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Preliminary Safety Evaluation for the Plutonium Stabilization and Packaging System

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Abstract: This Preliminary Safety Evaluation identifies the hazards, postulates accident scenarios, determines potential accident consequences and identifies safety class/safety significant items associated with the Plutonium Stabilization and Packaging System to be installed at the Plutonium Finishing Plant on the Hanford Site.

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PRELIMINARY SAFETY EVALUATION FOR
THE PLUTONIUM STABILIZATION
AND PACKAGING SYSTEM
PROJECT W-460

February 1997

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LIST OF TERMS

AED	Aerodynamic Equivalent Diameter
ARF	Airborne Release Fraction
CSER	Criticality Safety Evaluation Report
DBE	Design Basis Earthquake
DBW	Design Basis Wind
DCF	Dose Conversion Factor
DF	Decontamination Factor
EDE	Effective Dose Equivalent
EG	Evaluation Guideline
FSAR	Final Safety Analysis Report
HEPA	High Efficiency Particulate Air
LOI	Loss on Ignition
NDA	Nondestructive Assay
PF	Penetration Factor
PHA	Preliminary Hazards Analysis
PFP	Plutonium Finishing Plant
PSE	Preliminary Safety Evaluation
RF	Release Fraction
SC	Safety Class
SEL	Safety Equipment List
SPS	Stabilization and Packaging System
SS	Safety Significant
SSC	Systems, Structures, and Components

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1.0 INTRODUCTION AND SUMMARY

1.1 SCOPE

This Preliminary Safety Evaluation (PSE) describes and analyzes the installation and operation of the Plutonium Stabilization and Packaging System (SPS) at the Plutonium Finishing Plant (PFP). The SPS is a combination of components required to expedite the safe and timely storage of Plutonium (Pu) oxide. The SPS program will receive site Pu packages, process the Pu for storage, package the Pu into metallic containers, and safely store the containers in a specially modified storage vault. The location of the SPS will be in the 2736-ZB building and the storage vaults will be in the 2736-Z building of the PFP, as shown in Figure 1-1.

The SPS will produce storage canisters that are larger than those currently used for Pu storage at the PFP. Therefore, the existing storage areas within the PFP secure vaults will require modification. Other modifications will be performed on the 2736-ZB building complex to facilitate the installation and operation of the SPS.

1.2 DESIGN DESCRIPTION

The design of the SPS is to provide a method to safely store Pu oxide at PFP for long term (50 years). The goal of the SPS operation is to process at least two storage canisters per 8-h shift. The system will maintain a continuous, successive operation through a series of attached gloveboxes. The mechanism for accomplishing this is as follows:

- The Pu oxide will be transferred from an existing PFP storage vault to the SPS
- The Pu oxide will be removed from the existing storage containers and placed in trays, and any process waste will be bagged for disposal
- The Pu oxide trays will be stabilized in a furnace
- All Pu oxide will be transferred into convenience cans
- Each convenience can will be loaded into an inner can and the cap welded
- The inner can will be checked for leaks and inserted into an outer can. The outer can will be welded and checked for removable surface contamination and leaks. Some previously stabilized Pu oxide may be received from other areas of the PFP. In those areas, the sealed cans received will be inserted into the larger cans, the cap welded, and checked for leaks.
- The completed storage canister will be transported to the storage vault

- The existing storage vaults will be modified to receive and store the larger canisters
- The ventilation system will be tied into the existing building HVAC to provide a path for filtering and removing the gases.

1.3 STABILIZATION AND PACKAGING SYSTEM PROCESS DESCRIPTION

The SPS process consists of three parts: preparation, stabilization, and packaging. The following defines the entire process from receipt of unprocessed material to placement of the new containers into the storage vault.

1.3.1 Preparation

The Receipt Area consists of the receipt hood, the airlock container handler, and the entry airlock. The receipt hood is a glovebox at the start of the SPS system that contains radiation monitoring and data recording equipment. The airlock container handler consists of a robotic arm and is located inside the entry airlock. The entry airlock is purged with dry air to match the atmosphere of the material preparation area.

The Dry Air System will supply dry air to the different glovebox areas from the Receipt Area to the Inner Can Handling Area. The 2731-ZA building will require modification to house the compressors and dryers for the Dry Air System.

The Material Preparation Area consists of a glovebox, can handlers, entry and exit isolation doors, container opener, powder dispensing station, metal brushing station, convenience can transfer port, decontamination station, compactor station, and material transfer ports.

The Ventilation System will consist of two stages of High Efficiency Particulate Air (HEPA) filters with isolation dampers that will connect to the existing fan inlet plenum. A redundant (parallel) train will be provided to allow a fan to draw air downstream of the HEPA filters and direct the exhaust into an existing stack. All exhaust ductwork, fittings, and flanges will be schedule 5S stainless steel.

The Fire Protection System above the SPS will be modified to add seismically qualified supports. (See Section 7.1.4 for additional discussion)

The Transport Area contains a glovebox with viewports, fixed position television cameras, and robotic arms.

1.3.2 Stabilization

The Furnace Area consists of two furnace gloveboxes, each with a stabilization furnace.

The Loss On Ignition (LOI) Test Area is a glovebox with gloveports, lights, shielded windows, equipment for weighing Pu oxide, and a small furnace.

1.3.3 Packaging

The Tipping Area consists of a glovebox with handling equipment to provide for the semi-automatic handling of Pu trays.

The Inner Cap Insertion Area contains can handling devices to load the inner can with a convenience can and follow with a special cap. The filled cans are then weighed and provided with identification (bar code).

The Inner Can Handling Area consists of a fume cabinet containing can handling equipment, laser welding equipment, and inner can storage racks.

The Outer Can Weld and Monitoring Area is a semi-circular indexing device that contains stations to perform the final steps in the packaging process, such as can handling, welding, helium leak checks, contamination tests, and final insertion onto the lag storage trolley.

The Lag Storage Trolley is a manually wheeled cart with a shielded compartment on top that holds two Pu SPS storage packages.

A new Air Conditioning Unit will be added to Rooms 641 and 642 to supplement the existing cooling capacity. The air-cooled condensing units will be located outside of the building.

1.4 VAULT MODIFICATIONS

The Pu storage vaults are located in the 2736-Z building. The type of vault redesign, either floor embedded or rack system, has not been decided. The floor modification will result in the installation of a 0.91-m (3-ft) high floor type vault resting on the existing floor. The vault would consist of 0.37 m^2 (4 ft^2) by 0.91-m (3-ft) high modular units that will house three storage cylinders. The modular units will interlock to form a secure deck with internal expansion joints. The top of the units consists of 30.5-m (12-in.) of concrete deck held in place by a metal structure. The design description of the rack type storage system is not available at this time.

1.5 SUMMARY OF PSE CONCLUSIONS

This PSE has been prepared in accordance with the requirements identified in WHC-CM-4-46, Section 5.0, "Preliminary Safety Evaluation." Section 4.1 describes the preliminary hazards analysis used to identify potential hazards posed by SPS operations and the storage of the containers produced by the SPS in modified vaults. The accident scenarios with the potential to result in significant consequences outside the facility are evaluated in detail in Section 4.3. Based on the results of the accident analyses in Section 4.3 and the safety classification criteria defined in WHC-CM-4-46, Section 9.0, a preliminary safety equipment list (SEL) has been developed for Project W-460. This SEL is summarized in Section 2.4 and Table 2-1. The SEL identifies the safety class and safety significant systems, structures, and components (SSCs) needed to prevent or mitigate significant accidents associated with the SPS and the storage of repackaged PuO_2 in the modified vaults, and describes their functional requirements.

The accident analyses and SEL provided in this PSE will be revisited in subsequent safety analyses to support the detailed design effort on Project W-460. In developing the hazards accident analyses in Chapter 4.0 several items were identified that also require further evaluation during the detailed design phase. These items are summarized in Chapter 8.0.

The PFP Final Safety Analysis Report (FSAR) will be amended to include the Project W-460 modifications before operating authorization for the SPS is issued. The amended FSAR will contain a finalized list of safety class and safety significant SSCs based on the final SPS and storage vault designs and applicable supporting analyses.

2.0 DESIGN CRITERIA

2.1 SAFETY CLASSIFICATION CRITERIA

Safety class (SC) and safety significant (SS) SSCs are derived from the guidelines in WHC-CM-4-46, Section 9.0, *Safety Structures, Systems, and Components*, which implement DOE Order 6430.1A, Section 1300-3, *Safety Class Criteria*. The system for classifying safety class and safety significant items is based primarily on potential radiological releases should the item fail.

- Safety class items are those SSCs whose failure may result in consequences that will expose the offsite public to radiological doses in excess of 5 mSv (0.5 rem) effective dose equivalent.
- Safety significant items include those SSCs whose failure may result in consequences that will expose the onsite worker to radiological doses in excess of 50 mSv (5 rem) EDE.

The safety significant designation also applies to SSCs that are judged to substantially contribute to defense-in-depth independent of quantitative analysis and to SSCs that protect the facility worker from serious injury due to other than standard industrial hazards (those not controlled by institutional safety programs). SSCs whose failure could prevent SC or SS SSCs from adequately performing their safety function, either by loss of control or monitoring function or by damage through physical interaction, are classified the same as the SSC being protected.

2.2 DESIGN CRITERIA

The SPS shall be designed to perform the following:

- Maintain material process rate of at least 2 containers per 8-h shift
- Minimize waste generation during operation and maintenance
- Provide radiological containment and shielding at all times
- Provide the capability to receive and unload all existing containers
- Meet Pu control and accountability requirements
- Perform thermal stabilization of Pu oxides
- Perform packaging of Pu oxide into canisters fabricated in accordance with DOE-STD-3013 (DOE 1996)
- Transport processed storage packages from the SPS to the remote storage area

- Modify the existing storage vaults to accept the larger canisters.

2.3 SAFETY RELATED CRITERIA

- Criticality analysis shall be provided. All components and systems shall be designed and operated to remain sub-critical for all fissile materials to be stabilized or stored at the PFP
- Safety SSCs shall conform to the requirements in the PFP FSAR for safety class and safety significant SSCs
- Contamination shall be confined to the vicinity of the source to minimize the spread of contamination
- The equipment shall be provided with all shielding necessary to meet administrative dose limits at the PFP
- Provisions for maintenance and decontamination operations shall minimize exposure to personnel performing those functions
- Industrial hazards shall be eliminated or reduced through implementation of Safety and Health Standards, WHC-CM-1-10, *Safety Manual*
- Fire Protection shall be considered in the facility modifications and glovebox design in accordance with NFPA and DOE regulations.

2.4 SAFETY EQUIPMENT LIST

Table 2-1 provides the preliminary list of safety class and safety significant SSCs that have been identified based on the safety classification criteria from WHC-CM-4-46, Section 9.0, and the accident analyses presented in Chapter 4. Table 2-1 identifies each safety class or safety significant SSC selected, provides the rationale behind the SSCs safety classification, describes the safety function(s) required by the SSC, and identifies the accident analyses germane to each SSC safety classification. Analyses to determine the need for additional safety class and safety significant SSCs are identified in Chapter 8.

3.0 HAZARDOUS INVENTORIES

This PSE includes SPS stabilization and repackaging operations and the storage of the 3013 repackaging cans inside modified vaults in the 2736-Z building. The hazardous radioactive and chemical inventories associated with SPS operation and vault storage are addressed in the following sections.

3.1 HAZARDOUS RADIOACTIVE MATERIALS

The SPS will stabilize and repackage primarily PuO_2 powders and ash. Significant amounts of plutonium metal are not expected to remain in the PFP inventory when SPS operations begin. The oxide put through the SPS machine and the vault storage capacity are discussed in the following two subsections. The isotopic makeup of the oxide powders to be processed by the SPS is discussed in Section 3.1.3.

