedures	S1	F2	71 C before glove damage Jar fills slowly allowing for cooling of product
08.16		Natural Phenomena - External Events									
08.16.00/01	NPH	Seismic Event			Seismic Event	Potential continuous operation of calciner with loss of vacuum causing continuous release of plutonium through calciner relief port Release of plutonium to room through failed glovebox, windows, seals, and penetrations	Seismic switch shut down ventilation supply preventing pressurization of building	Large distance to offsite public	S2	F2	

Table A-6

Plutonium Finishing Plant
Laboratory Prototype Calciner HazOp

Node Id	Acc Group	Node Description	Design Function	Parameter Guide Word	Causes	Consequences	Engineered Safety Feature	Administrative Safety Feature	Cons Cat[1]	Freq Cat[2]	Remarks
08.16.00/02	NPH	Seismic Event			Seismic Event	Potential continuous operation of calciner with loss of vacuum causing continuous release of plutonium through calciner relief port Release of plutonium to room through failed glovebox, windows, seals, and penetrations Failure of E-4 and E-3 HEPA filters allowing release of glovebox 188-1 contamination to environment	Seismic switch shut down ventilation supply preventing pressurization of Building Sturdy glovebox design (metal walls, glass wire mesh windows, plastic viewing ports)	Large distance to offsite public	S2	F2	
08.16.00/03	E	Seismic Event			Seismic Event	Potential toppling of glovebox (if seismically unqualified) Potential criticality due to consolidation of plutonium and solution in one corner of glovebox	Seismic switch shut down ventilation supply preventing pressurization of building	Large distance to offsite public	S1*	F2	
08.16.00/04	NPH	Seismic Event			Seismic Event	Potential toppling of glovebox (if seismically unqualified) Release of plutonium to room through failed glovebox, windows, seals, and penetrations Failure of E-4 and E-3 HEPA filters allowing release of glovebox 188-1 contamination to environment	Seismic switch shut down ventilation supply preventing pressurization of building	Large distance to offsite public	S2	F2	
08.16.00/05	NPH	Seismic Event			Seismic Event	Failure of Swagelok fitting allowing product collection jar to drop and break releasing plutonium oxide Failure of E-4 and E-3 HEPA filters allowing release of glovebox 188-1 contamination to environment	Seismic switch shut down ventilation supply preventing pressurization of building	Large distance to offsite public	S2	F2	
08.16.00/06	NPH	Seismic Event			Seismic Event	Puncture or toppling of 55 gallon drum of caustic from falling debris	Seismic switch shut down ventilation supply preventing pressurization of building	Large distance to offsite public	S1*	F2	
08.16.00/07	NPH	Seismic Event			Seismic Event	Spray leak of caustic from failed fitting or line	Seismic switch shut down ventilation supply preventing pressurization of building	Large distance to offsite public	S1*	F2	
08.16.01	NPH	Ash Fall			The effects of Ash Fall on the PFP are described in Chapter 3.0 of the PFP FSAR. In general, ashfall represents a roof loading concern, abrasive concern to moving equipment, and an electrical concern due to the conductivity of the ash. The addition of the calciner to Glovebox 188-1 does not significantly alter the effects of ashfall on PFP.				S0	F2	
08.16.02	NPH	Range Fire			A range fire can affect facility power supply may represent a fire threat to Building 234-5Z. The effects of fires have been analyzed in Chapter 9.0 of the PFP FSAR. The addition of Glovebox 188-1 does not significantly change the results of the existing fire analysis. Fires initiated internally to the glovebox are addressed in this Hazard and Operability Study.				S0	F3	
08.16.03	A1	Loss of Facility Electrical Power			The effects on the PFP due to a loss of facility power is not significantly altered by the addition of the calciner to Glovebox 188-1 to the PFP. The effects of loss of power to Glovebox 188-1 as an internal event are addressed in this Hazard and Operability Study.				S0	F3	

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

APPENDIX B

HYDROGEN CONCENTRATION VERSUS TIME FOR TRANSPORT CONTAINERS

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HYDROGEN CONCENTRATION VERSUS TIME FOR TRANSPORT CONTAINERS

Hydrogen Generation and Buildup

Three liter polybottles are used to transfer the plutonium nitrate solutions from Glovebox HC-227S to Glovebox 188-1. The bottles, filled in Glovebox HC-227S with a nominal 2.5 L of solution, have a double bag overwrap. The first plastic bag is placed over the bottle during bag-out from the glovebox. The second bag is placed over the bottle outside of the glovebox. The bottles are transported to Glovebox 188-1 in either PR Containers or in Isolated Transport Containers (ITC).

Temporary storage of these containers between departure from Glovebox HC-227S and arrival at Glovebox 188-1 is usually necessary. If the storage is prolonged, free hydrogen, generated by radiolytic decomposition of the solutions, first accumulates in the polybottles, moves by venting and diffusion to the plastic bags and finally into the transport containers. If the concentration of hydrogen in any space reaches the lower flammability limit (LFL), ignition of the gas is possible. A deflagration in a PR container presents a serious hazard from the ejected container lid to facility workers close to the container.

Hydrogen concentration is predicted by making a hydrogen mass balance on the gas phase in any given space, accounting for hydrogen generation by radiolysis and depletion by leakage and diffusion:

$$\text{accumulation rate} = \text{input rate} - \text{output rate} \tag{1}$$

where:

accumulation rate = hydrogen buildup rate in a volume, moles/s
input rate = hydrogen generation by radiolysis, moles/s
output rate = depletion by leakage and diffusion, moles/s

Formulating these components in terms of parameters of the system gives:

$$\text{accumulation rate} = V\frac{dC}{dt} \tag{1a}$$

$$\text{input rate} = G \tag{1b}$$

$$\text{output rate} = QC + DC \tag{1c}$$

where:

V = volume of gas space, cm^3
C = hydrogen concentration, moles/cm^3
G = hydrogen generation rate, moles/s
Q = headspace ventilation rate, cm^3/s
D = diffusional admittance, cm^3/s
t = time, seconds

Substituting equations 1a, 1b, and 1c into Equation (1), the differential equation that describes the buildup of concentration with time is:

$$V\frac{dC}{dt} = G - QC - DC \qquad (2)$$

The solution to Eqn.(2), under conditions where G, Q, D, and V are constants, is:

$$C = \frac{G[1 - \exp - (Q+D)t/V)]}{Q+D} \qquad (3)$$

The maximum in C occurs when t is large, causing the exponential term to go to zero. The maximum, or equilibrium concentration, is:

$$C = \frac{G}{Q+D} \qquad (4)$$

The terms in Equations (3) and (4) are numerically evaluated in the following section, to estimate the value of C.

G - Hydrogen Generation Rate

The plutonium nitrate solution radioisotopic inventory contains various Pu isotopes and Am-241. The hydrogen production rate due to radiolysis is given by the following equation:

$$m'(H_2) = \sum_{i=1}^{i=n} I_i \, E_i \, F \, G(H_2) \, A_i \, d \qquad (4a)$$

where:

$m'(H_2)$ = the hydrogen production rate, molecules/s
I_i = total inventory of the ith isotope, Ci/m^3
E_i = the average energy for the ith isotope, eV/disintegration
F = fraction of ionizing radiation absorbed by the target molecules
$G(H_2)$ = radiolysis constant, molecules H_2 produced/eV of ionizing radiation absorbed
A_i = average activity, Ci/m^3 of waste
d = conversion from Ci to Bq, 3.7×10^{10} Bq/Ci = 3.7×10^{10} disintegrations/s/Ci

Data and Assumptions

For the determination of hydrogen generation in the solution in the polybottles, information and assumptions used to describe the situation are as follows:

- The total quantity of plutonium nitrate solution is assumed to be 2.5 L in a 3 L polybottle. Calculations will also be performed for 1.0 L to see if generation rate, or available volume dominates in determining hydrogen concentration.

- The concentration of Pu in the polybottles can range from 50 g/L to 450 g/L. The bottles are normally filled to no more than 2.5 L. To give bounding hydrogen generation rates, the maximum concentration of 450 g-Pu/L is assumed, giving a total Pu quantity of 1,125 g Pu. Also, for the case mentioned in the first bullet, where the amount of nitrate solution is 1.0 L, at 450 g-Pu/L, the total Pu quantity will be 450 g.

- Isotopic composition of TRU in the nitrate solution is taken from Table 9-44 of the PFP FSAR (FDH 1999), for ^{240}Pu contents > 10%. The isotopes present and the percentage of each are given in column 1, Tables B-1 and B-2. The isotope ^{241}Pu is not included because of its low alpha activity.

- For this analysis, the radiolysis constants $G(H_2)$ for two acid concentrations of the plutonium nitrate solutions are used:

  - The hydrogen radiolysis constant, $G(H_2)$, for 8 M HNO_3 exposed to alphas with an energy of 5.3 MeV is 2.4×10^{-4} molecules H_2/eV (BNWL 1968).

  - $G(H_2)$ for 4 M HNO_3 exposed to alphas with an energy of 5.3 MeV is 5.9×10^{-4} molecules H_2/eV (BNWL 1968).

- F, the fraction of ionizing radiation absorbed by the target molecules, is conservatively assumed to be 1.0.

Tables B-1 (for 8 M nitric acid) and B-2 (for 4 M nitric acid) are used to solve Equation 4a, to determine the potential hydrogen production rate in the polybottle. The values for the variables E_i, $G(H_2)$, A_i, and d are provided, respectively, in the columns. The hydrogen

production rate from each isotope is calculated in the last column as the product of the respective values in each column of a row. The fourth column in the table gives the average energies for each isotope disintegration, values for the variable E_i, in Equation 4a. The average discharge energies for each isotope were determined using the RadDecay computer program (Grove 1990). Column 5 gives the radiolysis constants $G(H_2)$ used. Column 3 provides the specific activities for each isotope. The conversion constant (3.7×10^{10} Bq/Ci) for converting the activities from units of Ci to units of Bq, or disintegrations per second is not shown in the table, but is multiplied by the product of each of the values in a row. The fraction F, which is unity (1) for these solutions where no solids are present, is applied to the sum of the production rate.

Table B-1. Hydrogen Production Rate in 8 M Nitric Acid.

Isotope (%)	Isotope Inventory (g)	Isotope Activity (Ci/g)	Energy per Disintegration (eV/disintegration)	Radiolysis Constant (molecules H_2/eV)	Hydrogen Production Rate per m^3 (molecules/s-m^3)
Pu-238 (0.21%)	2.363	1.71×10^{1}	5.49×10^{6}	2.40×10^{-4}	1.97×10^{15}
Pu-239 (81.39%)	915.750	6.20×10^{-2}	5.10×10^{6}	2.40×10^{-4}	2.57×10^{15}
Pu-240 (16.34%)	183.375	2.27×10^{-1}	5.15×10^{6}	2.40×10^{-4}	1.90×10^{15}
Pu-242 (0.67%)	7.538	3.88×10^{-3}	4.91×10^{6}	2.40×10^{-4}	1.28×10^{12}
Am-241 (2.47%)	27.788	3.43×10^{0}	5.48×10^{6}	2.40×10^{-4}	4.64×10^{15}
Total	1136.814				1.11×10^{16}

Table B-2. Hydrogen Production Rate in 4 M Nitric Acid.

Isotope (%)	Isotope Inventory (g)	Isotope Activity (Ci/g)	Energy per Disintegration (eV/disintegration)	Radiolysis Constant (molecules H_2/eV)	Hydrogen Production Rate per m^3 (molecules/s-m^3)
Pu-238 (0.21%)	2.363	1.71×10^{1}	5.49×10^{6}	5.90×10^{-4}	4.84×10^{15}
Pu-239 (81.39%)	915.750	6.20×10^{-2}	5.10×10^{6}	5.90×10^{-4}	6.32×10^{15}
Pu-240 (16.34%)	183.375	2.27×10^{-1}	5.15×10^{6}	5.90×10^{-4}	4.68×10^{15}
Pu-242 (0.67%)	7.538	3.88×10^{-3}	4.91×10^{6}	5.90×10^{-4}	3.14×10^{12}
Am-241 (2.47%)	27.788	3.43×10^{0}	5.48×10^{6}	5.90×10^{-4}	1.14×10^{16}
Total	1136.814				2.72×10^{16}

The sum of the values in the last column of Table B-1 gives a total estimated hydrogen production rate, of 1.11×10^{16} molecules/s for an 8 M nitric acid solution. Dividing by Avogadro's number gives a molar flow rate of:

$$G = \frac{1.11 \times 10^{16} \text{ molecules/s}}{6.0235 \times 10^{23} \text{ molecules/mole}}$$

$$= 1.84 \times 10^{-8} \text{ moles } H_2\text{/s}$$

$$= (1.84 \times 10^{-8} \text{ moles/s})\left(\frac{22.4 \text{ L}}{\text{mole}}\right)\left(\frac{300 \text{ K}}{273 \text{ K}}\right) = 4.54 \times 10^{-7} \text{ L/s}$$

Similarly, for a 4 M nitric acid solution,

$$G = \frac{2.72 \times 10^{16} \text{ molecules/s}}{6.0235 \times 10^{23} \text{ molecules/mole}}$$

$$= 4.52 \times 10^{-8} \text{ moles } H_2\text{/s}$$

$$= (4.52 \times 10^{-8} \text{ moles/s})\left(\frac{22.4 \text{ L}}{\text{mole}}\right)\left(\frac{300 \text{ K}}{273 \text{ K}}\right) = 1.11 \times 10^{-6} \text{ L/s}$$

When the hydrogen production rate is calculated as above for 1.0 L of 4 M nitric acid solution, the sum of the values in the last column gives a total estimated hydrogen production rate, of 1.09×10^{16} molecules/s.

$$G = \frac{1.09 \times 10^{16} \text{ molecules/s}}{6.0235 \times 10^{23} \text{ molecules/mole}}$$

$$= 1.81 \times 10^{-8} \text{ moles } H_2\text{/s}$$

$$= (1.81 \times 10^{-8} \text{ moles/s})\left(\frac{22.4 \text{ L}}{\text{mole}}\right)\left(\frac{300 \text{ K}}{273 \text{ K}}\right) = 4.46 \times 10^{-7} \text{ L/s}$$

Since the hydrogen production rate for 1.0 L of 4 M nitric acid solution is much less than that for 2.5 L of 4 M solution, the value of 4.52×10^{-8} moles H_2/s (1.11×10^{-6} L/s) is used for all further calculations.

Calculation of Time to Reach Flammability

Since the greatest hazard associated with hydrogen buildup involves a potential deflagration that would eject the PR container lid, the hydrogen generation rate is used to determine the time it takes, assuming that the PR container is perfectly sealed, for the hydrogen

concentration in the PR container to become flammable. A fuel is flammable when the fuel to oxidant ratio is within a range where a flame front will propagate when ignited. A fuel/oxidant ratio where flame propagation is initially possible is termed the lower flammable limit (LFL). The top of the range is the point beyond which the ratio is too rich in fuel to burn and is termed the upper flammable limit (UFL). For hydrogen, the LFL is 4% and the UFL is 75%. In order to assure an adequate margin for safety, 25% of the LFL for hydrogen, or 1% hydrogen, is considered in this analysis as the lower criteria for the hazard of a hydrogen deflagration.

Information and assumptions used to determine the amount of material released are as follows:

- It is assumed that there is no leakage or diffusion from the PR container.
- Hydrogen is assumed to vent unimpeded through the vent path in the polybottle cap and the bags surrounding the polybottle into the PR container atmosphere. This gives the worst-case concentration of hydrogen in the PR container.
- The volume occupied by the polybottle is 3 L.

The internal volume (V_D) of the PR container, which has a 22.5 in. ID and a height of 33.25 in., is:

$$V_D = \pi[(11.25 \text{ in.})(2.54 \text{ cm/in.})]^2(33.25 \text{ in.})(2.54 \text{cm/in.})$$

$$= 216{,}644.52 \text{ cm}^3$$

$$= 216.64 \text{ L}$$

The internal volume (V_{ITC}) of the ITC, which has a 16 in. ID at the top tapering to 12 in. ID at the bottom and a height of 20 in., is:

$$V_{ITC} = \pi\left[\frac{(8 + 6\text{in.})}{2}(2.54 \text{ cm/in.})\right]^2(20 \text{ in.})(2.54 \text{cm/in.})$$

$$= 50{,}451.85 \text{ cm}^3$$

$$= 50.45 \text{ L}$$

Time (t) to reach 1 vol% (25% of LFL) in the PR container space when acid is 8 M is:

$$t = \frac{(216.6 \text{ L} - 3.0 \text{ L})(0.01)}{4.54 \times 10^{-7} \text{ L/s}} = 4.71 \times 10^6 \text{ s} = 54.5 \text{ days}$$

Time (t) to reach 1 vol% (25% of LFL) in the PR container space when acid is 4 M is:

$$t = \frac{(216.6\ L - 3.0\ L)(0.01)}{1.11 \times 10^{-6}\ L/s} = 1.92 \times 10^{6}\ s = 22.3\ days$$

Time (t) to reach 1 vol% (25% of LFL) in the ITC space when acid is 8 M is:

$$t = \frac{(50.5\ L - 3.0\ L)(0.01)}{4.54 \times 10^{-7}\ L/s} = 1.05 \times 10^{6}\ s = 12.1\ days$$

Time (t) to reach 1 vol% (25% of LFL) in the ITC space when acid is 4 M is:

$$t = \frac{(50.5\ L - 3.0\ L)(0.01)}{1.11 \times 10^{-6}\ L/s} = 4.28 \times 10^{5}\ s = 5.0\ days$$

Calculation of Hydrogen Concentration in Bag

The analysis, up to this point, has not considered the terms Q and D in equation 2, because it was assumed that no leakage or diffusion occurred to maximize the concentration for determination of minimum time to 25% of LFL. In order to analyze the accident identified in the hazards analysis (Section 3.2.2), involving the deflagration of hydrogen in the glovebox due to ignition of hydrogen in the bags surrounding the polybottle, the concentration of the hydrogen in the bags must be determined.

To determine the concentration, the complete form of equation 2 and its solution, equation 4, are used.

Q - Ventilation Rate

Ventilation could occur by atmospheric pressure fluctuations and by the outflow of gases. The flow admittance of leak paths is uncertain. It is possible that the drum, bags, and polybottle, inhales and exhales in response to atmospheric pressure fluctuations, but for the case of a double bagged polybottle, it is assumed that there is no ventilation from the bags.

D - Diffusional Admittance

Hydrogen has a high molecular diffusivity and can diffuse through porous boundaries at an appreciable rate. For the current exercise, a best estimate of diffusion rate is made for the exposed sides of the plastic bags. First, a simple version of Fick's law is assumed to apply for the diffusional transport of hydrogen within plastic:

$$N_A = D_H \frac{\Delta C}{\Delta X} \quad (5)$$

where:

N_A = diffusion flux of H_2, moles/cm^{2}s
D_H = molecular diffusivity of H_2 in plastic, cm^2/s
ΔC = concentration difference across the plastic walls, moles H_2/cm^{3}s
ΔX = thickness of plastic, cm

The total transport rate of hydrogen through the plastic bag is the flux multiplied by the cross-sectional area for transport:

$$D_P = AN_A = AD_H \frac{\Delta C}{\Delta X} \quad (6)$$

Equation (6) is expanded with the specific variables:

$$D_P = AN_A = AD_H \frac{C_P - C_A}{t} \quad (7)$$

where:

A = surface area of plastic bag, cm^2
N_A = diffusion flux of H_2, moles/cm^{2}s
D_H = diffusion coefficient of H_2 in plastic, cm^2/s
C_P = concentration of hydrogen on inner surface of plastic bag, moles H_2/cm^{3}s
C_A = concentration of hydrogen in air outside of the bag, assumed to be 0
t = thickness of plastic, cm

The concentration of hydrogen on the inner surface of the plastic is calculated using a Henry's solubility constant:

$$C_P = (S_H)(P_H)$$

where:

S_H = solubility constant of hydrogen in plastic, moles/cm^3-atm
P_H = partial pressure of hydrogen on inside of plastic, atm

The partial pressure of hydrogen can be calculated in terms of the concentration of hydrogen in the plastic, C, using the ideal gas law so that the term for the concentration becomes:

$$C_P = (S_H)(R)(T)(C)$$

where:

S_H = solubility constant of hydrogen in plastic, mol/cm^3-atm
R = ideal gas constant, atm-cm^3/mol-K
T = temperature of the gas, K
C = concentration of hydrogen in the plastic bag, mol/cm^3

If it is assumed that the concentration of hydrogen in the air outside the bag is 0, then $C_A = 0$. Substituting the term for C_P from above into Equation 7 with $C_A = 0$, gives:

$$D = AD_H S_H RT \frac{C}{t} \qquad (8)$$

Data and Assumptions

For the determination of the equilibrium hydrogen concentration in the plastic bag surrounding the polybottle, information and assumptions used to describe the situation are as follows:

- Hydrogen is assumed to vent unimpeded through the vent in the polybottle cap into the plastic bags surrounding the polybottle.
- It is assumed that there is no leakage from the bags, but that hydrogen can diffuse through the plastic. This gives the worst-case concentration of hydrogen in the bag.
- As noted above, the concentration of hydrogen in the space outside the bag, i.e. the space in the PR container, is assumed to be 0.
- Since the polybottle is contained within two bags, each with a wall thickness of 0.012 in., it is assumed that the effective wall thickness of the plastic around the polybottle is 0.024 in.
- For determination of the surface area of the bag, it is assumed that the bag is a cylinder 20 in. in length and 6 in. in diameter.
- Temperature of gases in the PR container is assumed to be 300 K.

- Ideal gas constant, R = 82.05 atm-cm^3/mol-K.
- Diffusion coefficient for hydrogen through plastic, $D_H = 1.45 \times 10^{-6}$ cm^2/s.
- The solubility of hydrogen in plastic is assumed to be similar to the solubility of hydrogen in neoprene, $S_H = 5.42 \times 10^{-6}$ mol/cm^3-atm.

The total area of the cylindrical bag which has a 6 in. (15.24 cm) OD and a height of 20 in. (50.80 cm) is:

$$A = 2\pi(15.24/2 \text{ cm})^2 + \pi(15.24 \text{ cm})(50.80 \text{ cm})$$

$$= 2.80 \times 10^3 \text{ cm}^2$$

Substituting into Equation 8 to determine the diffusion coefficient in terms of C,

$$D = \frac{(2.8 \times 10^3 \text{ cm}^2)(1.45 \times 10^{-6} \text{ cm}^2/\text{s})(5.42 \times 10^{-6} \text{ mol/cm}^3\text{-atm})(82.051 \text{ atm-cm}^3/\text{mol-k})(300 \text{ K}) C}{(0.024 \text{ in.})(2.54 \text{ cm/in.})}$$

$$= (8.89 \times 10^{-3} \text{ cm}^3/\text{s})\, C$$

With the assumption that there is only diffusion of hydrogen from the bag, no leakage, and using the above value for D, Equation 4 becomes:

$$C = \frac{G}{D} = \frac{G}{(8.89 \times 10^{-3} \text{ cm}^3/\text{s})}$$

Since the hydrogen generation rate (G) for 4 M solution was determined to be 4.52×10^{-8} mol/s, the concentration C in the plastic bag becomes:

$$C = \frac{4.52 \times 10^{-8} \text{ mol/s}}{8.89 \times 10^{-3} \text{ cm}^3/\text{s}}$$

$$= 5.08 \times 10^{-6} \text{ mol/cm}^3$$

Since it was assumed that hydrogen vents from the polybottle unimpeded into the plastic bag, the concentration inside the bottle and the bag are the same. The internal volume of the bag and the

polybottle headspace minus the 2.5 L of nitrate solution (volume of polybottle walls, lid, etc., are conservatively neglected) is:

$$V_{bag} = \pi(15.24/2 \text{ cm})^2(50.80 \text{ cm}) - 2500 \text{ cm}^3$$

$$= 6.77 \times 10^3 \text{ cm}^3$$

$$= 6.77 \text{ L of hydrogen}$$

The quantity of hydrogen in the bag and polybottle is then:

$$5.08 \times 10^{-6} \text{ mol/cm}^3 \times 6.77 \times 10^3 \text{ cm}^3$$

$$= 3.44 \times 10^{-2} \text{ moles hydrogen}$$

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APPENDIX C

RADIOLYSIS OF PU NITRATE SOLUTIONS IN PR CAN DRUMS

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B & W Hanford Co.

a McDermott company

To:	M. A. Gibson	T5-55		
From:	T. D. Cooper, Plutonium Finishing Plant Project	T5-12	File No. or Ref.:	15F00-99-079
Subj:	GAS GENERATION IN PRODUCT RECEIVER CAN DRUMS		Date:	June 17, 1999

References:

(1) HNF-2061, Revision 0, *Plutonium Finishing Plant Project: Gas Generation from Plastics during Vault Storage via Radiolysis Reactions*, dated 1999.

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(3) Kuno Y., H. Tetsuro, and J. Masui, *Radiolytically Generated Hydrogen and Oxygen from Plutonium Nitrate Solutions*, J. Nuclear. Science and Tech., 30:9, pp 919-925, dated 1993.

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Introduction

The Plutonium Reclamation Facility (PRF) has stored plutonium nitrate-nitric acid liquid solutions in Product Receiver (PR) Drums in Room 236 for several years. Storing these liquids represents a hazard to the plant since they are corrosive, contain plutonium, and are continuously generating hydrogen-oxygen gas mixtures through radiolysis that may potentially reach flammable limits.

It is desirable to open these drums and remove the liquids for stabilization. Safety concerns must be addressed in opening these drums since a hydrogen-oxygen reaction in the drum vapor space could potentially threaten worker safety.

To adequately assess the potential for a hydrogen-oxygen reaction within the drum vapor space, the hydrogen and oxygen concentrations must be known. Since we have no analytical data, Steady state hydrogen concentrations were calculated from the radiolytic hydrogen production rates and the drum breathing rates. A finite difference model was created to follow the hydrogen concentration as a function of time to verify the creation of a steady state. The results of the steady state calculations and of the finite difference model are presented in a later section. A detailed description of the finite difference model is provided in Attachment 1.

Gas Generation Rates - The radiolytic gas generation rates (G values) depend upon the types of radiation particles, their integrated energies, the chemical composition of the solutions, and the chemical composition of the containers. Other studies (Reference 1) have shown that alpha radiation from plutonium dominates the production of radiolytic gases from hydrogenous substrates. The integrated alpha energies can be calculated by summing the alpha energies obtained from each isotope. This isotope energy is calculated from the plutonium mass, its isotopic distribution, the decay constants for each isotope, and the isotope decay energy.

G values represent the number of gas molecules produced per 100 eV of radiolytic energy absorbed by the substrate. Literature sources for G values in actinide-nitric acid solutions for hydrogen, oxygen, nitrogen, and nitric oxide are given by Savel'ev et. al. (Reference 9), Sheppard (Reference 8), Bibler (Reference 7), and Kuno et al. (Reference 3). The G values in all of these reports are consistent except for oxygen. Sheppard shows oxygen G values decreasing with increasing nitric acid concentration, while the other three show a reverse trend. Despite this discrepancy, Sheppard's G values are used in this report. The reason Sheppard's oxygen G values are accepted is that our solutions are stored in plastic bottles within the PR containers. Sheppard shows that oxygen G values are strongly and negatively affected by the presence of plastic.

G values are not truly constants. They are simply "snapshots" of the gas production efficiency for a given set of conditions. Fortunately alpha driven G values tend to be much less sensitive than beta-gamma G values to radiolysis parameters.

The nitric acid concentration has a powerful negative influence on hydrogen G values. As an example, the hydrogen G value in pure water is 0.45, while the hydrogen G value in 8 M nitric acid is 0.024. The concentration of nitric acid is not known for all of the PR cans in PFP. It is

known that many contain Purex plutonium solutions that were shipped with nitric acid in the 7-8 M range.

Gas Leak Rates - The plastic bottle containing the plutonium solution has a hole in the top designed to vent the bottle. The plastic bag surrounding the bottle uses a "horse-tailed" seal that will not hold gas pressure. Therefore, the first real barrier that controls gas pressure is the PR can drum seal.

Two studies were performed and published on drum leak rates. Cooper's tests (Reference 4) show average drum leak rates ranging from 143 to 274 ml/min over one year at five psig for three drums. These tests were performed on drums with bolted ring closures tightened to 40 feet per pound. No tests were performed on PR can drums with snap ring closures.

These tests used three new drums and lids with Neozan gaskets. Neozan is a plastic gasket material fabricated from a mixture of butadiene and styrene. The exact mixture was not known.

The lid for drum A was removed and replaced on a periodic basis to simulate wear on the gasket. The lids on drums B and C were locked into place and not disturbed for the entire year to allow "cold flow" of the gasket material to occur. Drum C contained a one-liter open beaker of 12 M HNO_3-0.3 M HF to simulate a corrosive environment. Cooper's leak rates at five psig are included as Attachment 2. Cooper's lowest average leak rate occurred on drum B and was 143 cc/min.

Ludowise (Reference 5) also measured leak rates for five drums. The first four contained vent clips and the fifth did not and therefore is comparable to Cooper's tests. Ludowise's fifth non-vented drum leaked at 837 cc/min at five psig. Ludowise's four vented drums leaked approximately four to five times faster than the unvented drum.

Atmospheric Pressure Variations - In calculating the gas flow through leak paths in the drum seal, it is necessary to know both the drum internal pressure, and the external atmospheric pressure. The internal pressure is calculated from the gas inventory in the drum. The external pressure distribution was determined from Crippen's (Reference 2) results.

It would be desirable to reconstruct the natural atmospheric pressure excursion amplitudes and frequencies and apply these to this model, however that can only be performed from the raw data records and these are not readily available. Crippen's report does contain a description of the distribution of pressure fluctuations per hour over a four-year interval. Since the pressure fluctuations are random, an average hourly pressure fluctuation (0.0003768 atmospheres) was calculated and applied alternately in a plus and minus direction such that the drum experienced a constant breathing frequency.

The pressure amplitudes are smaller and the breathing frequency is higher for this model as compared to nature. The justification for the model is that the integral of pressure change versus time is the same for both the model and nature over long periods of time.

Equivalent Leak Path Area - Using the slowest experimentally measured leak (143.1 mls/min at 5 psig, Darcy's formula was used to calculate an equivalent hole area (0.000229448 cm2). Edge effects and internal resistance were neglected since the same type calculation is reversed in the model to estimate leak rates from known pressure differentials. Edge effects and internal resistance parameters therefore cancel over the entire calculational cycle.

Leak Rates- Using the equivalent hole size calculated above and assuming an intitial pressure differential, one can calculate the flow rate by Darcy's formula. This is done in the finite difference model so that flow rates and pressure differentials can be updated on whatever time frequency is desired. This model shows that starting with Crippen's average pressure swing, the pressures equalize within approximately 30 minutes and that maximum gas flow is achieved for each hourly pressure change i.e. we are not limited by too small of an equivalent hole. Another argument to show the equivalent hole size is not a choke point is contained in Table 1.

Table 1- Gas Flow Through PR Can Drums

dP atm	Ft^3/sec	mole/yr
0.0003678	6.239E-05	2282
0.00003678	6.239E-06	228
0.000003678	6.239E-07	22.8

Table 1 shows that when the pressure differential drops to 1% of Crippen's average hourly pressure swing, the gas flow through the drums is still larger than that required for the annual flow (14.4 g-moles/yr).

Once it is understood that that maximum flow is achieved for each pressure swing, one may calculate the annual flow by calculating the hourly flow and multiplying by the number of hours per year. This annual flow will be used in a later section to calculate the steady state hydrogen gas concentration

Calculation of Steady State Hydrogen Concentrations

Two PR cans were chosen for this analysis. The first PR can L1050 was filled with weapons grade Pu nitrate several years ago and stored in Room 236. The contents of L1050 were intended to supply Pu nitrate to the prototype vertical calciner, but were caught in the stop work order. This PR can is fairly representative of many other PR cans in the PFP inventory.

The second is PR can PN-48-02-02-003 and is intended to represent a "worst case". The plutonium nitrate in this can was separated from contaminants in 1988 at the Purex plant, and has been stored at PRF since. The contents of this can have the highest alpha activity of any PR can in PRF for which complete isotopic data is available. The Pu-240 isotopic distribution was adjusted slightly higher to account for the fact that other PR can solutions exist for which only partial isotopic data is available and which possess slightly higher Pu-240 concentrations.

A description of the material contained in the PR cans follows in Table 2.

Table 2- Isotopic Distribution within Selected PR Solutions

ID No.	L1050	PN-48-02-02-003	PN-48-02-02-003 adjusted**
Grams Pu	581	3180	3180
Pu g/l	232	341	341
SpG	1.5291		
HNO_3	8.64		
Pu-238 wt%	0.0334	0.067	0.067
Pu-239 wt%	93.4966	86.778	85.282
Pu-240 wt%	6	11.667	13.163
Pu-241 wt%	0.4337	1.376	1.376
Pu-242 wt%	0.036		
Am-241 wt%	0.2659	0.122*	0.122

* assigned by mass balance
** adjusted Pu-240 concentration to create an "isotopic worst case" PR can solution

From the data in Table 1, the gas production rates were calculated as recorded in Table 3.