3.1.1 Stabilization and Packaging System PuO_2 Inventory

The SPS is designed to produce two 3013 packages per 8-h shift, 3 shifts per day. Each site convenience can that is entered into the SPS is expected to contain from 0.5 kg to 2.5 kg of PuO_2. Each 3013 package produced is designed to hold very close to 5 kg of PuO_2. Several site convenience cans have to be input into the SPS for every 3013 package produced. The mass throughput through the SPS is 10 kg of PuO_2 per 8-h shift. Because SPS operations are performed in batch, the oxide mass loading in the SPS under normal operations can be expected to peak at around 30 kg. If a mass unit is defined as 5 kg (one 3013 can's loading), typically two mass units of oxide will be run through the repackaging portion of the SPS while two other mass units of oxide are being stabilized, cooled down, and LOI tested. Meanwhile, two other equivalent mass units of oxide can be expected to be run through the receipt and material prep areas of the SPS. It is anticipated that two to four lag storage trolleys may be used to transfer convenience cans/3013 cans to and from the SPS. Each trolley will hold two mass units.

The mass loading and material distribution described above defines the material at risk in a given SPS accident. PuO_2 powder is highly dispersible, with a relatively large fraction in the respirable size range (up to 40%).

3.1.2 Vault PuO_2 Inventory

The SPS is intended to produce 2,300 cans to meet the 3013 standard. At 5 kg per storage package, the maximum PuO_2 inventory in the storage vault (assuming the packages are stored in only one modified storage vault) is 11,500 kg. In most postulated storage vault accidents (e.g., drop of canister during loading), only a small fraction of the total inventory is at risk (e.g., that contained in a single canister, that contained in a single storage tube [in-floor storage concept], or that contained in a single cubicle [cubicle storage concept]).

3.1.3 PuO_2 Isotopic Makeup

The PuO_2 processed by the SPS will contain a mixture of plutonium isotopes and ^{241}Am. The isotopic makeup of the PuO_2 powder contained in PFP varies. Factors that affect the isotopic makeup of the plutonium include: the power level of the reactor in which the plutonium was produced, the fuel exposure time in the reactor, the neutron flux energy spectrum of the reactor, and the age of the plutonium since discharge from the reactor. Nondestructive analysis of shipments and periodic vault inventory verifications have allowed an estimate to be made of the isotopic distribution of plutonium at the PFP. This estimated distribution is provided in Table 9-43 of the PFP FSAR (WHC-SD-CP-SAR-021, WHC 1996b) and is reproduced in Table 3-1. The distribution presented in Table 3-1 reflects the different types of plutonium compounds stored at PFP (i.e., oxides, oxalates, fluorides, etc). For the purpose of performing consequence analyses, the PFP FSAR simplified the isotopic distribution, collapsing the distribution from seven bins to just two ranges, one for plutonium compounds containing less than 10% ^{240}Pu, and one for compounds containing greater than 10% ^{240}Pu. This was done because the inhalation dose potential for the plutonium compounds containing greater than 10% ^{240}Pu was found to vary much more than the inhalation dose potential for plutonium compounds containing less than 10% ^{240}Pu.

For the purposes of this safety analysis, PuO_2 released in any given accident is assumed to be composed of plutonium containing greater than 10% (by weight) ^{240}Pu. This ensures that conservative inhalation doses are estimated. The inhalation unit dose factor used in the accident analyses is discussed in Section 4.2.

3.2 HAZARDOUS CHEMICAL INVENTORIES

No routine chemical processes will be conducted within the SPS that involve the use of hazardous chemicals. Liquid solvents are not planned to be used to decontaminate the SPS gloveboxes, so significant storage quantities of solvents near the SPS are not anticipated.

Hydrogen can be produced inside site convenience cans due to radiolysis and the reaction of adsorbed water with plutonium oxide. There is a potential, therefore, for flammable hydrogen to be released inside the SPS when a site convenience can is opened. Hydrogen is not toxic, but a hydrogen deflagration could compromise the SPS confinement system. The release of significant quantities of organic vapors is not expected upon opening site convenience cans.

Plutonium is a poisonous heavy metal. However, the toxicological effects of exposure are far outweighed by the radiological effects. It is not expected that the toxicological consequences of the release of plutonium would require additional mitigating features beyond those already required by the radiological doses. The toxicological effects of plutonium exposure are not assessed in this PSE.

The SPS is to be connected to bottled gas supplies (carbon dioxide, helium, and nitrogen). These inert gases are not toxic in the traditional sense. The gas supplies can, however, pose an asphyxiation hazard to facility workers. This is true also for the dry fire suppression system (halon substitute or inert gas) connected to the SPS glovebox. The bottled gases are compressed and can therefore present a mechanical hazard to facility workers or equipment should the supply valve break off causing the bottle to act as a missile. With the exception of the SPS fire suppression supply, the compressed gas supply bottles will be located outside the 2736-ZB building and will not pose a missile threat to the SPS or storage vault. The compressed gas bottles supplying the SPS fire protection system will likely be located in the same room as the SPS. These bottles will have seismically qualified restraints to protect the SPS from potential missile damage.

A liquid nitrogen dewar system will be supplied with the SPS to provide cooling for the container assay monitor. This dewar will be located beneath the material preparation area of the SPS machine. The dewar system presents a potential cryogenic and asphyxiation hazard to operators.

The potential fire hazard posed by hydrogen released upon opening site convenience cans is addressed in Section 4.3.3. The facility worker hazards posed by the compressed gases, dry fire protection system and the nitrogen dewar system are identified in the hazards analysis discussed in Section 4.1. No significant hazardous chemical releases are expected under accident conditions as a result of operation of the SPS or storage of "3013" canisters.

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4.0 ACCIDENT ANALYSIS

4.1 PRELIMINARY HAZARDS ANALYSIS

4.1.1 Methodology

This section presents the methodology used to identify and characterize hazards of the SPS.

4.1.1.1 Hazard Identification Methodology. Hazard Identification is the process of highlighting material, system, process, and facility characteristics that have the potential to initiate accidents with undesirable consequences. The primary method of Hazard Identification/Hazard Evaluation used for the SPS was a Preliminary Hazards Analysis (PHA), a systematic approach in which the basic elements of the system and the hazards of interest for the conceptual design stage are identified, potential causes and effects are evaluated, and possible corrective and/or preventive measures are proposed. The PHA form is presented in Table 4-1. The completed PHA is contained in Appendix A.

PHA studies generally are considered a sufficiently thorough method of hazards identification at the Conceptual Design Stage of a project. However, two criticisms of this technique are (1) that the technique is not implicitly designed to highlight accidents initiated by natural phenomena or external events and (2) that the technique does not necessarily pick up standard industrial safety hazards. This PHA study addresses the effects of natural phenomena and external events in at least two ways. First, because the effects on process parameters initiated by natural phenomena and external events are generally of the same type as those that can be initiated by equipment failures, natural and external phenomena are included in the "Candidate Causes" column of the PHA as deemed applicable by the hazards analysis team. Second, because external events can add hazardous material to the system (such as fuel from a truck crash) that might initiate accidents, they are addressed under their own separate categories. Similarly, the confinement barrier deterioration potentially caused by external events or natural phenomena is also included specifically under the "Hazardous Event/Failure Mode" column in the PHA form.

Worker safety issues are discussed in this PHA as a general part of the information contained under the "Immediate Consequences" column as it relates to the "Hazardous Event/Failure Mode" item; a potential omission in the PHA discussion would be worker hazards from events not likely to cause process upsets. An example list of Hazards/Energy is presented in Appendix D. As part of the application of this list, worker hazards were also considered and documented in Section 8.0 of the PHA table.

The graded approach to hazards identification normally uses a PHA type of approach because of the conceptual nature of the design at the PSE stage. To provide additional assurance that accident initiating events that resulted from energy sources other than process material were not omitted, the PHA study was supplemented with a hazard/energy checklist adapted from the Systems Safety Development Center Job Safety Analysis Methodology. For the SPS, an "energy/barrier" checklist from DOE 76-4519, *Job Safety Analysis* (DOE 1976), was used as the basis for a general hazards inventory. The completed checklist is included as Appendix D.

In the PHA form (Table 4-1) the first column, designated "ID," is a an alpha-numeric identifier for the line of information in the table. This designator permits cross referencing of the information contained in the PHA with Accident Tables that are generated later in the hazards evaluation process. The second column, designated "Operational Area/System" is used to record the area of the SPS being evaluated or the system that is part of the SPS. The third column, "Operation(s)/Functions(s)," contains a description of the operation(s) being performed at an Operational Area that is being evaluated and a description of the system functions if a System is being evaluated. The fourth column, "Hazardous Event/Failure Mode," contains a description of the event if an Operational Area is being considered and the failure mode if a System is being considered. The fifth column, labeled "Candidate Causes," lists the potential cause or causes of the hazardous event or failure. The sixth column, "Material at Risk," describes the type and quantity of hazardous material that may be involved in the Hazardous event. The seventh column, labeled "Immediate Consequences," lists the potential consequences of the Hazardous Event. The eighth column, "Engineered Safety Features," is used to list the potential hardware design features that mitigate or prevent the event being considered. The ninth column is labeled "Administrative Safety Features" and lists the potential administrative controls such as procedures, training, practices, etc, that could mitigate or prevent the event.

The tenth column is labeled "Cons Cat." The Consequence column 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 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 was used to designate the severity, with 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, radiological dose consequences or chemical exposure 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.
- S3 Potential significant radiological dose consequences or chemical exposure to the offsite population; environmental discharges of hazardous material outside the Hanford site boundary or to the groundwater.

The "Freq Cat" column is 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 was used to designate the frequency, with the following "F" rankings characterizing safety consequences:

F0 Events not expected to occur and categorized as beyond extremely unlikely. The frequency range is $<1 \times 10^{-6}$/yr.

F1 Events not expected to occur within the lifetime of a typical facility and categorized as extremely unlikely. The frequency range is 1×10^{-6}/yr to $< 1 \times 10^{-4}$/yr.

F2 Events that could occur during the lifetime of the facility and categorized as unlikely. The frequency range is 1×10^{-4}/yr to $< 1 \times 10^{-2}$/yr.

F3 Events that are expected to occur one or more times during the lifetime of the facility and categorized as anticipated. The frequency range is 1×10^{-2} yr to < 1/yr.

The "Remarks" column contains information that the team judges to require documentation. This includes (but is not limited to) assumptions about facility operation or recommendations for changes in the planned design or operation.

The PHA was performed by the following individuals. The qualifications of the team are listed below:

Brett Hall	B. S. Chemical Engineering. Process/Specialty Engineer, FDNW Specialty Engineering. Over 6 years of experience at Hanford, including 5 years of experience in project Safety Analysis and 1 year of experience in Nuclear Waste Characterization.
Milton V. Shultz	B. S. Nuclear Engineering Technology. Senior Process/Specialty Engineer, FDNW Safety Analysis and Risk Assessment. More than 22 years experience at Hanford in a variety of areas. 1 year N Reactor fuel fabrication QA, 3 years N Reactor maintenance QA, 4 years N Reactor process standards, 5 years N Reactor process engineering, 1 year N Reactor independent safety, 9 years probabilistic risk assessment and risk evaluation.