Table 3- Gas Generation Rates

	L1050	PN-48-02-02-003
alpha ev/yr	3.30E26	2.36E27
G H_2/ev*	0.00024	0.00024
G O_2/ev*	0.00009	0.00009
G N_2/ev*	0.00005	0.00005
H_2 g-mol/yr	0.128	0.940
O_2 g-mol/yr	0.0479	0.352
N_2 g-mol/yr	0.0266	0.196

* Sheppard JC, "Alpha Radiolysis of Plutonium (IV)-Nitric Acid solutions," BNWL-751, 1968

Using the gas generation rates in Table 3, and an average hourly pressure fluctuation (as calculated from Crippen's data, one may calculate the steady state hydrogen concentration:

Annual Gas Flow Rate

n(Moles gas) = PV/RT

dn = dP(V/R*T)

dn/dt = 0.0003768 (atm/hr)* 55gal*3.875(L/gal)/(0.08205(L-Atm/M-K)*298K)

= 0.003284moles gas/hr

= 14.4 moles gas/yr

Case 1- 8 Molar HNO3, Container L1050, No Organic Solution

The number of moles of gas produced radiolytically must also be added to the gas flow induced by atmospheric pressure swings. Total gas flow for this case is then

14.4 + 0.2 = 14.6 g-moles/yr

At the steady state:

The production rate of hydrogen - the diffusion rate must equal the mass flow loss rate.

The diffusion rate can be calculated as follows:

Diffusion Through Equivalent Hole

g-mole/hr = K*A*dc/dx

= 0.712 * 3600*0.000229448 cm^2 * ((0.00875/24464-0)/(2.54/8)

=6.63E-07

Diffusion Through Drum Gasket

is calculated first by calculating the solubility of hydrogen in the inner gasket surface

g-mole/cc = 9.01E-06 g-mole/cc/atm* 0.00875 atm =7.88E-08 g-mole/cc

g-mole/hr = 0.00000431*3600*(3.1416*23*2.54*1/16*2.54)*
(7.88E-08-0)/(2.54*1/8)

= 1.122E-07

Total H_2 diffusion rate = 6.625E-07 + 1.122E-07

= 7.747E-07 g-mole/hr

=6.79E-03 g-mole/yr

To finish the calculation:

0.128 g-moles/yr -0.00679 g-moles/yr = 0.12 g-moles H_2/yr

g-moles H_2/g-moles gas = 0.121 g-moles/yr/14.6 moles gas/year

= 0.00828 g-moles H_2/g-moles gas

= 0.828 % H_2

Case 2- 8 Molar HNO3, Container PN-48-02-02-003, no Organic Solution

The number of moles of gas produced radiolytically must also be added to the gas flow induced by atmospheric pressure swings. Total gas flow for this case is then

14.4 + 1.5 = 15.9 g-moles/yr

At the steady state:

The production rate of hydrogen - the diffusion rate must equal the mass flow loss rate.

The diffusion rate can be calculated as follows:

Diffusion Through Equivalent Hole

mole/hr = K*A*dc/dx

= 0.712 * 3600*0.000229448 cm^2 * ((0.0592/24464-0)/(2.54/8)

=7.59E-07

Diffusion Through Drum Gasket

is calculated first by calculating the solubility of hydrogen in the inner gasket surface

g-mole/cc = 9.01E-06 g-mole/cc/atm* 0.0592 atm =5.33E-07 g-mole/cc

g-mole/hr = 0.00000431*3600*(3.1416*23*2.54*1/16*2.54)*
(5.33E-07-0)/(2.54*1/8)

= 4.48E-06

Total H_2 diffusion rate = 7.59E-07 + 4.48E-06

= 5.24E-06 g-mole/hr

=4.59E-02 g-mole/yr

To finish the calculation:

0.940 g-moles/yr -0.0459 g-moles/yr = 0.894 g-moles H_2/yr

g-moles H_2/g-moles gas = 0.894 g-moles/yr/15.9 moles gas/year

= 0.0563 g-moles H_2/g-moles gas

= 5.63 %H_2

Factors that can increase the hydrogen generation rate as compared to those calculated above are:

- Decreased nitric acid concentration. The G values for hydrogen production increase by a factor of 20 as the nitric acid decreases from 8 to 0 M.
- Slower leak rates
- Increased radiolytic energy
- The presence of organic compounds

To establish a more conservative case, the following parameters were established:

- the worst case isotopic concentrations i.e., 13.1% Pu-240 were used
- a 4 M nitric acid concentration was assumed
- 1 vol % organic was included in the model
- The organic was assumed to be a 20 vol % TBP-CCl_4 mixture.

A hydrogen G-value of 0.5 as measured by Rigg and Wild (Reference 9) for wet TBP-HNO_3 mixtures was used to estimate the hydrogen generation rate in the organic phase. This calculation showed the initial hydrogen generation rate in the organic phase was approximately 20 % of that occurring in the aqueous phase. The hydrogen generation rates in both organic and aqueous phases were summed to prepare Table 4 below.

Table 4- Gas Generation Rates*

	L1050	PN-48-02-02-003
alpha ev/yr	3.30E26	2.36E27
G H_2/ev*	0.07	0.07
G O_2/ev*	0.04	0.04
G N_2/ev*	0.005	0.005
H_2 g-mol/yr	0.41	2.92
O_2 g-mol/yr	0.22	1.57
N_2 g-mol/yr	0.0274	0.19

* 4 Molar HNO_3, 1% CCL4 containing 20% TBP
** Sheppard JC, "Alpha Radiolysis of Plutonium (IV)-Nitric Acid solutions," BNWL-751, 1968

Using the results in Table 4, one may calculate steady state hydrogen concentrations as follows:

Case 3- 4 Molar HNO3, Container L1050, 1% Organic
The number of moles of gas produced radiolytically must also be added to the gas flow induced by atmospheric pressure swings. Total gas flow for this case is then

14.4 + 0.66 = 15.1 g-moles/yr

At the steady state:

The production rate of hydrogen - the diffusion rate must equal the mass flow loss rate.

The diffusion rate can be calculated as follows:

Diffusion Through Equivalent Hole

mole/hr = K*A*dc/dx

= 0.712 * 3600*0.000229448 cm^2 * ((0.0272/24464-0)/(2.54/8)

=2.06E-06 gm/hr

Diffusion Through Drum Gasket

is calculated first by calculating the solubility of hydrogen in the inner gasket surface

g-mole/cc = 9.01E-06 g-mole/cc/atm* 0.00875 atm =7.88E-08 g-mole/cc

g-mole/hr = 0.00000431*3600*(3.1416*23*2.54*1/16*2.54)*
(2.45E-07-0)/(2.54*1/8)

= 3.49E-07

Total H_2 diffusion rate = 3.49E-07 + 2.06E-06

= 2.41E-06 g-mole/hr

= 2.11E-02 g-mole/yr

To finish the calculation:

0.41 g-moles/yr -0.0211 g-mole/yr = 0.39 g-moles H_2/yr

g-moles H_2/g-moles gas = 0.39 g-moles/yr/15.1 moles gas/year

= 0.0272 g-moles H_2/g-moles gas

= 2.72 % H_2

Case 4- 4 Molar HNO3, Container PN-48-02-02-003, 1% Organic
The number of moles of gas produced radiolytically must also be added to the gas flow induced by atmospheric pressure swings. Total gas flow for this case is then

14.4 + 4.7 = 19.1 g-moles/yr

At the steady state:

The production rate of hydrogen - the diffusion rate must equal the mass flow loss rate.

The diffusion rate can be calculated as follows:

Diffusion Through Equivalent Hole

mole/hr = K*A*dc/dx

= 0.712 * 3600*0.000229448 cm^2 * ((0.153/24464-0)/(2.54/8)

=1.16E-05 gm/hr

Diffusion Through Drum Gasket

is calculated first by calculating the solubility of hydrogen in the inner gasket surface

g-mole/cc = 9.01E-06 g-mole/cc/atm* 0.153 atm = 1.38E-06 g-mole/cc

g-mole/hr = 0.00000431*3600*(3.1416*23*2.54*1/16*2.54)*
(1.38E-06-0)/(2.54*1/8)

= 1.97E-06

Total H_2 diffusion rate = 1.16E-05 + 1.97E-06

= 1.36E-05 g-mole/hr

= 1.19E-01 g-mole/yr

To finish the calculation:

2.92 g-moles/yr -0.119 g-mole/yr = 2.80 g-moles H_2/yr

g-moles H_2/g-moles gas = 2.8 g-moles/yr/19.1 moles gas/year

= 0.147 g-moles H_2/g-moles gas

= 14.7 % H_2

In cases 1-4, steady state hydrogen calculations were used. Since the PR can drums have been stored for 10 or more years in most cases, we strongly suspect that the steady state has been achieved. To verify this assumption, a finite difference model was run for case 4. The results appear in Figure 1.

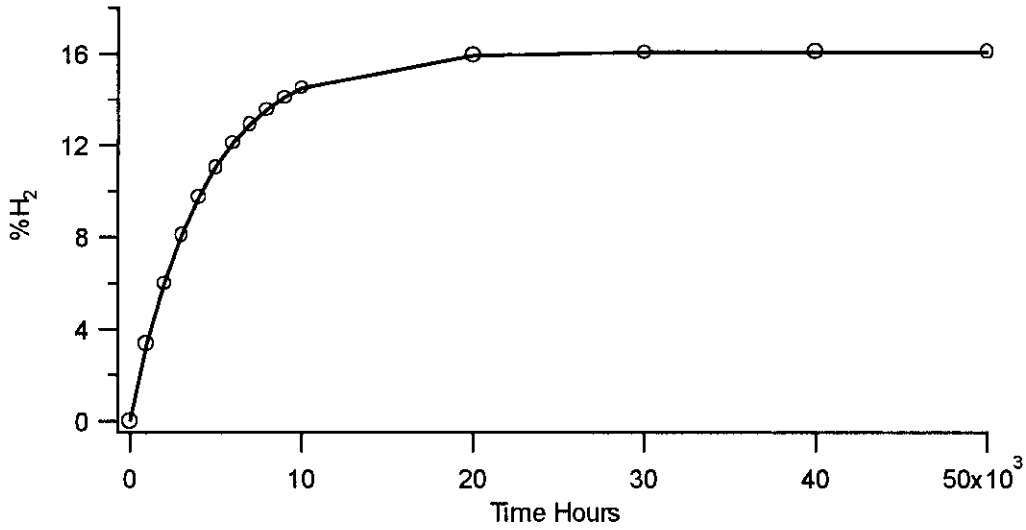


Figure 1- Hydrogen Concentrations in Container PN-48-02-02-003 (Case 4)

Figure 1 shows that the steady state is achieved within 20,000 hours or about 3 years.

It should be understood that the primary factors responsible for the high hydrogen concentrations are high G values resulting from the low nitric acid concentration and high total alpha radiolytic energy.

The results for cases 1 through 4 were obtained using measured leak rates for non-vented drums. Since drums with vent clips have openings at least 10 times larger than those estimated above, it is safe to say that no flammable hydrogen concentrations will be found in vented drums. This statement applies to both snap ring and bolt ring closures due to the design and function of the vent clip.

To be extremely conservative, a bounding hydrogen concentration was calculated for PR cans L1050 and PN-48-02-02-003 assuming no gross leaks and only diffusion through a neoprene gasket. The results are presented in Figure 2.

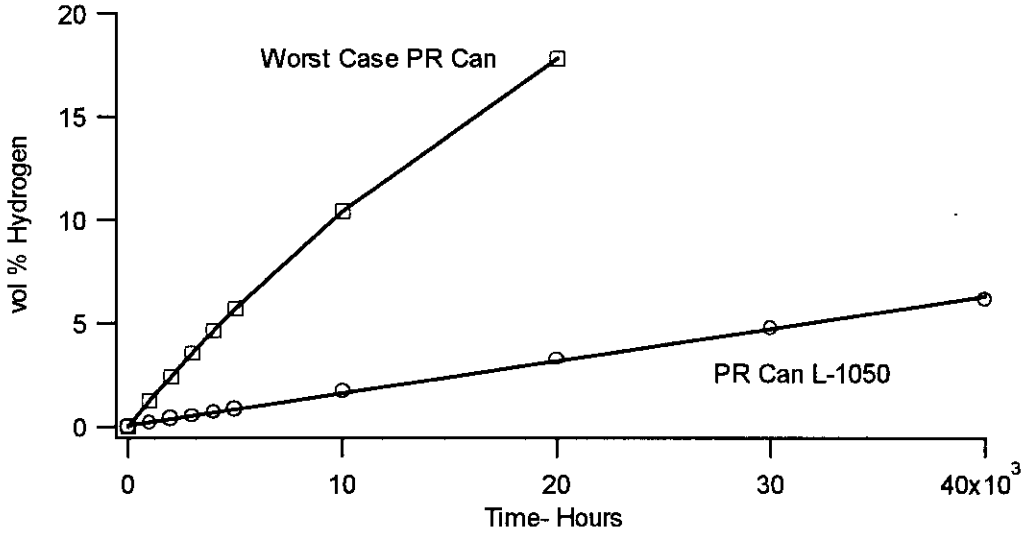


Figure 2- Hydrogen in PR Can Drums Assuming Diffusion Through Gaskets and 8 M HNO_3

For this "diffusion only" case, the worst case fuels grade PR can drum reaches the flammable limit in approximately 3,000 hours and reaches the detonable limit in 20,000 hours. The total pressure within the worst case PR can drum is 1.4 atmospheres at 20,000 hours.

The weapons grade PR can drum reaches the flammable limit in 20,000 hours and reaches the detonable limit in 109,000 hours. The total pressure within PR can drum L1050 is 1.05 atmospheres at 20,000 hours.

Marchetti's (Reference 6) report contains a description of an apparent burn of flammable gases upon opening an L-10 container in 1976. A loud report was heard, the operator saw flames emanating from the drum as it was being opened, and his eyebrows were singed. The operator was grossly contaminated in the incident. This proves that these storage drums can indeed reach a flammable gas concentration, however one cannot ascertain from Marchetti's report the radiolytic and chemical composition of the liquid, whether organic solutions were present, and the leak rate of the drum in question was never measured.

Summary

This study has shown that bolted ring PR can drums with vent clips will not reach a flammable hydrogen concentration under "worst case" conditions. This is primarily because the vent clips increase the vent hole area by roughly a factor of 10 over the natural hole area. Although snap

ring closures were not tested, it is believed the vent clips will function as well on snap ring closures as bolted ring closures.

Non-vented but leaking PR can drums (as defined by 4 test drums with bolted ring closures) only reach flammable hydrogen concentrations for PR cans with the highest isotopic energies. Since most of our drums contain 6-8 molar nitric acid and are not at the worst case condition, this implies that the vast majority of non-vented PR can drums do not contain flammable hydrogen concentrations, although one cannot exclude the possibility of a flammable drum atmosphere.

Non-vented, non-leaking drums that can lose hydrogen only through diffusion are not known nor believed to exist in our inventory. Nevertheless, if one assumes such a case, one may calculate a gaseous diffusion rate through a neoprene gasket that may reach a flammable hydrogen concentration within 3,000 hours and a detonable concentration within 20,000 hours under "worst case" conditions. The "diffusion only" case is considered extremely unlikely, however insufficient data exist to define the exact probability.

Due to the uncertainties in nitric acid concentrations, drum lid leak rates, and organic concentrations and due to the demonstrated ability of at least one solution storage drum to reach a flammable hydrogen concentration, it seems prudent to accept flammable hydrogen concentrations as a bounding condition for PR can drums without vent clips.

jr

Attachments 2

Detailed Model Description

The data used in this model description apply to "case 2".

1) Initialization of the model at time 0

Radiolytic Energy

meV Pu-238 is determined as follows:

Wt% Pu-238 = 0.067

Grams Pu = 3180

g-moles Pu-238 = 0.00067*3180/238 = 0.00895201

atoms Pu-238 present initially = 8.95E-03*6.023E23 = 5.39E21

Atoms Pu-238 surviving in 1999 = 5.39E21*Exp(-0.00802*11) = 4.93E21

(11 yrs represents the time since the actinides were separated in Purex)

Decay Rate dpy = $-\lambda N$ = -0.00802*4.93E21 = 3.96E19

MeV per year = dpy*5.592 = 2.21E20 MeV/yr

Similarly the alpha energy from the other isotopes in solution can be calculated and summed.

Gas Production Rates

If all of the alpha energies for each isotope are so calculated and summed, the total alpha energy absorption rate for the worst case is 2.36E27 eV/yr. Using Sheppard's 0.024 G value for 8 M HNO_3 solutions:

H_2 molecules/yr = 2.36E27*0.00024 H_2/ev = 5.66E23

g-mole H_2/hr = (5.66E23/6.023E23)/(365.25*24) = 1.07E-04

g-mole H2/yr = 0.94

Similarly the gas production rates for oxygen, and nitrogen may be calculated:

g-mole O_2/hr = 4.02E-05

g-mole N_2 = 2.19E-05

The NO production rate was not included because of the small G value indicating that it is not significant.