Personnel from the project and PFP were contacted as needed to resolve questions of configuration and operation. Personnel involved were:

PFP Facility

- Evelyn Weiss

PFP Projects

- Jerry Johnston
- Charles O'Neal

4.1.1.2 PHA Performance Methodology. This section describes the details of the SPS PHA performance.

The PHA (Appendix A) is organized in sections to provide a structure that ensures a comprehensive look has been taken at all aspects of the SPS. Each section is oriented either to an Operational Area and Operational Activity breakdown or a System and System Function breakdown strategy. Sections 1.0, 2.0, 3.0, 5.0, 7.0, 8.0, and 9.0 are organized along the lines of an Operational Area. Sections 4.0 and 6.0 are broken down along a Systems orientation. Operational Areas are generalized groupings of functions according to what is performed in a localized area. Systems are groupings of components that provide a specific support service to the SPS, such as Ventilation Supply or Helium Inerting Atmosphere. Regardless of the breakdown strategy, each item was evaluated by applying the following questions:

What activity or function is intended?
What can go wrong or what can fail?
What is the failure characteristic or mode?
What hazardous material is involved in the failure?
What is the estimated consequence and frequency?

The PHA sections selected are as follows:

1.0 Front End Operations

2.0 SPS Operations

3.0 Storage Vault Operations (associated with the "3013" Canisters)

4.0 SPS Interfacing Systems (including facility interfaces to the SPS)

5.0 Final Storage-Vault Utilities

6.0 External Events (events external to the operational area but not related to natural phenomena)

7.0 Natural Phenomena

8.0 Worker Hazards (including industrial hazards-general to all locations unless otherwise specified)

9.0 Construction Hazards (threats to building and existing process during installation of SPS).

The general order of the PHA is according to process flow of the Pu oxide being stabilized for long-term storage. Section 1.0, "Front End Operations," is where the Pu oxide is brought out from current storage and moved to the SPS input area. Section 2.0, "SPS Operations," moves the Pu oxide stepwise through the various glovebox areas until it is ready to be placed in permanent storage. Section 3.0, "Storage Vault Operations," addresses the movement and permanent storage of the stabilized Pu oxide. Section 4.0, "SPS Interfacing Systems," addresses each of the systems that interfaces to the SPS glovebox system, supplying such things as electrical power, pressurized air for motive force, ventilation to maintain confinement, etc. Section 5.0 evaluates the final vault storage utilities in a similar manner to the way Section 4.0 evaluated SPS utilities. Sections 6.0, 7.0, 8.0, and 9.0 address items not specifically internal to the process. These are items such as the impact of potential external events from activities not associated with the SPS, natural phenomena that can affect many portions of the SPS simultaneously, worker hazards that are common to many industrial activities that may have similarity to those performed in the SPS, and events related to the construction activities that are necessary for initial installation of the SPS.

This approach results in considerable redundancy of the identified hazardous events/failure modes; but it ensures that any event is looked at from several different perspectives. An example would be failure to supply air of appropriate dryness to the glovebox. The difference in approach is that in Section 2.0 the concern is for adequate stabilization of Pu oxide, where in Section 4.0 the concern is for the system to perform the function of supplying dry air. A failure will show up under Section 2.0 as an operational problem that results in possible storage canister rupture, but will be listed in Section 4.0 as a system failure that results in possible storage canister rupture. In both sections, undesirable releases are postulated to result.

Therefore, by using an organization based on process flow, breaking that flow into sections to allow detailed evaluation, and including specific treatment of items external to the process, completeness of the evaluation can be qualitatively demonstrated.

4.1.1.3 Hazard Evaluation Methodology. The qualitative consequence and likelihood estimates for accidents that potentially could result from the identified events were generated by the PHA team using a modified Delphi approach based on the team members' experience and judgment. The criteria for the consequence and likelihood categories are listed in Section 4.1.1.1.

The selection of accidents for quantitative analysis was then performed by a binning process designed to comply with the requirements of Section 3.3.2.3.5 of DOE-STD-3009-94 (DOE 1994b) and the requirements of WHC-CM-4-46 in the areas of risk assessment, technical specifications, and safety class equipment. DOE-STD-3009-94 (DOE 1994b) suggests a matrix approach in which only "unacceptable accidents" (moderate to high consequences, unlikely to anticipated frequency) should be identified. The initial accident screening criteria used in this PHA is based entirely on qualitative consequence rankings. Any accident appearing in the S2 and S3 consequence categories is a potential candidate for quantitative analysis. This results in a broader spectrum of candidate accidents being considered for quantitative analysis than is required by DOE-STD-3009 (DOE 1994b); it 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 Technical Safety Requirements per selection criteria.

The selection process was performed according to the flow sheet included as Figure 4-1. All accidents were classified by Category and Type. The categories used were Internally Initiated accidents (process accidents), accidents initiated by Natural Phenomenon, and accidents initiated by causes external to the process (External Events). The type classification of an accident relates to the accident phenomena such as leak, fire, explosion, etc. For each selected major type with an S2 or S3 consequence, a representative accident was developed for analysis. A representative accident bounds the consequences of similar accidents or accident types. Similar accidents challenge analogous barriers. Analogous barriers reflect the same design philosophy for prevention and mitigation of the same accident type, even though they may be in different locations. 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. If there is only one accident of a given type, it is analyzed as a unique accident.

The results of the grouping process are presented in a series of simplified tables. There are a number of reasons that simplifying tables are used. The first, and primary, reason is due to a limitation, present in all qualitative Hazards Evaluation techniques, referred to as "inscrutability" (Guidelines for Hazard Evaluation Procedures). Another reason is that PHA tables are notes capturing a dynamic and creative process; they can be somewhat cryptic and often not easily understood by reviewers who are not part of the process. Also, the process flow orientation of the evaluation process does not create any kind of grouping of the information suitable for the accident selection process. For example, similar releases of Pu oxide can occur from different sections of the SPS. This results is a significant number of redundant identified hazards that are widely separated in the PHA table.

For these reasons, accident tables were developed to translate the PHA results into a clearer and more usable form based on the selected accident types and unique initiators. The accidents are also grouped into two sets of tables: tables of accidents that would not have effects of concern outside the facility boundary of the SPS (S1 category consequences, Appendix C, Tables C-1 through C-4) and tables of accidents that could potentially have effects of concern to either the maximum onsite individual or the maximum offsite individual (S2 category consequences, Appendix B, Tables B-1 through B-6). No S3 consequence items were identified. Appendix C also contains the Worker Hazard (Table C-5) and Process Upset (Table C-6) tables. The ID specifiers used in the accident tables are the same as the ID specifiers used in the PHA table (Appendix A) to permit identification of the precise source of the accident information.

4.1.2 Hazard Analysis Results

This section presents the results of the Hazards Analysis process.

4.1.2.1 Hazard Identification Results. The hazards identified during the PHA (Appendix A) are documented in tables contained in Appendix B and Appendix C. Appendix B contains hazards considered to have potential effects to the onsite worker and offsite public. Appendix C contains hazards considered to have potential effects to the facility worker. The hazards (inherent physical or chemical characteristics that have the potential to cause harm to people, property or the environment) associated with the SPS project are summarized in the energy barrier checklist in Appendix D.

Because the PHA consequence ranking is based on the worst case potential consequence, it is important to recognize that accidents with potential consequences of concern affecting the maximum offsite individual would generally also have potential consequences of concern affecting both the maximum onsite individual and the facility worker. Furthermore, even though various accidents would have virtually the same consequences, they could be initiated by a number of events.

4.1.2.2 Selected Accidents. Accident analysis criteria requires that a set of accidents be quantitatively analyzed. The results of this analysis demonstrate compliance with WHC-CM-4-46 risk acceptance criteria and justify the choice of Safety Class and Safety Significant systems, structures and components. The accident selection methodology is described in Section 4.1.1.2. This section documents the results of the accident selection activity.

The accident types with S2 consequences that were chosen for quantitative evaluation were Unfiltered Release Through Glovebox Ventilation System, Loss of Glovebox Confinement, SPS Glovebox Fire, "3013" Canister Failures During Storage, and Overheating of Storage Vault. Criticality was rated as an S1 consequence accident but was also included in the accident types chosen for quantitative evaluation. Other accidents that were found to have similar characteristics to one of the main types were grouped under these main types. The Seismic Event and High Wind were chosen from the Natural Phenomenon Category as unique initiators for unfiltered release through glovebox ventilation and loss of glovebox confinement. The Airplane Impact and Vehicle Impact were chosen from the External Event Category as also representing unique initiators for unfiltered release through glovebox ventilation and loss of glovebox confinement. Accidents that were deemed to be similar to the chosen accidents are shown below as indented under the main accident. The tables containing the S2 and S1 accident groupings are provided in Appendices B and C, respectively, and are as follows:

Table B-1	Unfiltered Release from Glovebox Ventilation System
Table B-2	Loss of Glovebox Confinement (Pressurization of room and glovebox) •Loss of Confinement by Glovebox Pressurization •Loss of Confinement by Glovebox Mechanical Damage
Table B-3	Fire in SPS Glovebox •External Events Causing Fire in Glovebox
Table B-4	Loss of Canister Confinement •External Event Causes Loss of Canister Confinement in storage vault
Table B-5	Vault Overheating
Table B-6	Aircraft Impact
Table B-7	Vehicle Impact
Table B-8	Seismic Event
Table B-9	Extreme Wind
Table C-3	Criticality •External Event Causing Criticality •Natural Phenomena Causing Criticality

A representative (bounding) accident was chosen (as appropriate) for each selected accident category or type. If a category or type contained a single accident, it was analyzed as unique. Accidents of the same type but differing categories may have different consequences, but similar safety features, depending on the availability of the safety features under different initiators. The representative accidents were chosen based on maximum consequences for an accident of a specific category and type.

The accidents chosen for analysis are as follows:

- **Unfiltered Release From Glovebox Ventilation System.** (Selected accident ID number 2.6.b.op, Table B-1.)

  Inside the SPS machine, plutonium oxide powder is poured from convenience cans and transferred through a screw conveyer system to furnace trays. It is postulated that during this normal operation the glovebox filter system fails and material is released to the environment during the period of time that the failure goes undetected. This accident was selected as bounding because the process would create the greatest normal equilibrium concentration of Pu oxide dust in the glovebox atmosphere.

- **Loss of Glovebox Confinement (with release via room structure).** (Selected accident ID number 4.13.b.is, Table B-2.)

  The SPS gloveboxes can be pressurized with resulting release of Pu oxide to the room due to a variety of causes. It is postulated that a ventilation system failure results in pressurization of both the gloveboxes and the room, resulting in a bounding amount of material being released outside the facility.

- **Fire in SPS Glovebox**. (Selected accident ID number 2.2.g-2.op, Table B-3.)

  A fire in the SPS gloveboxes could result in failure of glovebox confinement. It is postulated that various combustible materials are left in the glovebox from cleanup activities and catch on fire, resulting in glovebox confinement failure.

- **Loss of Canister Confinement**. (Selected accident ID number 2.7.j.op, Table B-4.)

  The stabilized oxide that comes from the SPS process will be packaged in new design canisters referred here as "3013" canisters. It is postulated that if a "3013" Canister is filled with improperly stabilized Pu oxide, significant pressure will build up during a period of time to rupture the canister with a significant release of material to the storage vault.

- **Vault Overheating**. (Selected accident ID number 3.5.b.op, Table B-5.)

  The stabilized Pu oxide will be contained in special storage canisters that will be stored in the storage vaults at the 2736 facility for an extended period of time. It is postulated that vault ventilation failure could result in significant rises in vault temperature from radioactive decay heat. If a sufficiently high temperature could be reached the structural integrity of the vault could be compromised.

- **Airplane Impact**. (Selected accident ID number 6.3.a.ex, Table B-6.)

  Aircraft occasionally overfly the Hanford Site. It is postulated that an aircraft crashes into the 2736 facility causing a significant release of Pu oxide.

- **Vehicle Impact**. (Selected accident ID number 6.3.b.ex, Table B-7.)

  Vehicles of various varieties are used on the Hanford Site. It is postulated that a large truck traveling in the vicinity of the 2736 facility crashes into the wall of the room housing the SPS with sufficient energy to penetrate the wall and damage the glovebox and cause a release of Pu oxide.

- **Seismic Event**. (Selected accident ID number 7.1.a.np, Table B-8.)

  The SPS process will have significant quantities of Pu oxide moving through the gloveboxes in non-sealed conveyances. It is postulated that a seismic event could damage the gloveboxes and cause failure of confinement systems (e.g., ventilation systems) resulting in a significant amount of Pu oxide being released to the room and perhaps the environment.

- **Extreme Wind**. (Selected accident ID number 7.1.b.np, Table B-9.)

  High winds have the potential for creating high velocity missiles. It is postulated that a high wind could generate a missile of sufficient energy and mass to penetrate the facility walls and damage the gloveboxes resulting in a significant release of Pu oxide.

- **Criticality**. (Selected accident ID number 2.1.d.op, Table C-3.)

  Wherever fissile material in significant quantities is present there is a potential for an inadvertent criticality. It is postulated that a sufficient quantity of fissile material is gathered into one place to permit a criticality to occur.

4.1.2.3 SPS Glovebox Project Impact on PFP FSAR Analyzed Accidents. The SPS and storage vault accidents identified in the previous section could impact accident analyses presented in the PFP FSAR, either by adding to or bounding the consequences of a representative FSAR accident or by increasing the likelihood of an FSAR accident. Table 4-1 lists the accidents evaluated in the FSAR and identifies whether an impact on the frequency or consequences of each accident can be expected due to the new accidents identified in this PSE.

4.1.2.4 (Section Deleted).

4.1.2.5 Safety Classification of Structures, Systems, and Components. Safety Class SSCs protect the offsite public; Safety Significant SSCs protect the onsite individual at a distance from the facility. The importance and adequacy of Safety Class and Safety Significant features are demonstrated by quantitative calculations based on the accident analysis performed for the chosen unique and representative accidents. The SSCs are specified in Section 4.3 in the accident analysis sections.

Candidate items for safety class or safety significant designation are listed in the "Engineered Features" column of the tables in Appendix A and Appendix B. Per DOE-STD-3009, safety-significant features do not necessarily include all items contributing to "defense-in-depth" but only the most important features. The Standard suggests that the final mitigating feature that protects the individual at a distance from the facility (building confinement features) is often chosen as the Safety Significant feature.

4.1.2.6 Worker Safety (Worker Protection). Worker safety for the SPS is ensured by a combination of confinement and shielding features and institutional practices. The main radiological hazard of the SPS is the Pu Oxide powder and direct radiation dose from the powder contained in canisters and deposited on the interior of the gloveboxes. Accidents related to worker safety are shown in Table C-5, Appendix C. The engineered and administrative features columns contain the controls that protect the worker. Controls could be identified for all the conditions which were identified. There were no conditions identified which required additional controls.

4.1.2.7 Environmental Protection. The project features, such as a ventilation system with multiple stages of HEPA filtration that maintains a negative pressure relative to the atmosphere outside of the 2736-ZB facility, protect the facility worker and serve to prevent and mitigate environmental releases of hazardous material. These features are listed in the accident tables in Appendixes A and B 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 that help discover unacceptable discharges.

4.1.2.8 Process Upsets. Table C-6, Appendix C, presents the items that were determined to only result in upset to the throughput of the process. This table is provided for completeness.

4.2 ACCIDENT ANALYSIS METHODOLOGY

The previous section identifies the representative accidents that were selected for further development. For each of the representative accidents, a detailed deterministic accident analysis was performed. The accident analyses are documented in Section 4.3. In deterministic accident analysis, worst-case accident initiators are postulated and active design features (e.g., ventilation systems) that could mitigate the accident are assumed to fail, concurrent with the accident initiator. Passive structures are not arbitrarily failed concurrent with the accident initiator, unless the accident initiator is capable of also causing failure of the structure. The purpose of the accident analysis is to determine the potential unmitigated consequences for comparison against the safety classification guidelines discussed in Chapter 2. The unmitigated consequences determine the need for safety class or safety significant design features. Accidents found to produce offsite inhalation doses in excess of the safety class limit of 0.5 rem effective dose equivalent (EDE) warrant safety class preventative or mitigative features. In general, accidents found to produce offsite inhalation doses below 0.5 rem (EDE) but above the onsite limit of 5 rem (EDE) warrant safety significant preventative or mitigative design features.

This PSE covers modifications to an existing facility. The focus of the accident analysis is to identify the design features associated with the Project W-460 modifications that warrant safety class or safety significant designation. Structures and systems previously determined to be safety class in the PFP FSAR (WHC 1996b) are, therefore, not assumed to fail in the accident analyses presented in Section 4.3. The residual consequences of accident scenarios, crediting previously defined safety class features, determines the need for additional design features associated with the Project W-460 modifications to be designated as safety class or safety significant.

Inhalation doses to the maximally exposed onsite and offsite receptors are estimated in Section 4.3 using the following equation:

$$Dose = (R)(X/Q')(BR)(DCF)$$

where,

Dose = Receptor dose, in rem (EDE)
R = Release of respirable sized particles to the environment, in g
X/Q' = atmospheric dispersion factor, in s/m^3
BR = receptor breathing rate, in m^3/s
DCF = dose conversion factor for Pu, in rem per g inhaled

The release quantity, R is a function of several factors, including the inventory at risk in the accident, the particle size distribution of the material at risk, the dispersing energy, and building leak path factors. In general, R is estimated in the accident analyses using release fractions (RF) from various handbooks, and crediting, where appropriate, decontamination factors (DF) provided by structures or other barriers in place to mitigate the release. In this PSE, RFs for releases of PuO_2 powder under various accident conditions are typically those recommended in DOE-HDBK-3010 (DOE 1994a), based on experiments with UO_2 and other powders that are judged to adequately simulate the behavior of PuO_2 powders. Since inhalation dose is the health effect of concern, the release is quantified only for respirable sized particles. In general, respirable sized particles are those that have aerodynamic equivalent diameters less than 10 um. Decontamination factors for safety class HEPA filters during accident scenarios are based on recommended penetration factors (PF) reported in Elder et. al (1986), *A Guide to Radiological Accident Considerations for Siting and Design of DOE Nonreactor Nuclear Facilities*. For more details on the development of the release estimates see the "source term development" discussions in the accident analyses.

The atmospheric dispersion factors, X/Q's, used in the accident analyses are provided in Table 4-2. These X/Q's come from Tables 9-39 and 9-40 of the PFP FSAR and reflect straight-line gaussian dispersion. The X/Q's in Table 4-2 correspond to 95th% meteorology and are corrected for both building wake and plume meander. For the purposes of this analysis, the maximum onsite receptor is assumed, as in the PFP FSAR, to be located at the nearest occupied facility outside the PFP exclusion area — 550 m in the WNW direction. The maximum offsite receptor is assumed to be located at the site boundary location (distance and direction) where the 95th% X/Q' occurs — 12,500 m to the W of PFP. The release quantity, R multiplied by the atmospheric dispersion factor gives the average airborne concentration during the plume's passage at the receptor's location.

The breathing rate applied in the accident analysis is the reference person's active breathing rate of 3.3×10^{-4} m^3/s from ICRP 23. The airborne concentration at the receptor's location, (R)(X/Q'), multiplying the airborne concentration [given by (R)(X/Q')] by the receptor's breathing rate gives the quantity of respirable sized particles deposited in the lungs of the receptor.

The plutonium dose conversion factor (DCF) used in the analysis is 1.7×10^8 rem/g. This DCF comes from Table 9-46 of the PFP FSAR. This DCF represents the 90th percentile (exceeded no more than 10% of the time) for the portion of the plutonium inventory in PFP containing greater than 10% Pu-240. See Section 3.0 for a description of the isotopic distribution of PFP plutonium compounds. The DCF corresponds to the Class Y solubility class, which is appropriate for oxide forms of the isotopes of concern in this analysis. Multiplying the quantity of material deposited in the lungs of the receptor [given by (R)(X/Q')(BR)] by the DCF gives the effective dose equivalent (EDE-50 yr committed) to the receptor. For the PuO_2 releases modelled in the accident analyses, using the DCF of 1.7×10^8 rem/g results in doses that are overestimated by approximately 11%, the weight fraction of the PuO_2 molecule taken up by oxygen.

4.3 ACCIDENT ANALYSIS

4.3.1 Unfiltered Release Through Glovebox Ventilation System

Should the filters in the glovebox ventilation system fail during normal processing operations or during an upset condition in the SPS gloveboxes, significant quantities of plutonium oxide powder could be released to the environment. This accident analysis examines the potential unmitigated release through the glovebox ventilation system to examine the ventilation filters' importance to safety.

4.3.1.1 Scenario Development. Inside the SPS, plutonium oxide powder is poured from convenience cans and transferred through a screw conveyer system to furnace trays. After drying in the stabilization furnaces, the plutonium oxide powder on the furnace trays is poured into the final 3013 convenience cans by tipping and vibrating the furnace trays. Equipment covers are used to limit the spread of contamination to the glovebox atmosphere while pouring or transferring powder. However, some spread of contamination to the glovebox ventilation airstream is expected during normal operations. Entrainment of plutonium oxide powder from loose beds in the furnace trays, as they are passed through the transport glovebox, is expected, as is entrainment of powder from furnace trays inside the stabilization furnaces. Off-normal events, such as spills of plutonium powder from furnace trays or canisters (due to handling errors), will increase the plutonium oxide concentration in the glovebox ventilation airstream.

Each glovebox is separately ventilated, provided with a HEPA filter at its outlet to the exhaust system. High efficiency sintered metal filters are located in the exhaust outlets from the stabilization and LOI furnaces. The exhaust from the SPS gloveboxes passes into the 638 room adjoining the 641 room (where the SPS is housed) and passes through two stages of HEPA filtration before being exhausted through the building exhaust stack. The exhaust fan for the various 2736-ZB building rooms also exhausts the SPS glovebox. Flow dampers are used to maintain the proper pressures in the various ventilation zones. The exhaust duct from the glovebox filters in Room 638 passes through the roof of the building, runs across the building roof to

Room 600, passes through the roof at that point and connects into the building exhaust system upstream of the building exhaust fan. A kicker fan is provided in Room 600 to maintain the SPS gloveboxes under negative pressure should both building exhaust fans shutdown. The glovebox exhaust flow bypasses the 2736-ZB building final filters (see HVAC composite diagram ES-W460-H5 provided with the CDR).

For this consequence analysis, plutonium oxide powder released to the glovebox airstreams during normal glovebox operations is assumed to pass unfiltered through the glovebox ventilation system into the environment. The dose consequences are modelled for a release during a 24-h time period. No decontamination factor is applied to the glovebox HEPA filters or the two stages of HEPA filters located in Room 638. This release scenario is hypothetical; it has been evaluated to determine the appropriate safety classification for the SPS exhaust system filtration system.

4.3.1.2 Source Term Analysis. The design throughput requirement for the SPS machine is two 3013 packages per shift. Each 3013 package is to contain 5 kg of plutonium oxide. It is assumed that the SPS will be operated three 8-h shifts a day. Plutonium oxide may be cooled inside the stabilization furnaces overnight. The total amount of plutonium repackaged in a 24-h time period is 30 kg.