Gas Composition in the Drum

Next, the gas composition in the drum is initialized.

Starting with the standard dry air composition: N_2 = 78.084 vol %, O_2 = 20.946 vol%, CO_2 = 0.033 vol%, Ar = 0.934 vol%, and including the 10.7 torr vapor pressure of water over an 8 M nitric acid solution:

vol % H_2O = 100*10.7/760 = 1.4079

vol% N_2 = 78.084*(100-1.4079)/100 = 76.9847

vol% O_2 = 20.946*(100-1.4079)/100 = 20.6511

vol% CO_2 = 0.033*(100-1.4079)/100 = 0.03254

vol % Ar = 0.934*(100-1.4079)/100 = 0.92085

g-m H_2 = 0

g-m O_2 = (0.206511*55 gal*3.785 L/gal*1 atm)/(0.08205 L-atm/mole-°K*298 °K) = 1.7582

g-m N_2 = (.769847*55*3.785*1)/(0.08250*298) = 6.5545

g-m CO_2 = (0.0003254*55*3.785*1)/(0.08250*298) = 0.00277

g-m Ar = (0.0002085*55*3.785*1)/(0.08205*298) = 0.078401

g-m H_2O = (0.014079*55*3.785*1)/(0.08250*298) = 0.119868

Gas Concentration in the Drum

H_2 g-m/cc = 0/(55gal*3.785 liters/gal*1000 cc/liter) = 0

O_2 g-m/cc = 1.7582/(55*3.785*1000) = 8.4460E-06

Similarly:

N_2 g-m/cc = 3.1485E-05

CO_2 g-m/cc = 1.3306E-8

Ar g-m/cc = 3.766E-07

H_2O g-m/cc = 5.7581E-07

From the gas concentrations one may calculate the gas pressures:

H_2 atm. = 0*1000*0.08205*298 = 0

O_2 atm = 8.4460E-06*1000*0.08205*298 = 0.207

N_2 atm. = 3.1485E-05*1000*0.08205*298 = 0.770

CO_2 atm. = 1.3306E-08*1000*0.08250*298 = 3.25E-04

Ar atm. = 3.7661E-07*1000*0.082305*298 = 9.21E-03

H_2O atm. = 5.7581E-07*1000*0.08205*298 = 1.41E-02

Internal Pressure = $H_2 + O_2 + N_2 + CO_2$ + Ar + H_2O = 1 atm.

External Pressure is initialized at 1 atm.

Initial Pressure differential should be 0 but is calculated at -2.95776E-05 due to rounding of numbers.

Diffusion of Hydrogen through the Neoprene Gasket

The solubility of hydrogen is 9.01E-06 g-m/cc/atm in neoprene.

The equilibrium concentration at the inner face is:

9.01E-06*H_2 partial pressure = 0

Diffusion rate through neoprene is:

g-m H_2/hr = k*A*dc/dx

= 0.00000431cm^2/sec*3600sec*(3.1412*23 in.*2.54 cm/in*1/16 in. *2.54 cm/in.)*(H_2 inner- H_2 outer)/(1/8*2.54) = 0

The diffusion rates of the other gases through neoprene were ignored since the diffusion coefficents and pressure differentials are smaller than for hydrogen.

Gaseous Diffusion through Equivalent Hole

An equivalent hole through the gasket is calculated from experimental pressure leak-rate correlations.

An initial flow rate of 143.1 cc/min is assumed from the slowest flow rate measured by Cooper through a drum gasket at 5 psig.

$ft^3/sec = 143.1/60*(1/2.54)^3*(1/12)^3 = 8.42255E-05$

Now from Darcy's equation for the flow of a compressible gas through an orifice:

$$\text{flow rate} = YCA(2g * \Delta P)/\rho$$

where:

Y = an expansion factor = 0.85 from Crane's handbook
C = Flow coefficient dependent upon the Reynolds number = 0.6 in this application
A = equivalent hole area
g = acceleration of gravity
ΔP = pressure differential
ρ = gas density

Solving for A:

$A = 8.42255\ ft^3/sec/(0.85*0.6*(2*32.2\ ft/sec^2*144\ in.^2/ft^2*5\ lb/in.^2/0.1037\ lb/ft^3)^{0.5}$

$= 2.46975E-07\ ft^2 = 2.29448E-04\ cm^2$

Now the diffusion of gases through this equivalent hole may be calculated:

H_2 g-m/hr = 0.712 cm^2/sec*3600 sec/hr*2.29448E-04 cm^2*(H_2 inner conc – H_2 outer conc)/0.3175 cm

= 0.712 cm^2/sec*3600 sec/hr*2.29448E-04 cm^2*(0-0)/0.3175 cm = 0

The diffusion rate of the other gases through the equivalent hole are calculated similarly.

Gross Leak Rates

The gross leak rate is calculated through Darcy's formula, the equivalent hole size, and the pressure differential between the drum inner pressure and the external atmosphere.

total g-m/hr = 0.6*0.85*2.29448E-04 cm^2*3600 sec/
24,464 cc/g-m*(2*981.4 cm/sec^2*dp/0.0012845)$^{0.5}$
= -0.00372117

Once the gross leak is established, the partial leaks for each gas species can be proportioned according to their molar concentrations.

The reader may note that internal resistance and edge effects were ignored in this calculation for two reasons:

- The number and dimensions of the actual holes are unknown and therefore such effects are impossible to estimate.
- Since we define the equivalent hole from pressure-leak rate measurements, and then use the equivalent hole and pressure differential measurements to calculate the leak rate, the entire calculation is cyclical and such effects cancel out.

2) Reiteration of the Model for the first Hour

The gas inventory at the beginning of the first hour is taken to be the same as calculated above for the initialization. Gas production rates and gas leakage and diffusion rates are calculated.

3) Reiteration of the Model for the Second and Succeeding Hours

During the second and all succeeding hours, the initial gas inventory is established by summing the previous inventory with the production and dissipation rates calculated during the previous hour.

Gas Leak Rates in cc/min

Time Days	Drum A	Drum B	Drum C
0	236	130	213
1	248	142	201
4	331	130	224
8	224	130	201
14	236	154	189
21	295	165	201
28	224	142	236
32	189	154	342
42	248	95	213
52	298	198	284
60	223	153	293
68	272	147	295
73	272	147	295
81	280	120	160
87	428	93	296
93	422	150	299
151	243	146	282
234	292	170	303
366	253	153	285
average leak rate	274.4	143.1	253.3

data from Cooper's 1988 letter report

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APPENDIX D

Evaluation of Compressed Air on the Confinement Capability of Laboratory Gloveboxes

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Evaluation of Compressed Air on the Confinement Capability of Laboratory Gloveboxes.

Glovebox pressurization could cause a release of plutonium with the potential for inhalation by workers in the same room. A release requires breaching a HEPA filter where air normally flows into the glovebox from the room. Pressurization of a glovebox is normally assumed possible only if pressurized gases are forced into the glovebox. Generation of gases by chemical reaction is assumed to be too slow to present a problem under credible operating conditions.

Scenario. Most laboratory gloveboxes are equipped with compressed gas sources where the compressed gas can be air or an inert gas. Dry air gloveboxes are designed such that a failure in the E-4 exhaust system results in a shutdown of the dry air source. Other sources of compressed gas are not interlocked to the E-4 system. In the event of a failure in the E-4 system the compressed gas will continue to be supplied to the glovebox unless it is manually shut off. This analysis treats the consequences of an event where the E-4 system fails and a compressed gas source continues to supply the glovebox due to failure of compressed air lines within the glovebox or from failure of the compressed air supply regulator.

At risk are the glovebox inlet HEPA filters. Glovebox 188-1 in Room 188 has five inlet HEPA filters with dimensions of 8 in. x 8 in. x 5 7/8 in. Rated flow capacity of each filter is 50 scfm. For these filters, rated flow corresponds to approximately 1.3 in. w.g. pressure drop. Typically, 10 in. w.g. is the maximum ΔP a filter can maintain (BWHC 1999). Compressed air is available to Glovebox 188-1 through one outlet which is a 3/8 in. OD, 0.305 in. ID tubular source at a maximum of 90 psig (104.7 psia).

In the event of a failure of the E-4 exhaust system, the maximum instantaneous flow rate from a compressed air line into the glovebox, venting it through a circular orifice of 0.305 in. ID, can be calculated from Equation 3-22 of Crane (1969) for flow of compressible fluids through nozzles and orifices. The flow is given by:

$$q'm = \frac{412\, Y\, d_o^2\, C}{S_g}\sqrt{\Delta P\, \rho_1}$$

where:

q'm = flow rate, scfm
Y = net expansion factor for compressible flow
d_0 = diameter of orifice, in.
C = flow coefficient for square edged orifice
S_g = specific gravity of gas relative to air, 1.0 in this case.
ΔP = differential pressure, psi
ρ_1 = density of gas, lbs/ft^3

The pressure inside the glovebox was assumed to be - 0.3 psig (14.4 psia) due to the successive pressure drops between (1) the atmosphere and the building non-radiation zone, (2)

the building non-radiation zone and radiation zone, and (3) the building radiation zone and the glovebox interior. Pressure drops of 0.1 psi were assumed for each step. The source pressure is gauge pressure relative to the outside atmosphere due to their source at or near the outside atmosphere. The total pressure difference between the source and glovebox interior is then 104.7 -14.4 = 90.3 psia. For conservatism, no credit is taken for pressure drops in the line between the source and the outlet.

The value of Y is a function of the orifice size $d_0\backslash d_1$ (where d_0 = diameter of orifice and d_1 = diameter of pipe), $\Delta P/P$, and the specific heat ratio for the gases of concern, k. The differential pressure (ΔP) was determined from above to be 90.3 psia. The absolute pressure of the compressed air source (P) is 90.3 + 14.7 = 105.0 psia, so:

$$\Delta P/P = 90.3/105.0 = 0.86.$$

For the gases of concern (i.e. air) in this analysis, k = 1.4. For the orifice size in this analysis $d_0\backslash d_1$ is very small and falls in the range of 0 to 0.2. From the graph on pg. A-20 of Crane (1969):

$$Y = 0.75$$

The value of C is a function of the nozzle orifice size ($d_0\backslash d_1$), and the Reynolds Number (Re) of the flow. For the orifice size of concern in this analysis $d_0\backslash d_1$ is very small and falls in the range of 0 to 0.2. From Appendix E, Section E.7.1.2 of BWHC (1999), Re = 6.2×10^4 for the flow through a 1/16 in. conduit, and from Section E.7.1.3 of BWHC (1999), Re = 1.28×10^5 for the flow through a 1/8 in. conduit. In the graph for determination of C on pg. A-20 of Crane (1969), the value of C (when $d_0\backslash d_1$ = 0 to 0.2) is a constant value for Re numbers in the range from 10^4 to 10^6.

From the graph on pg. A-20 of Crane (1969), then:

$$C = 0.985$$

From WHC (1992), $S_g = 1.0$, and $\rho = 0.0764$ lb/ft^3. Accordingly, the estimated flow rate through the orifice with a 0.305 in. diameter is:

$$q'm = \frac{(412)(0.75)(0.305)^2(0.985)}{1.0}\sqrt{(90.3)(0.0764)}$$

$$= 74.37 \text{ scfm.}$$

As stated above, rated flow for each of the five inlet filters for Glovebox 188-1 is 50 scfm, and rated flow corresponds to approximately 1.3 in w.g. pressure drop. Maximum ΔP a filter can maintain is 10 in. w.g.

Pressure drop across a filter is proportional to the square of flow velocity and the square of flow rate:

$$\Delta P \propto \text{velocity}^2 \propto \text{flowrate}^2$$

Then, knowing ΔP = 1.3 in. w.g. for 50 scfm, the pressure drop at the estimated maximum flow through each of the five filters is:

$$\Delta P = \frac{(1.3 \text{ in})(74.4/2 \text{ scfm})^2}{(50 \text{ scfm})^2} = 0.72 \text{ in. w.g.}$$

Since this is much less than 10 in. w.g., there is no danger of filter failure.

Mitigation. Mitigation is provided by administratively limiting the use of pressurized gas in the glovebox. This control limits the quantity of pressurized air or other gas in Glovebox 188-1.

Probability. The pressurization of Glovebox 188-1 due to compressed air is an unlikely event, defined in the PFP FSAR (FDH 1999), Table 9-49, as having an annual probability of occurrence in the range of 1×10^{-2} to 1×10^{-4}. This probability is based on the occurrence of a seismic event that initiates the failure of the E-4 exhaust system.

Consequence. Since the pressure drop at the estimated maximum flow through each of the two filters, 0.72 in. w.g. is much less than 10 in. w.g., there is no danger of filter failure.

Conclusions. The estimated maximum air flow rate from Glovebox 188-1 was calculated to be 74.4 scfm, based on the number of air lines entering the glovebox and the location and pressure of the air source. Figures 6B through 9B of Appendix B of WHC (1992), show that the calculated glovebox interior pressures barely exceed 1.1 in. w.g. (0.04 psi) when exhausting an air flow of 75.2 scfm. The HEPA filters on the gloveboxes operate routinely with a ΔP of up to 3 in. w.g. (0.11 psi); thus, filter breaching at an air flow rate of 75.2 scfm is extremely unlikely. As further confidence, consider that the filters are tested for filtering efficiency by the manufacturer (Flanders Filters, Inc.; Washington, NC) prior to shipment. The efficiency test are performed at an air flow rate of 35 scfm per filter. The pressure difference in the test varies from filter to filter and ranges from 44 to 92 in. w.g. (1.6 to 3.3 psi) without breaching the filter, well beyond the pressure difference allowed for use on Plutonium Finishing Plant gloveboxes. The PPSL gloveboxes are normally installed with at least 2 inlet HEPA filters. A total flow rate of at least 100 scfm through the filters may be possible at each glovebox without breaching any filters.

Use of all available air supply lines into any of the PPSL gloveboxes does not deliver an air flow rate sufficient to cause a breach of containment. Additional flow restrictions are not necessary to keep the deliverable air flow rates less than safe exhaustible flow rates.

REFERENCES

BWHC, 1999, *Justification for Continued Operation for Tank 241-Z-361*, HNF-2024, Rev. 1, B&W Hanford Company, Richland, Washington.

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FDH, 1999, *Plutonium Finishing Plant Final Safety Analysis Report*, HNF-SD-CP-SAR-021, Rev. 1A, September 1999, Fluor Daniel Hanford, Inc., Richland, Washington.

WHC, 1992, *Effects of Compressed Gas Sources on the Pressure Profiles of Laboratory Gloveboxes*, WHC-SD-CP-DA-087, Westinghouse Hanford Company, Richland, Washington.

APPENDIX E

CALCULATION OF LABORATORY PROTOTYPE CALCINER BURST PRESSURE

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Calculation of Laboratory Prototype Calciner Burst Pressure

1.0 PURPOSE

This appendix documents the theoretical burst pressure of the calciner at operating temperature.

2.0 METHODOLOGY

The analysis does not consider thermal stresses or stress risers that might develop in various portions of the calciner shell. Instead, a simple hoop stress analysis is performed. Calculating potential failure pressures for flanges, bolts, and fittings would require complicated and time-consuming analyses. The burst pressure estimated in this calculation is non-conservative because it looks at what is likely the strongest part of the calciner vessel; the shell wall instead of the weakest section. This analysis is useful however because it provides the maximum pressure the vessel is likely to withstand.

The burst pressure calculated can be compared against predicted overpressures in the calciner due to explosions, fires, etc. to determine whether calciner ruptures are likely in such events.

For cylindrical vessels, burst pressure due to hoop stress in the wall of the vessel is given by the following equation (Lindeburg 1994):

$$P = 2\sigma t/D \qquad (1)$$

Where:

P = burst pressure, psig
D = outside diameter of the vessel, in.
t = vessel wall thickness, in.
σ = ultimate tensile strength, psi

This equation assumes that the split is longitudinal and that the shell is seamless.

For circumferential split failures, the applicable equation is:

$$P = 4\sigma t/D$$

which gives pressures twice as high as equation (1).

3.0 ASSUMPTIONS

The calciner vessel is assumed to burst due to hoop stress in the wall of the pipe of which it is constructed. This gives potentially non-conservative results as other areas of the calciner may be weaker than the pipe wall due to thermal stress or stress concentration risers.

The pipe wall is assumed to be at an average temperature of 816 °C when it is overpressurized. The calciner normally operates at 1000 °C. A metal temperature of 816 °C was assumed because it is the highest temperature for which tensile strength data is available. Burst pressures calculated at this temperature are somewhat overestimated.