During a 24-h period, the 30 kg of plutonium is poured and transferred between containers twice: once when the furnace trays are filled in the material preparation box, and once when the furnace trays are poured into the final convenience can. Oxide hoppers are used to minimize the spread of the powder to the glovebox airstream. However, some release is anticipated. For this analysis, a release fraction of 4×10^{-6} is applied to estimate the powder released to the glovebox airstream during each pour. Table 4-13 of DOE-HDBK-3010-94 (DOE 1994a), summarizes the results of experiments where various materials were poured from heights of 1 m. For 500 g quantities of UO_2, spilled from a height of 1 m, the measured respirable release fraction was 4×10^{-5}. This release fraction is judged to apply to spills of PuO_2 powder. The respirable release fraction was reduced by a factor of 10 to credit the decontamination factor provided by the hoppers. The total release due to transferring plutonium oxide powder between containers in the SPS is estimated by multiplying the material at risk (30 kg) by the number of pours and by the respirable release fraction:

$$\text{Release (powder transfers)} = (30\ \text{kg})(2)(4 \times 10^{-6}) = 2.4 \times 10^{-4}\ \text{kg} = 0.24\ \text{g}$$

In addition to the release caused by transferring the plutonium oxide powder, loose powder in the various SPS gloveboxes is subject to resuspension in the glovebox ventilation air. The majority of the plutonium oxide that is subject to resuspension will be contained in the furnace trays. The plutonium oxide will be processed on six furnace trays (5 kg/tray) in the 24-h time frame. It is assumed that four of the furnace trays are vulnerable to resuspension for a 16-h time frame (those that are allowed to cool overnight in the furnaces), and that the other two trays are subject to resuspension for only 8 h these are assumed to be repackaged in the first 8-h shift. DOE-HDBK-3010-94, Section 4.4.4.1, recommends a bounding resuspension fraction of 4×10^{-5}/h for powders under low to moderate wind conditions. However, not all of the powder on the trays is subject to resuspension. Only the top layer of the powder on a tray can be entrained in the ventilation airstream. A correction factor of 0.1 is therefore applied to correct for the fraction of material subject to release. The total resuspension release during a 24-h period is calculated by multiplying the material at risk on each tray by the 0.1 correction factor, the number of trays, the resuspension release rate, and the duration of exposure:

Release (resuspension) = (4 trays)(5 kg/tray)(0.1)(4 x 10^{-5}/h)(16h)
+ (2 trays)(5 kg/tray)(0.1)(4 x 10^{-5}/h)(8h)
= 1.6 g

The total release from the transferring operations and resuspension off the furnace trays is 1.84 g.

During the 24-h release period, the average concentration of plutonium oxide powder in the exhaust stream can be estimated using the following equation:

$$C = R/[(V')(t)]$$

where,

C = airborne plutonium oxide concentration (in g/m^3),
V' = volumetric flow rate through the gloveboxes (in m^3/min),
t = time (min).

The SPS exhaust flow rate is estimated to be 10 m^3/min from WHC-SD-CP-FDC-005 (WHC 1996a). Solving gives:

$$C = 1.84\ g/[(10\ m^3/min)(60\ min/h)(24\ h)] = 1.3 \times 10^{-1}\ mg/m^3$$

This concentration is comparable to particulate mass concentrations measured in the ambient atmosphere (0.05 to 1.0 mg/m^3) and in air conditioned buildings (0.3 mg/m^3) (PNL-4154, *Accident Generated Particulate Materials and Their Characteristics—A Review of Background Information*). The above release estimate, therefore, is not overly conservative for normal operations. Upset conditions within the SPS, such as a spill of one or more furnace trays, could produce larger releases.

4.3.1.3 Consequence Analysis. The onsite and offsite doses are calculated using the methodology discussed in Section 4.2. From Table 4-2, the onsite X/Q' is 4.74 x 10^{-4} s/m^3. The offsite X/Q' is 1.01 x 10^{-5} s/m^3. The receptor's breathing rate is 3.3 x 10^{-4} m^3/s and the inhalation ULD for the plutonium oxide powder is 1.7 x 10^8 rem/g. The onsite and offsite doses are as follows:

Onsite Dose

$$= (1.84\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^8\ rem/g)$$
$$= 49\ rem$$

Offsite Dose

$$= (1.84\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^8\ rem/g)$$
$$= 1.0\ rem$$

4.3.1.4 Comparison to Evaluation Guidelines. The onsite and offsite doses are compared against the evaluation guidelines in Table 4-3. The doses exceed both the onsite and offsite guidelines. Safety class mitigation, therefore, is required.

4.3.1.5 Safety SSCs Required. Safety class filtration on the SPS glovebox exhaust system is required. Since the filters located on the exhaust outlets of the gloveboxes are not set up for easy aerosol testing, the dual-stage filter banks in Room 638 are designated safety class. The functional requirement of the safety class filters is to mitigate particulate releases through the glovebox exhaust system. Since the glovebox exhaust does not flow through the 2736-ZB building ventilation filters, the building ventilation system filters can not be relied on to prevent unacceptable releases due to particulate made airborne in the SPS gloveboxes.

The PF provided by two stages of filters is 2×10^{-6} (Elder et al. 1986). Multiplying the dose consequences estimated in Section 4.3.1.3 by this PF gives results that are orders of magnitude below the safety class and safety significant limits.

The confinement function provided by the SPS glovebox structures is examined in the following accident analysis, Loss of Glovebox Confinement.

4.3.2 Loss of Glovebox Confinement (SPS Glovebox Pressurization)

Loose PuO_2 inside the SPS can be released to the 641 and 642 rooms due to various causes. From the hazards analysis, Section 4.1, postulated causes for loss of SPS glovebox confinement include: sphincter failures, isolation door faults, errors during bagout of compacted canisters, spurious activation of the glovebox dry fire protection system, internal impacts on the glovebox structure (e.g., due to equipment failures, canister drops), external impacts on the glovebox structure (e.g., impacts from room equipment or carts), and ventilation faults or utility gas supply failures that result in pressurization of the SPS gloveboxes. The pressurized glovebox case presents the bounding loss of confinement accident for the SPS gloveboxes and is analyzed in detail below. A hydrogen deflagration upon opening of a convenience can inside the SPS could also cause a loss of glovebox confinement but is analyzed as a fire scenario in Section 4.3.3.

4.3.2.1 Scenario Development. The SPS gloveboxes could be pressurized due to a number of faults, including: loss of the 2736-ZB building exhaust fan (which exhaust both the SPS gloveboxes and the 641 and 642 rooms), a closed damper in the SPS exhaust path (or other blockage), a loss of flow control on the dry air supply system, failure of the utility gas lines feeding equipment inside the glovebox, or various combinations of these faults (as could occur in a seismic event). Loss of the building exhaust fan would be expected to pressurize the SPS gloveboxes less than the last three causes. The dump valves on the SPS gloveboxes will not prevent pressurization should the exhaust path from the machine become blocked. The damp valves and exhaust system may not be able to accommodate the flow from compressed air or other utility gas leaks inside the SPS machine.

For this analysis, the SPS gloveboxes are postulated to be pressurized due to an oversupply of dry air to the system (i.e., supply airflow exceeding exhaust airflow). This can be caused by a regulator or control valve failure on the dry air supply system, a failure of the exhaust system fans, or closure of an exhaust system damper. The excessive pressurization is postulated to cause the glovebox gloves to rupture and entrained plutonium oxide powder from inside the SPS to be blown into the 641/642 rooms.

Secondary confinement, in the event of a release from the SPS gloveboxes, is provided by the 2736-ZB building walls and (normally) the building exhaust system. The exhaust ductwork for the facility and the exhaust system filters were previously designated as safety class in the PFP FSAR (WHC 1996b), to minimize potential releases from the facility. The exhaust fans, however, were not designated as safety class. In addition, current drawings show a door on the exterior East wall of the building. This door is located just a few feet away from the proposed location for the SPS machine and provides a potential leakage path directly to the environment. Upon glovebox pressurization, pressure alarms on the machine and CAMS in the 641/642 area will result in operators exiting the area, potentially through the exterior door.

For assessment purposes, the exterior door is assumed to be ajar during the pressurization event and exhaust from the room is assumed to be shutdown. Loss of room exhaust flow concurrent with pressurization of the SPS glovebox is not all that unlikely as the 2736-ZB building exhaust fan is relied on to maintain negative pressure in both the SPS and the 641 and 642 rooms. A kicker fan is provided on the SPS to provide backup to the building exhaust fans. However, no interlock could be identified to shutdown the SPS dry air and compressed utility gas supplies on detection of high pressure in the gloveboxes. The supply air to the glovebox and the supply air to the 641 and 642 rooms is postulated to pressurize the 641 and 642 rooms and force a portion of the plutonium powder released from the glovebox through the open exterior door into the atmosphere.

4.3.2.2 Source Term Analysis. Plutonium oxide powder is poured from canisters and transferred through a screw conveyer to furnace trays inside the second section of the material preparation area. Plutonium oxide powder in open furnace trays is susceptible to entrainment inside the transport area and the furnace stabilization area. Plutonium oxide powder is poured into convenience cans in the tipping/dispense/fill area. Although covers are used when pouring or dispensing powder, some release is expected to contaminate the glovebox atmospheres during normal glovebox operation. This analysis conservatively assumes that the plutonium oxide concentration in the glovebox atmospheres is 100 mg/m^3 at the time the gloveboxes are pressurized and the gloves are blown out. The 100 mg/m^3 value is the upper-limit mass concentration for quasi-stable, accident-generated, airborne concentrations recommended in BNWL-1732 (1973). The estimated total volume for the three SPS gloveboxes where powder is susceptible to release is 18 m^3. It is assumed that 20% of the volume of the gloveboxes is taken up by equipment. The initial plutonium oxide release from the gloveboxes is, therefore, 1440 mg ([100 mg/m^3][18 m^3][0.80]). This release is assumed to be 100% respirable.

Up to 20 kg of plutonium oxide powder can be present on furnace trays inside the SPS machine at any given time. Small amounts of plutonium oxide will, over time, also accumulate on the floor of the gloveboxes due to minor spills during processing. A fraction of the plutonium oxide powder in the open in the glovebox is subject to entrainment in the air blowing through the gloveboxes and out through compromised seals and the openings left by the blown out gloves.

DOE-HDBK-3010-94 (DOE 1994a), Section 4.4.4.1, recommends an airborne respirable release rate under low to moderate wind speeds of 4×10^{-5} weight fraction per h. Not all of the powder on the furnace trays, however, is susceptible to release. Only the top portion of the powder in the trays can be entrained in the air blowing over the surface. A correction factor of 0.1, therefore, is applied (i.e., only the top 10% of the powder on the trays is assumed to be resuspendable). The continuous release from the gloveboxes to the room atmosphere is, therefore, 0.08 g/h ([20,000 g][0.1][4×10^{-5}/h]).

The gloveboxes in Room 641 do not handle open convenience cans. The majority of the plutonium oxide powder release will occur in Room 642, where the door on the exterior wall is located. The supply air flow rate to the room plus the dry air forced from the glovebox is expected to result in several volume exchanges per hour in the 642 room. The open door will provide much less resistance to flow than the exhaust ductwork from the room. Hence, the majority of the release from the gloveboxes estimated above can be expected to be released through the open door into the environment. Given the short distance between the SPS machine and the door, gravitational settling is not expected to significantly reduce the release quantity from the building.

For the purposes of this consequence analysis, the release is assumed to continue unabated for 2 h. Within this time frame, it assumed the dry air and compressed gas supplies can be shut off and the exterior door closed. The total release to the environment is the sum of the initial puff release from the SPS and the resuspension release during the 2-h time frame.

$$R(total) = 1.44 \text{ g} + (0.08 \text{ g/h})(2 \text{ h}) = 1.6 \text{ g}$$

The above release estimate does not include potential airborne particulate release caused by continuous operation of oxide handling equipment (e.g., continuous operation of canister handlers, tray tippers, screw conveyers) during the 12-h duration of the accident. The handling equipment is assumed to be shut down following the initial pressurization and release leaving resuspension off the furnace trays as the only release mechanism.

4.3.2.3 Consequence Analysis. The onsite and offsite doses are calculated using the methodology discussed in Section 4.2. From Table 4-2, the onsite X/Q' is 4.74×10^{-4} s/m^3. The offsite X/Q' is 1.01×10^{-5} s/m^3. The receptor's breathing rate is 3.3×10^{-4} m^3/s and the inhalation ULD for the plutonium oxide powder is 1.7×10^8 rem/g. The onsite and offsite doses are as follows:

Onsite Dose

$$= (1.6\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^8\ rem/g)$$
$$= 43\ rem$$

Offsite Dose

$$= (1.6\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^8\ rem/g)$$
$$= 0.91\ rem$$

4.3.2.4 Comparison to Evaluation Guidelines. The onsite and offsite doses are compared against the evaluation guidelines in Table 4-4. The onsite and offsite doses exceed the evaluation guidelines. It is therefore concluded that safety class design features are warranted to prevent releases from the SPS gloveboxes or to provide secondary confinement in the event of a release from the SPS gloveboxes.

4.3.2.5 Safety SSCs Required. The exterior door on the east side of the 2736-ZB building provides a potential release path to the environment should plutonium oxide be expelled from the SPS glovebox. The exterior door is required for emergency egress in the event of a fire or criticality and, therefore, cannot be sealed shut. Should operators exit the building through the exterior door in a glovebox loss of confinement accident, however, the building exhaust system's ability to maintain secondary confinement is compromised. The exhaust fan for the building is not qualified to safety class requirements and could fail concurrently with the event that causes the release of plutonium oxide from the SPS.

Further analyses are needed to define the functional requirements for design features to prevent or mitigate a release from the SPS (see Section 8.0). Safety class secondary confinement is required unless all potential causes for glovebox pressurization are prevented with safety class design features. Safety class automatic interlocks to shut off the dry air and compressed utility gas supplies to the SPS on detection of high pressure in the SPS should be considered. Consideration should also be given to converting the external door to an airlock arrangement, with reliable automatic door closers on each door. Modelling would be required to demonstrate that the potential release through the airlock arrangement, given operator egress in an event, is acceptable.

The accident analysis above justifies the safety class designation for the building structure and final HEPA filters (F-14 through F-17) previously determined in the PFP FSAR. An unfiltered release through the building vent system, should both stages of HEPA filters be breached during a glovebox pressurization event with the exhaust fan running, could be expected to produce doses as large as those estimated above. Two HEPA filters in series provide a PF of 2×10^{-6} (Elder et al. 1986). Crediting the safety class HEPA filters, therefore, results in onsite and offsite dose consequences that are well below the evaluation guidelines (5.4×10^{-5} rem and 1.2×10^{-6} rem, respectively).

The release of plutonium oxide into the 641 and 642 rooms presents a serious hazard to operators in those rooms during glovebox operations. The glovebox confinement structure and seals and the glovebox ventilation system, therefore, are classified as safety significant for the protection of facility workers. The functional requirement of the glovebox and ventilation system is to confine radioactive material within the gloveboxes and ventilation system. The glovebox ventilation system kicker fan and its controls are safety significant to ensure it activates and maintains negative pressure within the glovebox should the building exhaust fans shut down during SPS operations. In addition, CAMs located in Rooms 641 and 642 are safety significant for the protection of facility workers.

4.3.3 SPS Glovebox Fire

The plutonium stabilization and packaging system components were reviewed to determine the potential for a fire. Fires have become of great concern since the Rocky Flats glovebox fire of 1969. Fires in the SPS gloveboxes are much less likely than that at Rocky Flats because of the absence of combustible shielding and structural material, and combustible glovebox windows and doors. The *System Design Document* (BNFL 1996) states that the shielding must either be non-combustible or encased in non-combustible material if it is combustible. On that bases the beechwood-lead shields discussed in BNFL (1996) are assumed to be a sandwich of beechwood covered by lead. While the BNFL System Design Document states that acrylic panels and doors are used in various locations, non-combustible materials (such as glass) will be used at PFP.

The Rocky Flats gloveboxes were made primarily of combustible plastics. These materials made up storage arrays, the large glovebox windows and other structural features of or within the glovebox. The SPS gloveboxes are primarily stainless steel with small glass windows and non-combustible shielding. The Rocky Flats gloveboxes did not have fire detectors within the gloveboxes. The PFP system will have heat detection in the gloveboxes.

4.3.3.1 Fire Conditions. A review of the SPS operations and structure showed that ignition sources were present as was oxygen and fuel. A discussion of each follows.

4.3.3.1.1 Ignition Sources. There are ignition sources within and outside of the gloveboxes. Inside the glovebox there are electrical wires powering internal receptacles, lighting in some gloveboxes, the furnaces, cap removal equipment, tipping drive motor, as well as some other equipment. Outside the glovebox are the same sources plus power for solenoid valves, vacuum blower, the compactor, etc. The laser beam from the welder may also be an ignition source if misdirected.

4.3.3.1.2 Fuel and Ignition Sources Simultaneously. While there are the standard ignition sources, the combustible material only exists in isolated locations and in small quantities.

The receipt area will contain plastic and paper from the removal of the packaging, but there are no ready, energetic ignition sources in this area. The containers are still sealed while in the receipt area so that ignition due to hydrogen is not possible.

The material preparation area could have a small hydrogen deflagration if upon opening of a can a spark should occur due to a failure within the can opener mechanism. However, there are no sources of fuel except for the rubber gloves in the general vicinity of the deflagration.

As an indication of the size of the events described, assume that a container is pressurized to 200 psig and that the container is filled with 2 kg of plutonium oxide powder. At a density of 10 g/cm^3, 2 kg of powder occupies 200 cm^3 leaving an open volume of about 1 liter. Using the ideal gas law and assuming the entire open volume was filled with hydrogen at 200 psig and 27 °C (80 °F), the quantity of hydrogen present is 0.6 moles or 1.2 g. Assume that all of the hydrogen burned. The heat released would be 32 kcal based on a heat value of 26.8 kcal/g. The material preparation glovebox is estimated to be 11 ft long, about 9 ft wide and 5 ft tall. The volume is 500 ft^3. Given the density of air of 0.075 lb/ft^3 and specific heat of 0.24 cal/g-°C, and assuming no heat transfer to any of the metal, the final air temperature is 7.8 °C above the initial temperature or about 35 °C (95 °F). Using the ideal gas law, the glovebox pressure is 15.1 psia or 0.4 psig. This will blow out the gloves, but should not affect other parts of the glovebox. Note that if the hydrogen were spread uniformally over the glovebox volume (a reasonable assumption based on 1 liter pressurized to 200 psig), the concentration would be 2% of the lower flammability limit.

The furnace area may experience small fires within the furnace if the powder is contaminated with combustible organic compounds. Again, there is no other combustible material in the vicinity of this fire should it occur.

The laser is capable of igniting combustible material if a failure occurs in the position device. However, there is no combustible material except gloves. The laser may be capable of cutting a hole in the SPS walls somewhat compromising confinement and allowing inleakage of moist air. However, since the glovebox walls are constructed of metal, or beachwood sandwiched in metal, a fire involving the glovebox structure due to laser impingement is not expected.

The laser may heat the contents of the can if misapplied. To get an idea of the effect of this failure, assume that the can fails at 200 psig. Using the ideal gas law, to raise the can pressure to 200 psig (or 14.6 atm) requires heating the can air to a temperature 14.6 times greater than its initial temperature (or to about 4400 °K). The mispositioning failure has to occur after the can is sealed. If water in the can were heated to vapor, the result could be a can pressurization. Turning 20 grams of water into steam results in a pressure increase of 500 psig based on the ideal gas law using an open volume of one liter and a temperature of 100 °C. This requires 11,000 calories (at a heat of vaporization of 539 cal(g) or 45,000 J. The laser energy is 2000 W or 2000 J/s. If one-half of that energy is absorbed by the liquid, it would take 45 s to heat the water to the point where steam is made and the container pressurizes. This has to occur after the can is sealed.

4.3.3.1.3 Oxygen. There is oxygen in all of the gloveboxes.

4.3.3.2 Scenario. The most likely accident of those described above is the hydrogen deflagration accident. A fire in the receipt area will not pressurize a can. Overpressurization of the can due to misapplication of the laser is too remote to occur. Furnace fires will be small and contained within the furnace or furnace glovebox.

The deflagration occurs above the can of powder. Per DOE (1994a), deflagration of a large volume (large in comparison with the volume of powder) suspends all of the powder. In this case, the powder is confined within a container. It will be assumed that half is suspended. The value of one half is based on the assumption that the deflagration knocks over the can, half of the powder spills out and is suspended by the turbulence and glovebox depressurization.

4.3.3.3 Source Term Analysis. The PFP FSAR uses a respirable fraction of 4% for plutonium powders except for that powder associated with button burning. Since all of the powder to be established has not been characterized, a value of 10% is used. Therefore, 2.5 kg of plutonium powder is suspended in the glovebox of which 0.25 kg is respirable.

The fraction of the release blown into the room is that which comes out during depressurization. It is assumed that the only flow path for depressurization is through the glove ports. The fraction that flows into the room is

$$F = (15.1 \text{ psia} - 14.7 \text{ psia})/15.1 \text{ psia}$$
$$= 0.03$$

The value will be raised to 0.05 to account for uncertainties in glovebox volume.

The quantity of respirable powder in the room is

$$F_R = 0.05(250 \text{ g}) = 12.5 \text{ g}$$

A fraction of this will be carried out through the filtration system via the room exhaust system and part will leave unfiltered through the door to the outside. The door is assumed to remain open after the operators evacuated through it. The air flow out the open door is assumed to be due to (or approximated by) infiltration from the opposite side of the building. Marks (1951) shows infiltration rates for industrial pivot doors as 110 ft^3/h per ft of crack at 10 mph. At 1 m/s (2.2 mph) the value, found by extrapolation, is 25 ft^3/h per ft of crack. Assume infiltration is due to the two double doors on the northwest and southwest portion of the facility. The crack length assuming 6.5 ft tall doors with a width of 6.5 ft is 65 ft. The flow out the open door is

$$Q = (25\ ft^3/h - ft)(65\ ft) = 1625\ ft^3/h$$

The room volume is about 10% of the total building volume. The building flow rate per the FSAR is 8800 ft^3/min with 6200 ft^3/min to Zone 2. The approximate flow rate through the room is 1000 cfm or 60,000 ft^3/h. As a result, the fraction going out the door is

$$F_d = (1625\ ft^3/h)/(60,000\ ft^3/h) = 3\%$$

The value will be rounded to 10% for conservatism. The total released unfiltered is

$$R = 12.5\ g\ (0.10) = 1.25\ g$$

4.3.3.4 Consequence Analysis. The onsite and offsite doses are calculated using the methodology discussed in Section 4.2. From Table 4-2, the onsite X/Q' is 4.74E-4 s/m^3. The offsite X/Q' is 1.01E-5 s/m^3. The receptor's breathing rate is 3.3E-4 m^3/s and the inhalation ULD for the plutonium oxide powder is 1.7E+08 rem/g. The onsite and offsite doses are as follows:

Onsite Dose

$$= (1.25\ g)(4.74E{-4}\ s/m^3)(3.3E{-4}\ m^3/s)(1.7E{+8}\ rem/g) = 33\ rem$$

Offsite Dose

$$= (1.25\ g)(1.01E{-5}\ s/m^3)(3.3E{-4}\ m^3/s)(1.7E{+8}\ rem/g) = 0.70\ rem$$

4.3.3.5 Comparison to Evaluation Guidelines. The onsite and offsite doses are compared against the evaluation guidelines in Table 4-5. The doses exceed both the onsite and offsite guidelines. Safety class mitigation is therefore required.

4.3.3.6 Safety SSCs Required. The consequences are such that safety class equipment is needed unless a more detailed analysis is performed to show the offsite doses are less. The obvious choice is non-sparking tools for can cutting and a glovebox with no ignition sources. A reliable door closer as well as a door travel limiter and stoop that do not prevent the door from closing are also needed as safety-significant. These items are also needed for risk acceptance as the consequence is only acceptable if the scenario is "extremely unlikely."