4.0 INPUT DATA

The calciner is constructed from 6 in. diameter, schedule 10, 310 stainless steel pipe. From Perry's handbook (Perry 1984), the outside diameter of the schedule 10 pipe is 6.625 in. and the wall thickness is 0.134 in. Therefore:

$$D = 6.625 \text{ in.}$$
$$t = 0.134 \text{ in.}$$

Ultimate tensile strength values for 310 stainless steel at elevated temperatures was not readily available. However, the allowable tensile stresses (for design purposes) of 310 stainless steel at elevated temperatures can be found in Perry (1984). Table 6-37 of Perry (1984) provides allowable tensile stresses for temperatures up to of 816 °C.

The allowable tensile stress for 310 stainless steel at 816 °C is taken from Table 6-37 of Perry (1984). Table 6-37 shows that the allowable tensile stress ranges from 200 to 800 psi, depending on grain size. The grain size for the stainless steel used in the calciner is unknown. Therefore, the lower allowable value is assumed.

5.0 CALCULATIONS

Because of the safety factors built in to designs, the allowable design stresses tend to be about a factor of three or four below ultimate values. Multiplying the 310 stainless steel design allowable (200 psi) by a factor of three gives an ultimate tensile strength estimate of 600 psi at 816 °C.

Substituting the appropriate values in equation (1) gives:

$$P = 2(600 \text{ psi})(0.134 \text{ in.})/(6.625 \text{ in.}) = 24 \text{ psig}$$

6.0 CONCLUSIONS

The estimated pressure in the calciner deflagration accident, as documented in Section 4.2.3.4 of this addendum, is 63 psig. The deflagration pressure is well above the calculated calciner burst pressure (24 psig) so it is possible that the calciner shell could rupture in the deflagration event.

It should be noted that the above calculated burst pressure is based on static pressure loading. In addition, the burst pressure (24 psig) estimated above is a maximum value since thermal stresses, stress concentration risers, and the shear strengths of bolt threads, etc. were not considered and could result in a lower burst pressure. However, in a true deflagration accident, the load is applied as a short-term impulse. Because of inertial effects, vessels can withstand impulse loads that are greater than static loads. No attempt was made to estimate the impulse load required to fail the vessel due to the low static pressure value calculated.

7.0 REFERENCES

Lindeburg, M. R., 1994, *Mechanical Engineering Reference Manual*, 9th Edition, Professional Publications, Inc., Belmont, California.

Perry, J. H., 1984, *Chemical Engineer's Handbook*, 6th Edition, McGraw-Hill Book Company, New York, New York.

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APPENDIX F

UNMITIGATED DESIGN BASIS EARTHQUAKE ACCIDENT ANALYSIS

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UNMITIGATED DESIGN BASIS EARTHQUAKE ACCIDENT ANALYSIS

1.0 INTRODUCTION

This Appendix presents an unmitigated Design Basis Earthquake (DBE) accident analysis for the Laboratory Prototype Calciner in Glovebox 188-1. Glovebox 188-1 is seismically qualified such that it will not topple given a DBE. However, the glovebox panels and equipment within the glovebox and supporting services are not qualified and may or may not fail. Accordingly, numerous scenarios, each with a different combination of system and component failures, can be hypothesized. Section 2.0 discusses the event tree constructed to define credible seismic event sequences. Section 3.0 quantitatively evaluates an unmitigated scenario in which the calciner continues to operate after the seismic event but loses vacuum resulting in pressurization and a release of plutonium.

2.0 DESIGN BASIS EARTHQUAKE EVENT TREE

An event tree was developed to identify DBE scenarios for the laboratory prototype calciner and to estimate their associated consequences and probability of occurrence. Event trees are constructed by postulating an initiating event and systematically evaluating subsequent system or component successes or failures. For the calciner event tree, the initiating event is taken to be the DBE. Systems and components evaluated for subsequent success or failure are listed below. These items were selected for evaluation as their failure could directly and significantly contribute to the release of plutonium.

Calciner - the calciner may or may not remain secured in place and maintain its integrity. Loss of integrity results in a spill of the entire calciner contents to the glovebox.

Calciner feed - feed to the calciner (driven by an electric pump) may or may not continue. Continuation of feed increases the quantity of material potentially released. In addition, continuation of feed can pressurize the calciner, given loss of vacuum.

Air supply - air supply to the feed nozzle (provided by the plant air supply system) may or may not continue. Continuation of the air supply can pressurize the calciner given loss of vacuum and also acts to loft powder.

Vacuum - the calciner vacuum (provided by the plant 26-in-Hg vacuum system) may or may not be maintained. Loss of vacuum can result in pressurization of the calciner, given continuation of feed or air supply.

Product tube - the product tube may or may not remain in place as designed. Loss of the product tube results in a spill of the entire calciner contents to the glovebox.

Agitator - the agitator (driven by an electric motor) may or may not continue to operate. Continued operation of the agitator increases the quantity of material spilled to the glovebox given the product tube remains in place.

The product receiver vessel was not included in the event tree as its contribution to the magnitude of the event consequences was judged to be insignificant compared to that of the feed tank and calciner unit, particularly for scenarios that pressurize the calciner unit.

Figure F-1 presents the calciner event tree. The event tree resulted in the identification of thirty event sequences, each representing a unique path through the tree. Each event sequence was qualitatively evaluated to determine the magnitude of the associated release, and assigned a relative release level of minor, small, medium, or large. Nine event sequences, or approximately 30%, resulted in large releases. Large releases are primarily associated with event sequences resulting in a pressurized calciner with continuous feed.

To quantify the event tree, success/failure probabilities were assigned to each system or component. Engineering analyses of the seismic response of the calciner systems and components have not been performed. Accordingly, the assigned probabilities were developed based on consideration of (1) the complexity of the system or component, i.e., complex systems are more likely to fail than simple systems, and (2) the fragility of the system or component, e.g., glass vessels are more likely to fail than steel vessels. The assigned probabilities are as follows:

- Calciner - 0.5 that the calciner survives
- Calciner feed - 0.3 that the calciner feed continues
- Air supply - 0.5 that air supply continues to the feed nozzle
- Vacuum - 0.2 that the vacuum continues
- Product tube - 0.70 that the product tube stays in place
- Agitator - 0.5 that the agitator continues to run.

The individual frequencies (or annual probabilities) of the nine event sequences having large consequences range from 1.5×10^{-5}/yr to 9×10^{-7}/yr. Summing the nine event sequences yields a frequency of 2.7×10^{-5}/yr. It is therefore concluded that a large release of plutonium from the calciner given a DBE is a credible event as the frequency exceeds 1×10^{-6}/yr.

The above described event frequencies are based on qualitative engineering judgement. Consequently, for risk acceptance purposes, all component and system failures are conservatively assumed to occur with a conditional probability of 1 given the occurrence of a DBE at an annual probability of 1×10^{-4}. Therefore, radiological consequences are evaluated against the risk acceptance guidelines given in Figure 9-34 of the PFP FSAR (FDH 1999) at a probability of 1×10^{-4}. This is conservative since larger doses are acceptable at lower probability values, which would be the case if components were determined to fail at probabilities less than 1.

3.0 UNMITIGATED SEISMIC EVENT SCENARIO

The event tree discussed in Section 2.0 of this appendix identified nine unique event sequences resulting in large releases. To quantify the consequences of an unmitigated scenario, it is assumed that the DBE results in a loss of vacuum, but that the calciner remains intact and that the liquid feed injector, agitator, and heaters continue to operate.

The calciner generates dust during normal operation. Air fed in through the feed nozzle and the liquid feed flashed in the oxide bed fluidizes the bed and lofts particulate into the freeboard of the calciner. Additional material is normally made airborne in the freeboard off the ceramic filters due to the action of the backpulsing air. The agitator also kicks up dust. The normal dust loading in the freeboard of the calciner is unknown, but is high enough that the ceramic filters have to be backpulsed with air on average every 40 s to prevent plugging.

Loss of the vacuum system flow will cause the calciner to pressurize and eject the pressure relief cap at an overpressure of approximately 2.0 psi. Two abnormal events that occurred during prior calciner operation indicate the release rate of material through the pressure relief cap could range from 4 g/min to 200 g/min. Scoping calculations indicate that the superficial velocity of the flashed vapor and airflow through the bed material is higher than the terminal settling velocity of much of the particulate material in the bed. Thus, bulk entrainment and ejection of the material from the calciner cannot be discounted. As bed material is ejected and the bed becomes shallower, the bed material becomes easier to entrain. For this analysis it is conservatively assumed that all bed material is lofted into the glovebox through the calciner pressure relief cap over several tens of minutes following the seismic event.

The pressurization of the calciner following loss of vacuum would result in operation of the pressure relief cap and ejection of powder into the glovebox. If uninterrupted, the 4 kg of plutonium in the chamber and the 2.25 kg in the feed could all be processed and ejected. Because the powder is ejected in the air stream, the ARF = 1. A respirable fraction of 3% is assumed, based on Figure 9-28 in the PFP FSAR.

The release of plutonium oxide (Class Y material) and plutonium nitrate (Class W material) are, respectively:

$$Q_y = \text{ARF} \times \text{RF} \times 4{,}000\ \text{g} = 4{,}000\ \text{g} \times 0.03 = 120\ \text{g}$$

$$Q_w = \text{ARF} \times \text{RF} \times 5.0\ \text{L} \times 450\ \text{g/L} = 67.5\ \text{g}$$

In the "ventilation" case, the E-3 and E-4 exhaust fans are assumed to continue to run and the HEPA filters are assumed to fail. Section 9.2.4.7.2 of the PFP FSAR states that 16% of the released material is held up in the exhaust ducts, resulting in release out the 291-Z-1 Stack of 84%. The released amounts of Class Y and Class W materials are about 101 and 57 grams, respectively. The doses are calculated by using the methodology from Section 9.3.6.

$$D(rem) = Q(g) \times \chi/Q'(sec/m^3) \times R(m^3/s) \times C(rem/g)$$

where:

D = Dose

Q = Quantity of plutonium released = 101g Class Y + 57 g Class W

χ/Q' = Atmospheric dispersion coefficient for elevated release =
1.62×10^{-5} s/m^3 for onsite receptor from FSAR Table 9-39
5.73×10^{-6} s/m^3 for offsite receptor from FSAR Table 9-40

R = Breathing rate = 3.3×10^{-4} m^3/s from FSAR Table 9-48

C = Gram plutonium-to-dose conversion factor for Class Y >10% ^{240}Pu, mass weighted average = 8.8×10^7 rem/g (EDE) and 1.3×10^9 rem/g (Bone Surface) from FSAR Tables 9-46 and 9-47, respectively, and;
Class W >10% ^{240}Pu, mass weighted average = 1.03×10^8 rem/g (EDE) and 1.9×10^9 rem/g (Bone Surface)

An example calculation for onsite EDE dose is as follows:
D = (101g Class Y >10%)(1.62×10^{-5} s/m^3)(3.3×10^{-4} m^3/s)(8.8×10^7 rem/g) +
(57 g Class W > 10%)(1.62×10^{-5} s/m^3)(3.3×10^{-4} m^3/s)(1.03×10^8 rem/g) = 78.9 rem.

The EDE doses are approximately:

- onsite = 79 rem
- offsite = 28 rem

The bone surface doses are approximately:

- onsite = 1,280 rem
- offsite = 453 rem

For an event with an annual probability of 1.0×10^{-4}, the risk acceptance guidelines (Figure 9-34 of the PFP FSAR [FDH 1999]) allow an onsite dose of 25 rem EDE and an offsite dose of 4 rem EDE. Thus, this "ventilation case" consequences exceed the risk guidelines for both onsite and offsite individuals.

In the "no ventilation" case, both the building supply and exhaust fans are assumed to shut down during the earthquake. Radiological material released inside the 234-5Z Building can leave only through open doors on the exterior of the building due to wind effects (Section 9.2.4.7.1 of the PFP FSAR). It is estimated that about 38% (71 g) of the material released into the facility could be released at ground level.

The doses due to the release of approximately 71 g of plutonium are:

$$D(rem) = Q(g) \times \chi/Q'(sec/m^3) \times R(m^3/s) \times C(rem/g)$$

where:

D = Dose

Q = Quantity of plutonium released = 45.6 g Class Y and 25.6 g Class W

χ/Q' = Atmospheric dispersion coefficient for ground level release =
4.74×10^{-4} s/m^3 for onsite receptor from FSAR Table 9-39
1.01×10^{-5} s/m^3 for offsite receptor from FSAR Table 9-40

R = Breathing rate = 3.3×10^{-4} m^3/s from FSAR Table 9-48

C = Gram plutonium unit inhalation doses for Class Y >10% ^{240}Pu, mass weighted average = 8.8×10^7 rem/g (EDE) and 1.3×10^9 rem/g (Bone Surface) from FSAR Tables 9-46 and 9-47, respectively, and;
Class W >10% ^{240}Pu, mass weighted average = 1.03×10^8 rem/g (EDE) and 1.9×10^9 rem/g (Bone Surface).

The EDE doses are approximately:

- onsite = 1,040 rem
- offsite = 22 rem

The bone surface doses are approximately:

- onsite = 16,900 rem
- offsite = 360 rem

For an event with an annual probability of 1.0×10^{-4}, the risk acceptance guidelines (PFP FSAR Figure 9-34) allow an onsite dose of 25 rem EDE and an offsite dose of 4 rem EDE. Thus, this "no ventilation case" consequences exceed the risk guidelines for both onsite and offsite individuals by a significant margin.

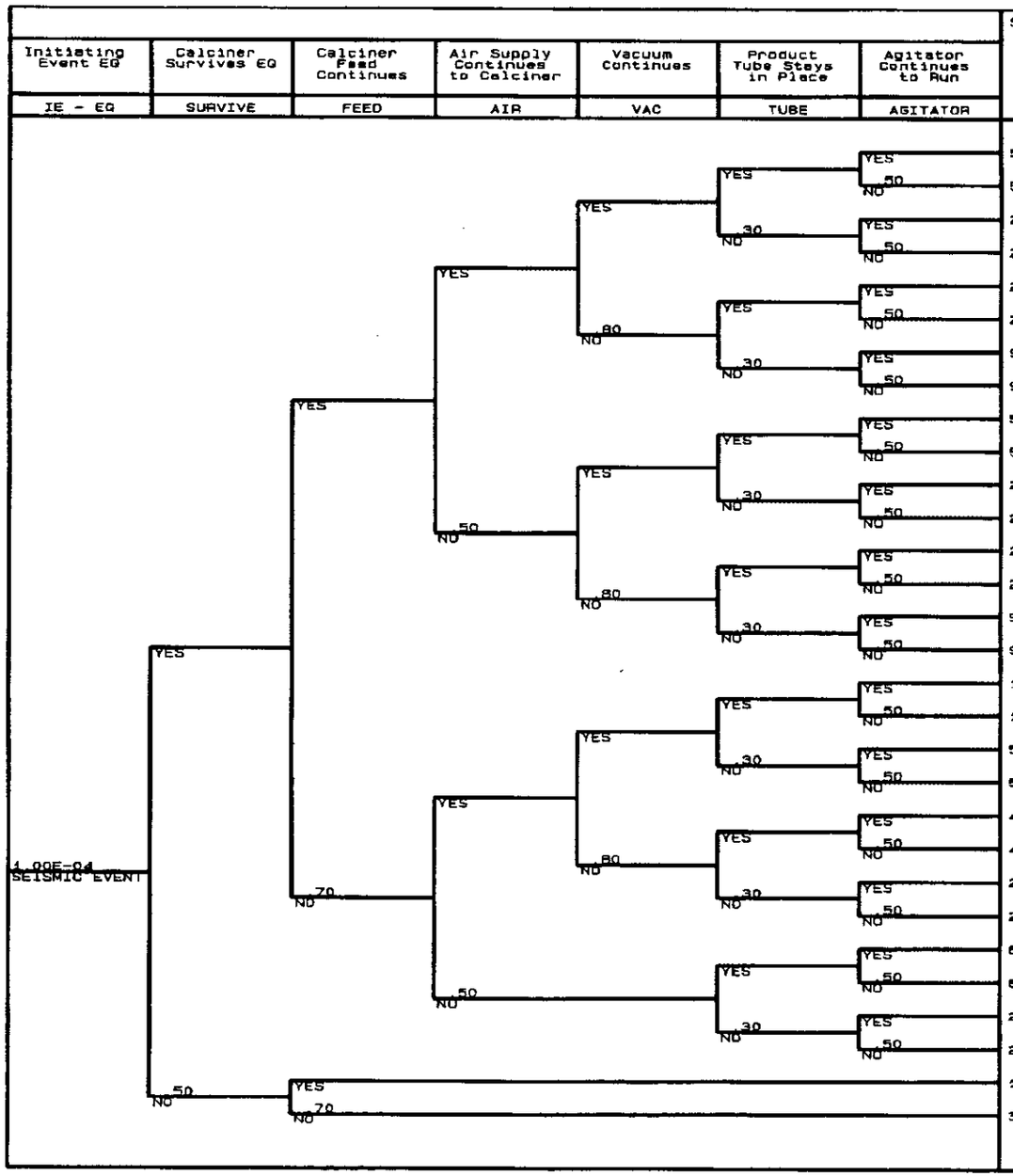
It is concluded from the analysis of this representative unmitigated scenario and others, that the consequences would exceed the RAGs by large margins. Therefore, it is concluded that a safety class seismic shutdown mechanism is required to prevent unacceptable releases from operation of the calciner during a seismic event.