To assure that the consequence calculation is correct, a more detailed particulate flow model is needed to handle accidents in which cans rupture into ventilated or stagnant rooms with one or more doors open (i.e., room is not at a lower pressure than adjoining rooms so air flow is not necessarily directed).

To protect the assumptions made in this section, the shielding, structural materials, windows, doors and lighting panels all must be non-combustible either with use of noncombustible material or by some other acceptable means. Use of un-encased combustible material may be shown to be acceptable in some locations after a suitable assessment has been performed.

4.3.4 Criticality

A criticality can occur within a certain volume only if the quantity of plutonium within that volume, the shape of the volume, the isotopic distribution of the plutonium within that volume and the quantity and shape of reflectors and moderators are within certain numerical limits. It is assumed that the plutonium stabilization system gloveboxes will contain only plutonium powders; not metal buttons or liquids. Table 4-6 (from Carter et al. 1969 and Paxton 1986) provides the smallest critical mass or concentration for various geometries, plutonium isotopic distribution and reflection. The data in Table 4-6 (from Carter et al. 1969 and Paxton 1986) assumes that the plutonium is mixed with water as well as having water as the reflector. The densities are chosen based on rationale in Section 4.3.4.1.1. If the plutonium is dry, the critical mass is much larger. Table 4-7 shows the difference.

The dry powder values are never used in criticality analyses as it is almost always assumed that water can enter the system in some manner. Therefore, the values from Table 4-6 will be used in the discussions that follow.

A review of the plutonium stabilization gloveboxes shows that a criticality is possible in the following locations:

a. Areas where containers holding plutonium can accumulate (e.g., receipt area).

b. Areas where plutonium powder, as well as containers, could accumulate (e.g., Container Opening Station, Oxide Tipping Process, Powder Dispensing Station).

c. Furnace (potential for moderation if water coolers in furnace wall fails). (The final design may use air instead of water to cool the furnaces).

d. Seismic event (areas where cans or powder accumulate [glovebox collapse] or storage vault [pedestals fail]).

4.3.4.1 Possible Criticality Scenarios.

4.3.4.1.1 Plutonium Powder in Containers. Plutonium containers have a volume of 1.0 to 1.24 L and hold 2 to 4.4 kg of plutonium as a powder. The bulk density of plutonium powder is 2 to 3 g/cm^3 but could be as large as 6 g/cm^3. There is typically no water in dry air gloveboxes containing plutonium. Therefore, the only reflection is that from the operators hands (equivalent to one inch of water), and the metal of the glovebox.

Table 4-6 shows that with one inch of reflection in a spherical geometry (the cans moved together so they touch and so they form a cube), the approximate number of containers needed for criticality is as follows:

- Five containers each with powder having a Pu density of 2 g/cm^3
- Three containers each with powder having Pu density of 6 g/cm^3 and filled to 5 kg (also requires double batch containers in the receipt area).

With no reflection, the number of containers is as follows:

- Eight containers (based on volume requirement of Table 4-6) with powder having a density of 2 g/cm^3
- Six containers (based on volume requirement of Table 4-6) with a powder having a density of 4 g/cm^3
- Four containers with powder having Pu density of 6 g/cm^3 (also requires double batch containers receipt area).

If the glovebox fills with water (seismic event with broken water main), the number of containers to go critical is as follows:

- Four containers each with powder having a Pu density of 2 g/cm^3
- Three containers each with powder having a Pu density of 4 or 6 g/cm^3.

The containers can come together either due to operator action or if the seismic event causes the gloveboxes to fail such that one corner or side of the glovebox is lower than the other. The diameter length ratio of the containers is such that seismic motions should not topple the containers. This needs to be verified.

A criticality can result with as little as three containers and as little as 13 kg of plutonium. It is assumed that in various locations used for storing, at least three containers will be stored. With this assumption, a criticality can occur due to glovebox failure resulting from a seismic event. This violates the double contingency principle. Therefore, the gloveboxes need to be seismically qualified. For the same reason, equipment outside the glovebox also needs to be qualified if failure could result in glovebox failure. The water lines outside the glovebox need to be qualified if the glovebox qualification, configuration, or ceiling strength is such that water could still enter the glovebox should the line fail.

Adequate protection against a criticality is afforded by seismic qualification, administrative controls on quantity, and spacing. Note the failure of administrative controls on quantity and spacing has a likelihood of greater than 10^{-6} and could result in a criticality. However, this situation has historically been considered acceptable.

4.3.4.1.2 Free Plutonium Powder. Powder spills resemble more of a slab geometry than spherical or cylindrical. Table 4-6 shows that with no reflection, eight containers (at 2, 4 or 6 g/cm^3) must be spilled to go critical. For this case as well as for the others to be discussed, the spill must be 1 ft^2 area before it is considered a slab. This is equivalent to the spill of four containers. Smaller spills are viewed as spheres.

Powder spills with one inch reflections require six containers (two containers spilled on top of the four spilled previously) to be spilled to go critical.

Powder spills with full reflection require four containers at 2 g/cm^3 and three containers at 4 to 6 g/cm^3.

The most likely criticality scenario in this case is a scenario involving two furnace boats. If one boat contains a double batch and both became filled with water from failure of the furnace water wall or supply to the water wall, a criticality could occur. A criticality may also be possible if the boats tipped over and the powder was wetted with the water.

Adequate protection against a criticality is afforded by mass and spacing limits as well as seismic qualification of the water walls and their water supply (if water cooling is used). In addition, the double failure criteria should be applied to the water walls to consider non-seismic failures which might wet normally full furnace trays and result in a criticality.

4.3.4.2 Consequences. The consequences of criticalities involving plutonium oxide can be greater than those involving plutonium nitrate solution as described in Section 9.2.3 of the PFP FSAR. Elder et al. (1986) presented data derived from Woodcock (1996) and Koelling et al. (1976), which showed that criticalities involving plutonium powder and liquid could yield 3×10^{20} fissions. This value exceeds the 1×10^{19} fissions used in Section 9.2.3 of the PFP FSAR. The DOE Handbook on release fraction (DOE 1994a) argues for the use of 10^{18} fissions in a single burst for "fully moderated or reflected solids." The argument considers the data presented in Elder et al. (1986) and provides rationale for the lower value. DOE (1994a) also argues for 10^{17} fissions for criticalities involving dry powder. Since the DOE Handbook provides reasonable arguments against the value of 3×10^{20} fissions, the 10^{18} value will be used. A 10^{18} fission criticality releases 1/10 the radionuclides as does the 10^{19} fission criticality discussed in the PFP FSAR. Unlike the criticality consequences calculated in the FSAR, the fission products are released all at once as the 10^{18} fissions occurs in a single burst. The action of the ventilation quickly removes all of the fission products released.

The consequences are based on the assumption that the room doors remain open after the operators exit. There are three doors leading outside of the facility (one single door and one double door) and three doors leading to the rest of the building. The double door is locked. It is assumed that half of the released fission products leave the facility via the one open door to the outside and half via the ventilation system due to the fact that while the door is open the room is not at a negative pressure with all flow directed toward the exhaust system.

With this assumption, the dose due to the noble gas and the iodine release is 1/10 that of the FSAR. The dose due to the plutonium release and the release of other fission products cannot be determined until a detailed scenario is developed. It is not anticipated that the onsite and offsite consequences will be significantly greater than that determined for the FSAR as the doses from the noble gases and iodine usually dominate the dose. The onsite and offsite doses (EDE) from the FSAR for a criticality having ten times greater fissions with a release at ground level are 0.73 rem and 0.05 rem, respectively. The thyroid doses from the FSAR are 2.4 and 1.6 rem, respectively, for the onsite and offsite receptors. The doses are summarized in Table 4-8. The onsite and offsite EDE doses are below the evaluation guidelines. However, safety significant features and administrative controls are warranted to protect the facility workers from the extreme ionizing radiation released in a criticality event.

4.3.4.3 Conclusions. The analysis above resulted in the following conclusions:

1. The gloveboxes must be seismically qualified as well as external equipment whose failure could result in glovebox toppling or breach.

2. A criticality safety evaluation must be performed to set mass and spacing limits within the gloveboxes and storage locations. The criticality safety evaluation must also consider "off-normal" events such as inadvertently opening a container holding large plutonium metal pieces or a "button," gradual accumulation powder around equipment such as that in the oxide tipping process, inadvertent spilling of powder in the vicinity of other containers or other containers or other accumulated powder, failure of water within the furnace walls and supply to those walls, overpacking containers with plutonium powder of high density (i.e., 1.24 L of powder at 6 kg Pu/L results in a container holding 7.4 kg not 4.4 as allowed), and failure of the steam coils within the HVAC system of the storage room resulting in a water mist in the vicinity of the storage locations.

3. The storage equipment (tubes, pedestals, etc) and localized equipment nearby or above the storage equipment must be seismically qualified for the same reasons given for glovebox qualification.

4. The glovebox must be sealed so that if the fire protection system initiates or the lines fail, water will not enter the gloveboxes (under seismic and non-seismic conditions).

5. The analysis is valid only for plutonium powder. The processing of pieces of Pu metal is not covered.

4.3.5 Package Failures in Storage Vault

Inside the SPS, the stabilized PuO_2 is loaded into a final convenience can and then overpacked and sealed inside two other cans. The convenience can is closed in the presence of dry air. The two outer cans are backfilled with helium and leak tested to ensure that only intact packages are stored in the final storage vault(s). The outer can is designed to withstand the maximum internal pressures expected to be generated by offgasses during a 50-yr storage life by PuO_2 that has been properly calcinated at 1000 °C per DOE-STD-3013 (DOE 1996).

PuO_2 powder can be released inside the final storage vault(s) in two ways. Although unlikely, it is conceivable that both the inner and outer canisters in a given storage package could develop leaks during storage due to weld failures. Should the welds heat affected zones or canister walls develop leak pathways, the built up pressure inside the cans could force contaminated helium and dry air from the storage container into the vault. The potential release to the vault atmosphere would be small because the PuO_2 would have to migrate through three barriers: the convenience can lid and the outer two canisters. For pinhole failures of the inner and outer can welds, agglomeration of the PuO_2 powder around the holes would tend to prevent the passage of further powder. Helium leak testing performed in the SPS minimizes the likelihood that a leaking package would be put in the storage vault. However, given the number of storage packages that are planned to be produced, over 2000 packages, it is judged that such leaks are credible during the 50-yr storage life of the vaults.

The second mechanism postulated to result in a PuO_2 release inside the storage vault(s) is a catastrophic failure (rupture) of a storage container due to overpressurization. Overpressurization can be caused by packaging faults that result in excess gas generation inside the storage container. The overpressurization case presents the bounding canister failure accident and is evaluated in detail below.

4.3.5.1 Scenario Development. Plutonium oxide powder has a high specific surface area (5 to 50 m^2/g) and is hygroscopic. Even oxide that has been calcinated at 1000 °C per the DOE-STD-3013 can generate a significant amount of offgas due to residual water content. Adsorbed water reacts slowly with the PuO_2 oxide to form hydrogen according to the following equation:

$$PuO_2 + 1/5\ H_2O = PuO_{2.2} + 1/5H_2$$

where $PuO_{2.2}$ is a binary oxide. Hydrogen and oxygen production may also occur due to radiolysis of the adsorbed water, although it is believed the H_2O/PuO_2 reaction dominates. The hydrogen and oxygen produced by the water add to the helium created from the alpha decay of the plutonium.