Reference:

FDH, 1999, *Plutonium Finishing Plant Final Safety Analysis Report*, HNF-SD-CP-SAR-021, Rev. 1A, September 1999, Fluor Daniel Hanford, Inc., Richland, Washington.

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Figure F-1. Event Tree for Laboratory Prototype Calciner Seismic Accident.



SEQ.PROB.	Systems Status	Release Levels
5.25E-07	feed/air/vac/tube/agitator	No Pressurization - Small
5.25E-07	feed/air/vac/tube/no agitator	No Pressurization - Minor
2.25E-07	feed/air/vac/no tube/agitator	No Pressurization - Small
2.25E-07	feed/air/vac/no tube/no agitator	No Pressurization - Small
2.10E-06	feed/air/no vac/tube/agitator	Pressurized - Large
2.10E-06	feed/air/no vac/tube/no agitator	Pressurized - Large
9.00E-07	feed/air/no vac/no tube/agitator	Pressurized - Large
9.00E-07	feed/air/no vac/no tube/no agitator	Pressurized - Large
5.25E-07	feed/no air/vac/tube/agitator	No Pressurization - Small
5.25E-07	feed/no air/vac/tube/no agitator	No Pressurization - Minor
2.25E-07	feed/no air/vac/no tube/agitator	No Pressurization - Small
2.25E-07	feed/no air/vac/no tube/no agitator	No Pressurization - Small
2.10E-06	feed/no air/no vac/tube/agitator	Pressurization - Large
2.10E-06	feed/no air/no vac/tube/no agitator	Pressurization - Large
9.00E-07	feed/no air/no vac/no tube/agitator	Pressurization - Large
9.00E-07	feed/no air/no vac/no tube/no agitator	Pressurization - Large
1.22E-06	no feed/air/vac/tube/agitator	Resuspension - Minor
1.22E-06	no feed/air/vac/tube/no agitator	Resuspension - Minor
5.25E-07	no feed/air/vac/no tube/agitator	Resuspension - Small
5.25E-07	no feed/air/vac/no tube/no agitator	Resuspension - Small
4.90E-06	no feed/air/no vac/tube/agitator	Resuspension/Pressurized/Small
4.90E-06	no feed/air/no vac/tube/no agitator	Resuspension/Pressurized/Small
2.10E-06	no feed/air/no vac/no tube/agitator	Resuspension/Pressurized/Med
2.10E-06	no feed/air/no vac/no tube/no agitator	Resuspension/Pressurized/Small
6.12E-06	no feed/no air/tube/agitator	Small Release - Minor
6.12E-06	no feed/no air/tube/no agitator	Small Release - Minor
2.62E-06	no feed/no air/no tube/agitator	Full Release - Medium
2.62E-06	no feed/no air/no tube/no agitator	Partial Release - Minor
1.50E-05	calciner fails/feed continues	Total Release - High
3.50E-05	calciner fails/no feed	Total Release - Medium

APPENDIX G

CALCINER METAL MASS AND HEAT TRANSFER POTENTIAL

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CALCINER METAL MASS AND HEAT TRANSFER POTENTIAL

The purpose of this appendix is to document the estimate of the calciner major metal parts that could transfer heat to the glovebox, glovebox components, equipment, and plutonium materials that could be postulated to spill in the 0.2 g DBE. The major metal components that are of interest because of their high operating temperature and stored heat are the bottom flanges (interface with the support bracket), middle flanges (interface with the upper and lower regions of the body, and the inner chamber. The body and chamber are a pipe-within-a-pipe construction and are made of 310 stainless steel, schedule 10 pipe. The drawing showing these components is SK-2-300303, 10-L/Calciner Assembly, Rev 1, sheet 2. The estimates of metal volumes and masses are provided below.

The volume of each flange is given by:

$$V_f = 3.142 \times (D_o^2 - D_i^2) \times T_f /4$$

where:

D_o = outer diameter of flange = 11.000 in.
D_i = inner diameter of flange = 6.625 in.
T_f = flange thickness = 0.5 in.

The volume of each flange is approximately 30 in^3. Therefore, the volume of four flanges equals 120 in^3.

The volume of the inner pipe section is given by:

$$V_f = 3.142 \times L_p \times D_o \times T_w$$

where:

D_o = outer diameter of pipe = 4.50 in.
L_p = length of pipe section, = 9.0 in.
T_w = pipe wall thickness = 0.12 in.

The volume of the inner pipe section is approximately 15.3 in^3.

The volume of the outer pipe section is given by:

$$V_f = 3.142 \times L_p \times D_o \times T_w$$

where:

D_o = outer diameter of pipe = 6.625 in.
L_p = length of pipe section = 21.0 in.
T_w = pipe wall thickness = 0.134 in.

The volume of the outer pipe section is approximately 58.6 in^3.

Thus, the total volume of the major steel parts is about 195 in^3 (3200 cm^3). The density of stainless steel is about 8 g/cm^3 (ORNL 1975, property code 3304, 316 SS, annealed). The data for 316 stainless steel is used to approximate 310 stainless steel. The total mass is 25,600 g or approximately 26 kg.

The specific heat of 316 stainless steel was also used as a reasonable approximation to 310 stainless steel. The specific heat of this steel ranges from 544 J/kg K (120 cal/g K) at 300 °C to 628 J/kg K (150 cal/g K) at the highest temperature provided in the table, 871 °C (ORNL 1975, property code 3108, 316 SS, annealed). A value for the temperature range of interest was assumed to be 140 cal/kg K.

REFERENCES

ORNL, 1975, *Nuclear Systems Materials Handbook*, TID-26666, Rev. 36, Volume 1- Design Data, Book 2, Section 4, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

APPENDIX H

SEISMIC EVENT DOSE CALCULATION FOR LAB CALCINER ONLY

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SEISMIC EVENT DOSE CALCULATION FOR LAB CALCINER ONLY

1.0 RELEASES FROM GLOVEBOX 188-1 BY LUNG CLEARANCE CLASS AND ^{240}PU CONTENT

Table 5.22.2 of the PFP OSRs (BWHC 1999) establishes a total dispersible Pu limit for the Analytical Laboratory, Plutonium Process Support Laboratory, and Standards Laboratory. The limit is 12,450 g total for all laboratory rooms of which no more than 5,250 g is allowed to have a ^{240}Pu content greater than 10%. This limit is the same as the limits for laboratories stated in Section 9.2.4.6.3.1 of the PFP FSAR (FDH 1999).

As discussed in Section 4.2.5 of this addendum, the typical inventory associated with the calciner is 7 kg which is distributed as follows:

- 4,000 g in the calciner chamber
- 750 g in the product receiver vessel
- 2,250 g in the liquid feed tank.

Plutonium nitrate solutions to be fed to the calciner originate primarily from weapons grade material. For this analysis, it is therefore assumed that all plutonium material associated with the calciner in Glovebox 188-1 has a ^{240}Pu isotopic content of less than 10%. Feed containing >10% ^{240}Pu will be blended to ensure that it has less than 10% ^{240}Pu content.

Plutonium nitrate (Lung Clearance Class W) is more soluble than oxide (Lung Clearance Class Y) and thus has a higher unit dose conversion factor. The above inventory maximizes the quantity of inventory in the glovebox with Class W lung clearance and maximizes the predicted doses because the plutonium nitrate liquid feed tank is assumed to be full at the time of the seismic event with solution having a maximum plutonium content of 450 g/L.

As discussed in Section 4.2.5 of this Addendum, of the 2,250 g of plutonium present as plutonium nitrate, 0.863 g is released into the facility in a seismic event. Of the 4,750 g of plutonium present as an oxide, 11.676 g is released into the facility given accumulator depressurization. If the check valves function as intended, 2.676 g Pu as oxide is released into the facility. In summary, the releases into the facility from the calciner by Lung Clearance class are:

- 0.863 g <10% ^{240}Pu, Class W
- 11.676 g <10% ^{240}Pu, Class Y (accumulator depressurization)
- 2.676 g <10% ^{240}Pu, Class Y (check valves function)

2.0 RELEASES FROM REMAINDER OF LABORATORIES

Given that 7 kg is associated with the prototype calciner Glovebox 188-1, the remaining allowable inventory in the three laboratories (Analytical, PPSL, and Standards laboratories) is 5,450 g. The calculations for releases from the remainder of the facility are found in Section 9.2.4 of the PFP FSAR.

3.0 RELEASES FROM THE LABS BY LUNG CLEARANCE CLASS AND 240PU CONTENT

As discussed in Chapter 9, Section 9.2.4.7 of the PFP FSAR, there are two release scenarios, i.e., "No Ventilation" case and "Ventilation" case. In the "no ventilation" case, the facility ventilation system is assumed to fail or be shut down as a result of the earthquake. Material is released from the facility through open egress paths due to wind effects on the building. In the "ventilation" case, the E-3 and E-4 Exhaust Systems are assumed to continue running, but with failed HEPA filters such that material is released through the 291-Z-1 Stack unfiltered. The FSAR analysis accounts for gravitational settling within the facility. Since material is drawn out of the facility faster in the "ventilation" case, a lower percentage of the material released from the prototype calciner glovebox settles out before release in the "ventilation" case than in the "no ventilation" case. However, the release is elevated in the "ventilation" case, which aids in dispersion.

3.1 "NO VENTILATION" CASE RELEASES

For the "No Ventilation" case, 38% of the material released into the laboratories from the lab calciner is released from the facility, as shown in Chapter 9, Section 9.2.4.7.1 of the PFP FSAR (i.e., of the 12.539 g released into the laboratories, 4.765 is released). The remaining 62% of the respirable plutonium material released into the laboratories settles out due to gravity. Crediting gravitational settling within the facility, the following releases from the facility are calculated:

$$(0.863\ g) \times (0.38) = 0.328\ g < 10\%\ ^{240}Pu, \text{ Class W}$$
$$(11.676) \times (0.38) = 4.437\ g < 10\%\ ^{240}Pu, \text{ Class Y(accumulator depressurization)}$$
$$(2.676\ g) \times (0.38) = 1.017\ g < 10\%\ ^{240}Pu, \text{ Class Y (check valves function)}$$

Thus, the total release is 4.765 grams if the accumulator depressurizes through the calciner bed or 1.345 g if the check valves function.

3.2 "VENTILATION" CASE RELEASES

For the "Ventilation" case, 84% of the material released into the laboratories from the lab calciner is released from the facility, as shown in Chapter 9, Section 9.2.4.7.2 of the PFP FSAR (i.e., of the 12.539 g released into the laboratories, 10.533 is released). The remaining 16% of the respirable plutonium material released into the laboratories settles out due to gravity. Crediting gravitational settling within the facility, the following releases from the facility are calculated:

$$(0.863\ g) \times (0.84) = 0.725\ g < 10\%\ ^{240}Pu, \text{ Class W}$$
$$(11.676) \times (0.84) = 9.808\ g < 10\%\ ^{240}Pu, \text{ Class Y(accumulator depressurization)}$$
$$(2.676\ g) \times (0.84) = 2.248\ g < 10\%\ ^{240}Pu, \text{ Class Y (check valves function)}$$

Thus, the total release is 10.533 grams if the accumulator depressurizes through the calciner bed or 2.973 g if the check valves function.

4.0 DOSE CALCULATIONS

The onsite and offsite EDE and organ doses are calculated consistent with the methodology presented in Chapter 9, Section 9.3.6 of the PFP FSAR:

$$D = (R) \times (\chi/Q') \times (BR) \times (UDF)$$

where:

D = dose to onsite or offsite receptor, rem (EDE or maximum organ)
R = release by lung clearance class and ^{240}Pu content, g
χ/Q' = onsite or offsite atmospheric dispersion coefficient, s/m^3
BR = reference breathing rate, m^3/s
UDF = unit dose factor, EDE or maximum organ, rem/g

The release of material by lung clearance class and ^{240}Pu content is provided above. The "no ventilation" case release occurs at ground level. The "ventilation" case release occurs through the 291-Z-1 Stack and is elevated. From Tables 9-39 and 9-40 of the PFP FSAR, the onsite and offsite ground-level χ/Q's, accounting for building wake and plume meander, are 4.74×10^{-4} s/m^3 and 1.01×10^{-5} s/m^3, respectively. The onsite and offsite elevated χ/Q's are 1.62×10^{-5} s/m^3 and 5.73×10^{-6} s/m^3. The reference breathing rate is 3.3×10^{-4} m^3/s from Table 9-48 of the PFP FSAR. The mass-weighted average EDE and organ unit dose factors are provided in Tables 9-46 and 9-47 of the FSAR. The bone surface gives the maximum organ dose. For <10% ^{240}Pu, Class W, the mass-weighted EDE unit dose factor is 3.7×10^{7} rem/g and the mass-weighted bone surface unit dose factor is 6.7×10^{8} rem/g. For >10% ^{240}Pu, Class W, the mass-weighted EDE unit dose factor is 1.0×10^{8} rem/g and the mass-weighted bone surface

unit dose factor is 1.9×10^9 rem/g. For >10% ^{240}Pu, Class Y, the mass-weighted EDE and bone surface doses are 8.8×10^7 rem/g and 1.3×10^9 rem/g, respectively. For <10% ^{240}Pu, Class Y, the mass-weighted EDE and bone surface doses are 2.8×10^7 rem/g and 3.2×10^8 rem/g, respectively.

4.1 "NO VENTILATION" CASE DOSES, ACCUMULATOR DEPRESSURIZATION

The releases from the facility for this case are (from Section 3.1):

- 0.328 g <10% ^{240}Pu, Class W
- 4.437 g <10% ^{240}Pu, Class Y

The onsite and offsite EDE and organ doses are calculated by ^{240}Pu content and lung clearance class as follows:

<10% ^{240}Pu, Class W

Onsite EDE: $(0.328\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.7 \times 10^7\ rem/g) = 1.90$ rem
Onsite Organ: $(0.328\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(6.7 \times 10^8\ rem/g) = 34.37$ rem

Offsite EDE: $(0.328\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.7 \times 10^7\ rem/g) = 0.04$ rem
Offsite Organ: $(0.328\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(6.7 \times 10^8\ rem/g) = 0.73$ rem

<10% ^{240}Pu, Class Y

Onsite EDE: $(4.437\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^7\ rem/g) = 19.43$ rem
Onsite Organ: $(4.437\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^8\ rem/g) = 222.09$ rem

Offsite EDE: $(4.437\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^7\ rem/g) = 0.41$ rem
Offsite Organ: $(4.437\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^8\ rem/g) = 4.73$ rem

No-ventilation case totals, accumulator depressurization

Onsite EDE: (1.90 rem) + (19.43 rem) = 21.33 rem
Onsite Organ: (34.37 rem) + (222.09 rem) = 256 rem

Offsite EDE: (0.04 rem) + (0.41 rem) = 0.45 rem
Offsite Organ: (0.73 rem) + (4.73 rem) = 5.46 rem

Table H-1 presents the above total doses in a tabular format. The doses are compared in the table against the Risk Acceptance Guidelines (RAG) for an event with a 1×10^{-4} annual probability.

4.2 "VENTILATION" CASE DOSES, ACCUMULATOR DEPRESSURIZATION

The releases from the facility (from Section 3.2 above) are as follows:

- 0.725 g <10% ^{240}Pu, Class W
- 9.808 g <10% ^{240}Pu, Class Y

The onsite and offsite EDE and organ doses are calculated by ^{240}Pu content and lung clearance class as follows:

<10% ^{240}Pu, Class W

Onsite EDE: $(0.725\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.7 \times 10^{7}\ rem/g) = 0.14$ rem
Onsite Organ: $(0.725\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(6.7 \times 10^{8}\ rem/g) = 2.60$ rem

Offsite EDE: $(0.725\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.7 \times 10^{7}\ rem/g) = 0.05$ rem
Offsite Organ: $(0.725\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(6.7 \times 10^{8}\ rem/g) = 0.92$ rem

<10% ^{240}Pu, Class Y

Onsite EDE: $(9.808\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^{7}\ rem/g) = 1.47$ rem
Onsite Organ: $(9.808\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^{8}\ rem/g) = 16.78$ rem

Offsite EDE: $(9.808\ g)(5.73 \times 10^{-6} s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^{7}\ rem/g) = 0.52$ rem
Offsite Organ: $(9.808\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^{8}\ rem/g) = 5.93$ rem

Ventilation case totals, accumulator depressurization

Onsite EDE: (0.14 rem) + (1.47 rem) = 1.61 rem
Onsite Organ: (2.60 rem) + (16.78 rem) = 19.38 rem

Offsite EDE: (0.05 rem) + (0.52 rem) = 0.57 rem
Offsite Organ: (0.92 rem) + (5.93 rem) = 6.85 rem

Table H-2 presents the above total doses in a tabular format. The doses are compared in the table against the RAG for an event with a 1×10^{-4} annual probability.

4.3 "NO VENTILATION" CASE DOSES (check valves function)

The releases from the facility for this case are (from Section 3.1):

- 0.328 g <10% ^{240}Pu, Class W
- 1.017 g <10% ^{240}Pu, Class Y

The onsite and offsite EDE and organ doses for <10% ^{240}Pu , Class W are the same as calculated in Section 4.1. The doses associated with a release of 1.017 g <10% ^{240}Pu, Class Y are as follows:

<10% ^{240}Pu, Class Y

Onsite EDE: (1.017 g)(4.74 x 10^{-4} s/m^3)(3.3 x 10^{-4} m^3/s)(2.8 x 10^7 rem/g) = 4.45 rem
Onsite Organ: (1.017 g)(4.74 x 10^{-4} s/m^3)(3.3 x 10^{-4} m^3/s)(3.2 x 10^8 rem/g) = 50.91 rem

Offsite EDE: (1.017 g)(1.01 x 10^{-5} s/m^3)(3.3 x 10^{-4} m^3/s)(2.8 x 10^7 rem/g) = 0.09 rem
Offsite Organ: (1.017 g)(1.01 x 10^{-5} s/m^3)(3.3 x 10^{-4} m^3/s)(3.2 x 10^8 rem/g) = 1.08 rem

No-ventilation case totals, check valves function

Onsite EDE: (1.90 rem) + (4.45 rem) = 6.35 rem
Onsite Organ: (34.37 rem) + (50.91 rem) = 85.28 rem

Offsite EDE: (0.04 rem) + (0.09 rem) = 0.13 rem
Offsite Organ: (0.73 rem) + (1.08 rem) = 1.81 rem

Table H-3 presents the above total doses in a tabular format. The onsite and offsite EDE doses and organ doses are shown to be below the RAGs.

4.4 "VENTILATION" CASE (check valves function)

The releases from the facility (from Section 3.2 above) are as follows:

- 0.725 g <10% ^{240}Pu, Class W
- 2.248 g <10% ^{240}Pu, Class Y

The onsite and offsite EDE and organ doses for <10% ^{240}Pu , Class W are the same as calculated in Section 4.2. The doses associated with a release of 2.248 g <10% ^{240}Pu, Class Y are as follows:

<10% ^{240}Pu, Class Y

Onsite EDE: (2.248 g)(1.62 x 10^{-5} s/m^3)(3.3 x 10^{-4} m^3/s)(2.8 x 10^7 rem/g) = 0.34 rem
Onsite Organ: (2.248 g)(1.62 x 10^{-5} s/m^3)(3.3 x 10^{-4} m^3/s)(3.2 x 10^8 rem/g) = 3.85 rem

Offsite EDE: (2.248 g)(5.73 x 10^{-6}s/m^3)(3.3 x 10^{-4} m^3/s)(2.8 x 10^7 rem/g) = 0.12 rem
Offsite Organ: (2.248 g)(5.73 x 10^{-6} s/m^3)(3.3 x 10^{-4} m^3/s)(3.2 x 10^8 rem/g) = 1.36 rem

Ventilation case totals

Onsite EDE: (0.14 rem) + (0.34 rem) = 0.48 rem
Onsite Organ: (2.60 rem) + (3.85rem) = 6.45 rem

Offsite EDE: (0.05 rem) + (0.12 rem) = 0.17 rem
Offsite Organ: (0.92 rem) + (1.36 rem) = 2.28 rem

Table H-4 presents the above total doses in a tabular the same format. The onsite and offsite EDE doses and organ doses are shown to be below the RAGs.

5.0 CONSEQUENCES OF SEISMIC EVENT WITH FIRE IN GLOVEBOX 188-1

As discussed in Section 4.2.5.3 of this addendum, Mitigated Seismic Event with Fire, a potential consequence of the 0.2 g DBE is a fire in Glovebox 188-1. This section provides the details of the additional release of plutonium materials and the additional doses due to the fire. In the fire case, all of the additional material released into the facility is plutonium oxide, Class Y, ^{240}Pu <10%. Because of this, the release amounts and dose consequences are simpler than in Sections 3.1 - 4.2 above.

The releases and doses are calculated for the "no ventilation" case and the "ventilation" case.

5.1 "NO-VENTILATION" CASE FOR SEISMIC-INDUCED FIRE

As shown in addendum Section 4.2.5.3, the fire in Glovebox 188-1 due to burning of trash, gloves, and panels adds 1.379 g release into the facility. In this case, 62% settles out and 38% is released from the facility as shown below.

$$(1.379\ g) \times (0.38) = 0.524\ g\ ^{240}Pu < 10\%, \text{ Class Y}$$

The incremental dose due to the above release is calculated as in Section 4.1 above and is as follows:

Onsite EDE: $(0.524\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^{7}\ rem/g) = 2.29$ rem
Onsite Organ: $(0.524\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^{8}\ rem/g) = 26.23$ rem

Offsite EDE: $(0.524\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^{7}\ rem/g) = 0.05$ rem
Offsite Organ: $(0.524\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^{8}\ rem/g) = 0.56$ rem

Total doses, accumulator depressurization

Adding the fire doses to the dose estimates from Section 4.1 above, gives the following total doses:

Onsite EDE: (21.33 rem) + (2.29 rem) = 23.62 rem
Onsite Organ: (256 rem) + (26.23 rem) = 282 rem

Offsite EDE: (0.45 rem) + (0.05 rem) = 0.50 rem
Offsite Organ: (5.46 rem) + (0.56 rem) = 6.02 rem

Table H-5 presents the above total doses for accumulator depressurization and fire in a tabular format. The doses are compared against the RAG for an event with a 1×10^{-4} annual probability in the table.

Total doses, check valves function

Adding the fire doses to the dose estimates from Section 4.3 above, gives the following doses:

Onsite EDE: (6.35 rem) + (2.29 rem) = 8.64 rem
Onsite Organ: (85.28 rem) + (26.23 rem) = 112 rem

Offsite EDE: (0.13 rem) + (0.05 rem) = 0.18 rem
Offsite Organ: (1.81 rem) + (0.56 rem) = 2.37 rem

Table H-6 presents the above total doses for check valves functioning and fire in a tabular format. The doses are compared against the RAG for an event with a 1×10^{-4} annual probability in the table.

5.2 "VENTILATION" CASE FOR SEISMIC-INDUCED FIRE

As shown in addendum Section 4.2.5.3, the fire in Glovebox 188-1 due to burning of trash, gloves, and panels adds 1.379 grams release into the facility. In this case, 16% settles out and 84% is released from the facility yielding the following result:

$$(1.379\ g) \times (0.84) = 1.158\ g\ ^{240}Pu < 10\%, \text{ Class Y}$$

The incremental dose due to the above release is calculated as in Section 4.2 above and is as follows:

Onsite EDE: $(1.158\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^{7}\ rem/g) = 0.17$ rem
Onsite Organ: $(1.158\ g)(1.62 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^{8}\ rem/g) = 1.98$ rem

Offsite EDE: $(1.158\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(2.8 \times 10^{7}\ rem/g) = 0.06\ rem$
Offsite Organ: $(1.158\ g)(5.73 \times 10^{-6}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(3.2 \times 10^{8}\ rem/g) = 0.70\ rem$

Total doses, accumulator depressurization

Adding the fire doses to the dose estimates from Section 4.2 above, gives the following total doses:

Onsite EDE: (1.61 rem) + (0.17 rem) = 1.78 rem
Onsite Organ: (19.38 rem) + (1.98 rem) = 21.36 rem

Offsite EDE: (0.57 rem) + (0.06 rem) = 0.63 rem
Offsite Organ: (6.85 rem) + (0.70 rem) = 7.55 rem

Table H-7 presents the above total doses for accumulator depressurization and fire in a tabular format. The doses are compared in the table against the RAG for an event with a 1×10^{-4} annual probability.

Total doses, check valves function

Adding the fire doses to the dose estimates from Section 4.4 above, gives the following doses:

Onsite EDE: (0.48 rem) + (0.17 rem) = 0.65 rem
Onsite Organ: (6.45 rem) + (1.98 rem) = 8.43 rem

Offsite EDE: (0.17 rem) + (0.06 rem) = 0.23 rem
Offsite Organ: (2.28 rem) + (0.70 rem) = 2.98 rem

Table H-8 presents the above total doses in a tabular format. The doses are compared against the RAG for an event with a 1×10^{-4} annual probability in the table.

6.0 REFERENCES

BWHC[1], 1999, *Plutonium Finishing Plant Operational Safety Requirements*, WHC-SD-CP-OSR-010, Rev. 0-K, Release Date August 19, 1999, B&W Hanford Company, Richland, Washington.

FDH, 1999, *Plutonium Finishing Plant Final Safety Analysis Report*, HNF-SD-CP-SAR-021, Rev. 1A, September 1999, Fluor Daniel Hanford, Inc., Richland, Washington.

Note 1: This document was originally prepared by a former Hanford Operating Contractor, Westinghouse Hanford Company. It has been adopted by the current Hanford Management and Integration Contractor, Fluor Daniel Hanford, Inc., and its major subcontractor, B&W Hanford Company.

Table H-1. Summary of Doses, Seismic Event, "No Ventilation" Case, Accumulator Depressurization

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1	4.765	21.33	256	0.45	5.46
Risk Acceptance Guidelines		25	250	4	40

Table H-2. Summary of Doses, Seismic Event, "Ventilation" Case, Accumulator Depressurization

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1	10.533	1.61	19.38	0.57	6.85
Risk Acceptance Guidelines		25	250	4	40

Table H-3. Summary of Doses, Seismic Event, "No Ventilation" Case (check valves function)

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1	1.345	6.35	85.28	0.13	1.81
Risk Acceptance Guidelines		25	250	4	40

Table H-4. Summary of Doses, Seismic Event, "Ventilation" Case (check valves function)

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1	2.973	0.48	6.45	0.17	2.28
Risk Acceptance Guidelines		25	250	4	40

Table H-5. Summary of Doses, Seismic Event with Fire, "No-Ventilation" Case, Accumulator Depressurization

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1 (seismic only)	4.765	21.33	256	0.45	5.46
GB 188-1 (fire only following seismic)	0.524	2.29	26.23	0.05	0.56
Total	5.289	23.62	282	0.50	6.02
Risk Acceptance Guidelines		25	250	4	40

Table H-6. Summary of Doses, Seismic Event with Fire, "No Ventilation" Case (check valves function)

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1 (seismic only)	1.345	6.35	85.28	0.13	1.81
GB 188-1 (fire only following seismic)	0.524	2.29	26.23	0.05	0.56
Total	1.869	8.64	112	0.18	2.37
Risk Acceptance Guidelines		25	250	4	40

Table H-7. Summary of Doses, Seismic Event with Fire, "Ventilation" Case, Accumulator Depressurization

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1 (seismic only)	10.533	1.61	19.38	0.57	6.85
GB 188-1 (fire only following seismic)	1.158	0.17	1.98	0.06	0.70
Total	11.691	1.78	21.36	0.63	7.55
Risk Acceptance Guidelines		25	250	4	40

Table H-8. Summary of Doses, Seismic Event with Fire, "Ventilation" Case (check valves function)

Facility	Release (g Pu)	Onsite Dose (rem)		Offsite Dose (rem)	
		EDE	Organ	EDE	Organ
GB 188-1 (seismic only)	2.973	0.48	6.45	0.17	2.28
GB 188-1 (fire only following seismic)	1.158	0.17	1.98	0.06	0.70
Total	4.131	0.65	8.43	0.23	2.98
Risk Acceptance Guidelines		25	250	4	40

APPENDIX I

MITIGATED SEISMIC EVENT – ACCUMULATOR AIR FLOW THROUGH THE LABORATORY PROTOTYPE CALCINER

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MITIGATED SEISMIC EVENT – ACCUMULATOR AIR FLOW THROUGH THE VERTICAL CALCINER

The mitigated seismic event analysis presented in Chapter 4, Section 4.2.5.2 assumes failure of the check valves and solenoid valve in the process air line between the accumulator and the calciner bed. Failure of the valves results in an open path between the accumulator tank and the calciner via the normal process airline. Normal process airflow does not occur due to the action of the seismically qualified solenoid valves upstream of the location where the accumulator airline enters the process airline. As soon as the path opens, the accumulator will depressurize. Air will flow into the oxide bed causing suspension of the oxide and pressurization of the calciner. The pressurization causes the pressure relief cap to lift, allowing some of the suspended oxide to be transported out of the calciner into the glovebox. It is assumed that the solenoid valves between the accumulator and the ceramic filters remain closed.

This analysis will proceed by first describing the oxide bed and the equipment protruding into it. Next, the accumulator depressurization data is used to obtain the airflow velocity. The calciner headspace volume is determined next, to allow for calculation of the headspace concentration. The next two subsections discuss the action of the air jet on the bed. The second of the two discussions is the most important. It is in this section that the plutonium release is determined.

1.0 VERTICAL CALCINER-PUO_2 POWDER BED DIMENSIONS

The shape and dimensions of the oxide bed of the vertical calciner are important to the understanding of the quantity of plutonium potentially suspended during the depressurization of the accumulator. The oxide bed is annular. The inside surface of the bed is a 4 inch Sch. 10 stainless steel pipe having an outside diameter of 4.5 inches. The outside surface is a 6 inch Sch. 10 stainless steel pipe having an inside diameter of 6.357 inches. The bed width is 0.93 inches, giving an area of 15.8 square inches. The bed is 6 to 7 inches deep. The process air and process feed enter the bed through coaxial concentric tubes. Process air flows in the outer tube. The outer tube is stainless steel with an inside diameter of 0.5 inches. The process feed enters through a 0.25 inch stainless steel tube having 0.035 inch thick walls which is located within the process air tube. The flow area for air is 0.12 in^2. The flow area for process feed is 0.05 in^2.

The agitator protrudes into the calciner. The agitator has 4 legs, each 0.3 inches thick and 1 inch wide. The bottom of the legs is near the bottom of the bed. The agitator rotates at 1 revolution per second. The legs are radially located in the middle of the bed, as is the process air and feed inlet. The legs rotate over the air and feed inlet 4 times per second which makes the single air and feed entry point act like many. The legs nearly cover the air inlet tube and do cover the process feed tube each time they rotate over the inlet tube. This results in an intermittent air and feed flow rate into the bed under normal operation. However, as a result of

the seismic event power is cut to the agitator. The size of the legs has the effect of dividing the bed into 4 even quadrants.

2.0 ACCUMULATOR

The accumulator volume is 2.3 L and is normally pressurized to 70 psig (5.76 atm or 84.7 psi, absolute). The flow rate during depressurization was found by testing. The process air line was opened up downstream of the rotameter. This position is near the calciner, which has the advantage of including the majority of the flow losses in the air path. In the test, the accumulator was allowed to depressurize through a valve put into the flow path at this location. The accumulator pressure vs. time was monitored during depressurization. The test showed that the accumulator depressurizes in 15.5 seconds (the average of the two tests). From this data, the ideal gas law and the air line flow area, the volumetric flow rate and air velocity in the bed can be determined. Table I-1 shows the test data.

Table I-1. Accumulator Depressurization Test Data

	Time(in seconds) to reach the pressure indicated	
Pressure (psig)	Test 1	Test 2
70	0	0
40	not recorded	4
30	4	not recorded
20	7	8
10	9	11
0	14.5	16.5

The results of Test 1 will be used as they provide the greatest flow rates through the line.

The air flow is found using the ideal gas law (PV = nRT). At 70 psig (5.76 atm or 84.7 psi, absolute) the accumulator contains 0.54 moles of air, assuming a temperature of 27 °C and a volume of 2.3 L. The density of air at 27 °C and atmospheric pressure is 1.179 g/L. Table I-2 shows the airflow rates. It is assumed that the airflow rates from the test are the same as the air flow rate into the calciner. Credit is not taken for line losses between the rotameter and the inlet to the calciner. The value for "L/s" assumes a pressure of 1 atm (i.e., the expanded volumetric flow rate).

Table I-2. Airflow Rates into the Bed from Accumulator Depressurization

Time	Pressure (psia)	Moles in accumulator	Moles released in the interval	Volumetric flow rate over the interval (L/s)	Velocity in tube, over the interval, m/s
0	84.7	0.54	0	0	0
4	44.7	0.28	0.26	1.6	21
7	34.7	0.22	0.06	0.5	6.5
9	24.7	0.16	0.06	0.7	9
14.5	14.7	0.09	0.07	0.3	4

3.0 CALCINER HEADSPACE VOLUME

The free headspace volume of the calciner above the bed is 315.7 in^3 (5.2L). This is found as follows. The exterior surface of the calciner headspace is made of 2 spools. Each spool is a 6 inch Sch. 10 (6.357 inch inner diameter) stainless steel pipe. The upper spool is 11 inches long. The lower spool is 9 inches long. The oxide bed takes up most of the volume of the lower spool. Using a bulk density of between 2 and 3 g/cm^3 for the oxide, the bed depth is about 6 inches. There is an open annular volume above the bed approximately one inch tall. Therefore the 6 inch diameter open volume above the bed is 13 inches long. Within the upper spool are the 3 ceramic filters. Each are 12 inches long and 2 inches in diameter. The volumes are as follows:

a. Six inch, Sch. 10 pipe, 13 inches long	=	413 in^3
b. Ceramic filters	=	37.7 in^3 each x 3 filters = 113.1 in^3 total
c. Annular space above bed (1 inch tall, 15.8 in^2 area)	=	15.8 in^3
TOTAL		315.7 in^3 (5.2 L)

4.0 BED EXPANSION

Airflow through beds of solids causes the beds to expand, a process known as fluidization. If the airflow is great enough, a spout will form. A spout resembles a water fountain that contains particles instead of water. Beds through which high velocity air flows are called spouted beds. The terminology used above and the correlation's to follow come primarily from *Fluidization* (Davidson et. al. 1985).

Davidson et. al. (1985) shows that typical airflow velocities for fluidization are less than 10 cm/s for beds the size of the calciner bed. Since the air velocity during accumulator depressurization is on the order of 20 m/s, the bed is likely a spouted bed. Page 212 of Davidson et. al. (1985) provides a correlation that provides the minimum velocity for spouting. The equation is as follows:

$$u = (D_1)(D_2)^{0.333}(L_1)^{0.5}$$

where:

- u = minimum velocity for spouting, m/s
- D_1 = d/D_c, where
- d = particle diameter, cm
  - = 0.002 cm (20 micron) based on the mean of the particle sizes by mass (see Attachment 1)
- D_c = bed diameter, cm
  - = 5.7 cm based on the assumption that the equivalent bed is ¼ of the entire bed, and that the annular bed can be represented by a circular bed of the same area.
- D_2 = D_i/D_c
- D_i = orifice diameter, cm

= 1.27 cm based on a 0.5 inch air line tube

L_1 = 2 g H $(\rho_S - \rho_f)/\rho_f$, where

g = acceleration due to gravity, cm/s^2

= 980

H = bed height, cm

= 15.2 cm based on a 6 inch bed

ρ_s = solids density, g/cm^3

= 10 for PuO_2

ρ_f = density of air, g/cm^3

= 5.7×10^{-4} based on 1 atm pressure and 618 K. 618 K is the logarithmic average temperature between 300 K and 1273 K.

Solving for u yields 5 cm/s. If the average temperature (500 °C) were used for ρ_f, u would equal 5.6 cm/s. If the annular width (2.4 cm) were used for D_c, u would equal 16 cm/s. So the bed is well within the range of spouted beds.

5.0 MASS ENTRAINMENT

Mass entrainment information is taken from Chapter 4 of Davidson et. al. (1985) on gas jets in fluidized beds. The first correlation for mass entrainment is found in Figure 4.16 of Davidson et. al. (1985) which presents a plot of mass entrainment rates as a function of height divided by orifice half-width.

The mass entrainment can be found from the evaluation of the plotted parameter W_s/W_{fo}

where:

W_s = mass flow rate of solids

W_{fo} = mass flow rate of air through the orifice

For the calciner, W_{fo} equals 0.93 g/s based on a density of 5.7×10^{-4} g/cm^3, an air velocity of 21 m/s and orifice area of 0.12 in^2.

The data for W_s/W_{fo} data presented comes from experiments with bronze and alumina particles having diameters of 300 micrometers. In the experiment, the air velocity was 90 m/s. Using the graph with the calciner bed depth (15 cm) and orifice half diameter (0.63 cm), the value of W_s/W_{fo} is found to be 25. Using the value for the mass flow rate of air (W_{fo}) in the calciner of 0.93 g/s, W_s is found to be 27 g/s. This entrainment rate however is based on 90 m/s airflow through a bed of 300 micron particles; somewhat different than the 20 m/s air velocity and 20 micron average particle diameter found in the calciner.

The second set of correlation is found in Table 4.3 of Davidson et. al. (1985) which presents other experiments in which mass entrainment was measured. Table I-3 presents this data as well as the corresponding data for the calciner.

Table I-3. Values of W_s/W_{fo} for other Experiments

Experimenter (from Table 4.3 of Davidson et. al. 1985)	Solid Material	Bed Height, cm	Air velocity, m/s	Orifice size, cm	Particle size, mm	W_s/W_{fo}
Toei	glass	--	6	0.5	0.25	4
Behie	plastic	--	61	1.9	0.06	1.3
Merry	lead	45	4	1.9	1	2
Donadono	plastic	4	90	2	2.9	20
Filla (1981)	glass	8	60	0.6	0.8	15
Filla (1985)	plastic	11	60	0.6	2.9	21
Filla (1983)	lead	6.5	60	6	1.8	60
Filla (1983)	plastic	11	60	6	2.9	20
Calciner	PuO_2	16	21	1.3	up to 0.1	--

Using the data for W_s/W_{fo} from Table I-3 and a value of W_{fo} of 1 g/s from the calciner yields an estimated mass flow rate of solids into the calciner headspace of 1.3 – 60 g/s.

A third correlation comes from H. Kono, who presents mass entrainment data for fluidized spouted beds and spouted beds in *Attrition Rates of Relatively Coarse Solid Particles in Various Types of Fluidized Beds* (Kono 1981), page 96. Kono uses 1 mm Si O_2 – Al_2O_3 particles having a density of 2.4 g/cm^3. The fluidized spouted bed in Kono (1981) is the closest analog to the PFP vertical calciner. Data from Figure 14 for 10 cm diameter beds with an airflow of 21 m/s shows a mass entrainment rate of 10 wt %/hr times the quantity "bed diameter (in. cm) raised to the 0.55 power." With a bed diameter of 5.7 cm (based on a ¼ bed) the entrainment rate is 26 wt %/hr. For the 1000 g bed (1/4 bed) in the vertical calciner, the entrainment rate is 0.07 g/s. While the flow rate and bed diameter match those of the calciner, the particles are much larger.

A fourth source of data for entrainment is the process incident that occurred during the testing phase of calciner operation. A plug occurred in the feed tube that plugged both the feed tube and the air tube. When the plug was broken with the clean-out rod, an inadvertent calciner pressurization occurred. Fifty to sixty grams of PuO_2 was discharged into the glovebox through the relief cap. With the airflow at normal flow rate and the vacuum on, the discharged PuO_2 was poured back into the calciner through the relief cap. This is the normal inlet to the calciner for oxide that requires recycle. The operator was unaware that at the time the oxide was poured back in, the ceramic filter was cracked. In the 15 seconds it took to pour the 50 – 60 g of oxide back into the calciner, 2 g appeared in the scrubber. This data suggests that the rest of the oxide fell back to the bed. Using the information above, the calciner headspace concentration is found to be 0.43 g/L (or 430 g/m^3). The value of 0.43 g/L was found as follows:

$$2\ g = (C)(Flow)(t)$$

where:

C = headspace concentration, g/L

Flow = flow through the calciner headspace. The flow is 0.66 ft^3/min
= 0.31 L/s
t = time = 15 s

The flow rate of 0.66 ft^3/min equates to a flow velocity 4 m/s using an orifice area of 0.12 in^2. The total accumulator discharge during the 15 seconds depressurization is found from Table I-2. A total of 11 liters was discharged over the 15 seconds. Using this release and an assumed concentration of 0.43 g/L, the release is found to be 4.7 g, or 0.3 g/s.

The 3 sets of experimental correlations for mass entrainment differ from the conditions within the calciner. The major differences are the air velocity and the particle size. A confounding aspect is that in the analyzed accident the flow will steadily decrease during the depressurization. There is no data to account for this aspect. Steady flow is judged to bound steadily decreasing flow.

The experimental data will next be used to determine scaling ratios for the parameters of interest. The data from Kono (1981), and from Davidson et. al. (1985) shows that the ratio of the entrainment is approximately proportional to the half of the ratio of the particle diameters. This is shown by using Table 4.3 of Davidson et. al. (1985) and comparing the data from Behie (1975) to Filla (1983). Both used 1 g/cm^3 particles with an air velocity of 60 m/s. The value of W_s/W_{fo} for the 0.06 mm particles used by Behie was 1.3. The value for the 3 mm particles used by Filla was 20. So, scaling 1 mm particles of the experimental data to the 20 μm PuO_2 particles (a ratio of 50) would reduce the entrainment by 15. The data for lead particles from Filla (1983) and Merry show a ratio of air velocity of 15, a ratio of particle size of 2 and a ratio of entrainment of 30. The data for plastic particles from Donadono for a velocity of 90 m/s shows the same entrainment as that from Filla (1985) at 60 m/s for the same particle size. Yet data from Kono (1981) shows a factor of 10 decrease in mass entrainment for air velocity of 20 m/s over that at 5 m/s and a factor of 4 decrease for air velocity of 40 m/s over that for 20 m/s. This suggests that for 1 mm particles the change in mass entrainment is greater for changes in velocities below 20 m/s (or so) and less for changes above 20 m/s. Kono's data shows that it is conservative to assume that the ratio of entrainment decreases as the ratio of velocity between 60 m/s (the air velocity for the majority of the experimental data) and 20 m/s (the calciner air flow rate). The following scaling factors will be used.

entrainment scaling = ½ (ratio of particle sizes)(ratio of air velocity)

The mass flow due to entrainment in the experiments, scaled to the calciner particle size and airflow velocity, yields values of mass entrainment of about 0.02 to 1 g/s. This is in the range of the 0.3 g/s found in the process incident.

The mass entrained during the accumulator depressurization is found in Table I-4. The entrainment rate is assumed to be 1 g/s (the high side of the range) during the period of high flow. Use of the high side of the range is conservative, and is used because of the lack of

experimental or theoretical data that closely match the situation in the calciner. It is judged that because of the small headspace, agglomeration (the attraction of smaller particles to produce large particles), interception (the removal of small particles by the settling of the large particles) and the use of the largest entrainment values from the experimental data, the actual entrainment rate will not exceed 1 g/s and could be 1/10 this value. The rate is divided by 2 as the flow during depressurization decreases.

Table I-4. Mass Entrained during Accumulator Depressurization

Time	Velocity	Assumed mass entrainment rate	Total released
0 – 4 s	20 m/s	1 g/s	4 g
4 – 14 s	4 – 9 m/s	0.5 g/s	5 g
			TOTAL: 9 g

It is further assumed that all of the 9 g are respirable. In the section below, it is shown that the calciner headspace could contain as much as 2.2 g at the start of the seismic event. This will also be blown out for a total release of 11.2 g.

This number differs from the release that occurred in the first step of the process incident (the 50-60 g release). The 9 g release comes from entrainment due to air flow. The first part of the process incident involved a slug of liquid process feed and air. Due to the plug the process feed was likely pressurized to 60 psig instead of the normal feed pressure of around 15 psig. It is postulated that the slug of feed and air removed all of the oxide within a cylinder defined by bed height and the radius of the orifice. This assertion matches the data in Kono (1981) and Davidson et. al. (1985). Kono (1981) shows in equations 9 and 10 and Figure 7, that the entraniment rate is a direct function of gas density. While Kono did not consider liquid, his experiments did consider gas densities up to 4.6 g/L (density of air is 1.12 at 27 °C). The density difference between the process feed (at about 1.5 g/cm^3) and air (at 5.7 x 10^{-4} g/cm^3) is 2600. This is not to imply that the difference in carryover should be 2600 times greater but to illustrate that the postulated difference in carryover of 9 g with air flow and 50 - 60 g with air and feed is attributable to the difference in fluids involved. Since the process feed is shut-off in the seismic event, carryover will only occur due to air flow.

It is assumed that the slug of feed and air removed all of the oxide within the cylinder defined by the radius of the orifice and the bed height. The volume of this region is

$$V = (\Pi/4)(\text{orifice dia.})^2(\text{bed height})$$

Solving for V using an orifice diameter of 0.5 in. and bed height of 6 in. yields 1.18 in^3. The oxide in this volume is 40 g based on 2 g/cm^3 bulk density of oxide. Continued airflow and feed flow at a much lower pressure acted to further pressurize the calciner and discharge the initial spike of material. The release of somewhat greater than 40 g matches the "50-60 g"

released. This release would not occur in the seismic event, however, as the feed flow is stopped by the seismically qualified solenoid valves.

If the check valves function, air can enter the calciner through the normal air path from the accumulator, i.e., through the ceramic filters, if the main and individual solenoid valves fail open. Under these conditions, all of the plutonium held up in the headspace will be blown out through the relief cap, as will the plutonium on the ceramic filters. The release from the plutonium in the headspace is 2.2 g based on 0.43 g/L in the 5.2L headspace. The plutonium on the filters is estimated to be 2.7 g. The basis for this quantity is as follows. The air flow through the calciner is 0.66 ft^3/min. Each filter is pulsed every 20 seconds to remove the accumulated oxide. All 3 filters are pulsed each minute. The total accumulation on all 3 of the filters is given by:

$$A = (0.66\ ft^3/min)(28.3\ L/ft^3)(0.43\ g/L)(1\ minute\ cycle\ time) = 8\ g$$

Under normal operation, the one of the solenoid valves pulse every 20 seconds.

During the seismic event, power to solenoid valves is shut off. It is assumed that at the time of the seismic event, one of the solenoid valves pulses and then sticks open. As a result, the 2.7 g on that filter plus the 2.2 g in the headspace will be blown out.

Air entering the filters will be dispersed in all directions as it travels through the line into the filter. There will be some resuspension from the bed which is a few inches below the filters. DOE (1994), Section 4.4.4.2 provides an airborne release rate of 4×10^{-5}/hr for air flow over a bed of powder under wind velocities of less than 2 m/s with gusts to 20 m/s. This value will be increased by a factor of 10 to account for a greater air flow, or unanticipated air circulation patterns. The resuspension release is:

$$R = (4000\ g)(4 \times 10^{-3}/hr)(15\ s/3600\ s/hr) = 0.07\ g$$

The total release is therefore, 5 g. While there are uncertainties in the above calculations it is clear that the release from air blowing through the filter is less than the 9 g released with air flow through the bed.

There could be air flowing through the bed and a single pulse of air through one of the filters if both the check valves and solenoid valves fail. Under this assumption the 2.7 g on one of the filters could instantly be transported to the headspace. The headspace concentration will increase causing additional agglomeration. Some of the oxide on the filters will also be removed by interception. As a result only a fraction of the 2.7 g release off the filters will escape the calciner. It is judged that the conservatism in the 9 g release, due to air flow through the bed, plus the 2.2 g calculated to be in the headspace, covers the release from the filters should air flow to both paths.

6.0 REFERENCES

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Kono, H., 1981, *Attrition Rates of Relatively Coarse Solid Particles in Various Types of Fluidized Beds, in Recent Advances in Fluidization and Fluid – Particle Systems,* American Institute of Chemical Engineers Symposium Series, New York, New York.

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Attachment 1

to Appendix I

(From PFP Laboratory Personnel)

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Data from Los Alamos National Laboratory Analysis of a Sample of PuO_2 from the bed of the Laboratory Prototype Calciner (data from PFP Plutonium Process Support Laboratories)

particle size range (μm)	avg. diameter (μm)	% mass basis
<0.7	0.7	0.44
0.7 - 1	0.85	0.12
1 - 1.3	1.15	0.25
1.3 - 1.8	1.55	0.26
1.8 - 2.3	2.05	0.33
2.3 - 3	2.65	0.90
3 - 4	3.5	1.70
4 - 5	4.5	2.21
5 - 6.5	5.75	3.41
6.5 - 8	7.25	5.35
8 - 10	9	6.94
10 - 13	11.5	7.23
13 - 17	15	7.55
17 - 20	18.5	9.76
20 - 25	22.5	11.87
25 - 31	28	12.27
31 - 37	34	10.07
37 - 44	40.5	8.22
44 - 53	48.5	6.10
53 - 63	58	3.30
75 - 88	81.5	1.32
88 - 105	96.5	0.39
105 - 125	115	0.00
	Total:	100

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