LOI samples are taken inside the SPS to ensure that the water content of the PuO_2 is less than 0.5% before it is sealed in the 3013 package. The maximum theoretical internal pressure developed during 50 years of storage in the vault, for PuO_2 containing 0.5% water, is about 600 psi (see next section). The outer can is to meet the requirements of the ASME VIII standard and is qualified to withstand pressures 1.5 times this maximum theoretical pressure. Catastrophic failure of the 3013 container could occur, however, if PuO_2 containing significantly more than 0.5% adsorbed water were inadvertently packaged. Another way to overpressurize a canister would be to inadvertently package PuO_2 containing organic compounds (or perhaps containing plastic bags commonly used with site convenience cans) that could degrade and offgas in the canister due to radiolytic decay.

The most likely way to overpressurize a package in storage would be to inadvertently seal up a 3013 package containing PuO_2 with excess adsorbed water. Inadequate stabilization can occur due to inadequate heating to drive off adsorbed water (i.e., furnace failures) or the ingress of moisture into the SPS gloveboxes after removal of a PuO_2 batch from the stabilization furnace. Inadequate stabilization could go undetected if LOI sampling, testing, or record keeping errors occur. Ingress of moisture into the SPS gloveboxes could occur due to leaks in the glovebox boundary or supply of moist air to the gloveboxes caused by a failure of the supply air dryer. The moisture content of the supply air is monitored. The current SPS design, however does not include moisture detection in gloveboxes where PuO_2 could be handled after removal from the stabilization furnaces.

The PuO_2 to be processed through the SPS could adsorb up to 8% of its weight in moisture if exposed to moist air. The next section shows that the potential pressures developed in the canister, should excess adsorbed water be present, could well exceed the qualification pressure of the storage package. For this analysis, it is assumed that the canister containing inadequately stabilized PuO_2 ruptures and releases highly dispersible PuO_2 powder into the storage vault air. The mitigative effects of the storage vault confinement system to the release are evaluated.

Based on the Pu inventory in PFP, 2300 final storage packages meeting the 3013 standard are expected to be produced. Due to LOI sampling, furnace controls and instrumentation, and the moisture analyzer on the dry air supply, the likelihood of a given canister overpressurizing in storage and rupturing is low. Periodically, storage packages will also be visually inspected for swelling and repackaged if necessary. Given the number of packages to be produced, however, it is prudent to assume that some small fraction of the storage packages may be susceptible to rupture due to overpressure caused by excess adsorbed water. Rupture of two or more packages due to overpressurization within a short time frame of each other (e.g., within a 24-h time frame) is considered to be extremely remote, however. The following analysis, therefore, only considers the rupture of a single package.

4.3.5.2 Source Term Analysis. The maximum theoretical pressure in the inner canister is caused by three factors: the temperature change in the gas inside the canister during storage, the pressure generated by chemical reactions involving residual adsorbates, and the pressure of helium generated by alpha decay of the contained plutonium during storage. The pressure (in psia) can be estimated using the following equation (from DOE-STD-3013-96):

$$P = (T/T_o)P_i + [0.67(LOI)(m)(T)]/[V-(0.0873m)] + [1.3 \times 10^{-4}(m)(t)(T)]/[V-(0.0873m)]$$

where,

T = the maximum average gas temperature (in °K) anticipated during storage--assumed to be 477 °K (400 °F).

T_o = the temperature of the gas (in °K) in the container when the container is sealed. For this analysis assumed to be 300 °K.

P_i = the atmospheric pressure (in psia) when the container is sealed, around 14.7 psia.

LOI = the loss on ignition value (in%).

m = the mass (in kg) of packaged oxide — 4.99 kg maximum.

V = the free volume (in L) in the container — estimated to be 1.85 L.

t = the elapsed storage time (years) after the package is sealed — 50 yr maximum.

The first term in the equation accounts for the pressure increase due to temperature change. The second term estimates the pressure change due to the hydrogen generated by the reaction between adsorbed water and PuO_2. The second term is large compared to the first and third terms and is the primary determinant of the pressure increase. The third term accounts for the pressure change due to helium production from alpha decay and is thus a function of storage time.

At the maximum LOI value of 0.5% allowed by DOE-STD-3013, the predicted maximum theoretical pressure using the above equation and parameter values is 598 psia. Should the water content of the oxide reach 2 weight percent due to furnace failures or loss of moisture control, the pressure predicted is 2289 psia. At an 8% water content value, the maximum theoretical pressure predicted for the canister is 9055 psia. Since the pressures predicted for oxide that contains excess water well exceed the pressure at which the container is qualified, it is assumed that container ruptures inside the vault can occur due to packaging errors.

DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE 1994a), Section 4.4.2.3.1, provides airborne release fractions for venting of pressurized powders. The reported release fractions are based on experiments with relatively large mass samples (350 g) of various oxide powders. For venting of UO_2 powder beds at 3.4 MPa (573 psia) an airborne release fraction (ARF) of 9×10^{-2} was measured in two experiments. The RF of the released material in the two experiments was determined to be 0.31 to 0.34. Using the more conservative RF, an airborne respirable release fraction of 3.1×10^{-2} is determined.

It is not likely that pressurization of the convenience can would cause a rupture through all three canister barriers at the same location at the same time. The convenience can (innermost container) would be expected to fail at the lid prior to failure of the inner overpack can. Likewise, the inner overpack could be expected to fail prior to the outer canister. The inner canister is supported by the outer canister except at its rounded bottom and its welded dished cap, where air gaps exist between the inner and outer cans (see Figure 4-2). The outer canisters would be expected to rupture by splitting along a weld or to fail at a weak point creating a "fish mouth" opening. Unzipping of the entire cap weld and expulsion of the entire cap at rupture would not be expected.

In the venting experiments, the oxide powder was free to escape through the top of the testing apparatus without constriction or impaction barriers in the way. The manner in which the container in the vault is expected to fail requires the PuO_2 powder to be released through tortuous paths and for the release to occur through a constricted opening. Impaction would be expected to reduce the airborne respirable release fraction substantially compared to the experimental case. For this analysis, the experimentally measured release fraction is reduced by a factor of ten to account for impaction. This gives an airborne respirable release fraction of 3.1×10^{-3}. Based on a convenience can PuO_2 inventory of 4.99 kg, the estimated release from the storage package is 15 g ([4.99 kg][1000 g/kg][3.1×10^{-3}]).

The mass of the gas and PuO_2 released from the storage package would be small in comparison to the mass of the package and its contents. Venting of the gas would occur quickly. The expulsion of the gas, therefore not cause the storage package to missile and significantly damage other canisters or the vault structure. The worst-case result would be "hopping" of the storage canister a short distance if the canister is not adequately restrained. In the in-floor vault storage concept, no significant consequences are expected due to canister movement, as the canister will be contained in a closed metal storage tube. The ruptured can is likely to be under other cans that would restrain its movements. In the cubicle storage concept, the canister could conceivably hop off its pedestal to the floor. The additional release from the canister due to the drop would be expected to be small in comparison to the release estimated above. In DOE-HDBK-3010-94 (DOE 1994a), Section 4.4.3.1.2, free fall spills of 500 g quantities of UO_2 powder from a distance of 1 m are reported to produce an ARF ranging from 4×10^{-5} to 8×10^{-5}. These values are three orders of magnitude below the ARF for the venting experiment.

The vault structure (2736-Z building) and the vault exhaust ventilation system HEPA filters (two stages) were previously designated as Safety Class in the PFP FSAR (WHC 1996b). The release from the ruptured canister, therefore, would normally be drawn through two stages of HEPA filtration, as failure of the exhaust fan would not be expected to occur concurrent with the canister rupture. The PF for one stage of HEPA filter is 1×10^{-3} (Elder et al. 1986). The PF for two stages of HEPA filtration is 2×10^{-6} (Elder et al. 1986). The release through the vault exhaust stack, crediting both HEPA filters, is:

$$\text{Release (filtered)} = (15\text{ g})(2 \times 10^{-6}) = 3.0 \times 10^{-5}\text{ g}.$$

This release estimate conservatively ignores gravitational settling within the vault and particulate removal in the storage tubes (in floor storage concept) or within the cubicles (cubicle storage concept).

Loss of vault ventilation flow concurrent with canister rupture is very unlikely. Should the supply and exhaust fans be off at the time of the release (e.g., due to loss of power), the heat load in the vault and wind effects on the building structure would cause the vault to breathe. The exhaust and supply ducts provide the paths of least resistance from the vault. The elevation of the vault exhaust stack would, under most atmospheric conditions, tend to cause the vault to naturally ventilate by breathing in through the supply and out through the exhaust. This gives a filtered release similar to the release estimated with the exhaust fan running.

Should airflow go in the opposite direction, contamination could spread to the mechanical equipment room and to the environment back through the supply ductwork. A prefilter is provided on the supply side. This prefilter would somewhat decontaminate any air drawn through the supply side. The DF provided by this prefilter for respirable sized particles is unknown. The prefilter was not designated as safety class in the PFP FSAR. Detailed modelling of the potential release from the vault on loss of supply and exhaust is beyond the scope of this analysis. Section 8.0 contains a commitment to model the stagnant case to determine whether safety class backflow dampers or HEPA filters on the supply system are necessary.

Should the exhaust system be off at the time of the leak but the supply fun is running, the vault would pressurize. The supply fan is interlocked to shutdown on loss of exhaust, making such a scenario even more remote than the stagnant case. Once again, the path of least resistance would be through the exhaust duct, and the majority of the release would be filtered. Small gaps around the vault door seals and other penetrations would allow some small fraction of the supply airflow to leak into the vault corridor. Such leak paths would be expected to provide a DF of at least 10 to the portion of release flowing through those paths. If it is assumed that 5% of the vault airflow passes through the vault door seals into the interior of the building, a total decontamination factor of 500 is provided for the for the release into the vault corridor. This release would pass through the 2736-ZB building ventilation system before discharge to the environment, unless that ventilation system also concurrently failed. Applying a conservative DF of 10 for passive breathing through the building shell (all release paths to the outside from the corridor involve passage through airlocks) gives a total DF of 5000 for release to the environment. For the pressurized vault cause, a conservative estimate for the release to the environment is:

$$(15\ g)[(0.95)(2 \times 10^{-6}) + (0.05/5000)]$$
$$= 1.8 \times 10^{-4} g$$

4.3.5.3 Consequence Analysis. The onsite and offsite doses for the pressurized glovebox case are calculated using the methodology discussed in Section 4.2. From Table 4-2, the onsite X/Q' is 4.74×10^{-4} s/m^3. The offsite X/Q' is 1.01×10^{-5} s/m^3. The receptor's breathing rate is 3.3×10^{-4} m^3/s and the inhalation ULD for the plutonium oxide powder is

1.7×10^8 rem/g. The onsite and offsite doses estimates for this case are as follows:

Onsite Dose

$$= (1.8 \times 10^{-4}\ g)(4.74 \times 10^{-4}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^8 rem/g)$$
$$= 4.8 \times 10^{-3}\ rem$$

Offsite Dose

$$= (1.8 \times 10^{-4}\ g)(1.01 \times 10^{-5}\ s/m^3)(3.3 \times 10^{-4}\ m^3/s)(1.7 \times 10^8 rem/g)$$
$$= 1.0 \times 10^{-4}\ rem$$

4.3.5.4 Comparison to Evaluation Guidelines. The onsite and offsite doses are compared against the evaluation guidelines in Table 4-9. Crediting the mitigative effects of the safety class vault structure, exhaust duct, and exhaust filters, the release from the facility is shown to produce doses well below both the onsite and offsite evaluation guidelines.

4.3.5.5 Safety SSCs Required. The 2736-Z building structure and the vault exhaust ventilation system HEPA filters (and ductwork up to the HEPA filters) were previously designated as safety class in the PFP FSAR. The safety class exhaust HEPA filters ensure that releases through the exhaust ductwork are adequately mitigated. If the HEPA filter PF credited in the analysis is removed, the resulting onsite and offsite dose estimates are well above the evaluation guidelines. The above analysis, therefore, justifies the safety class designation for the exhaust system filters.

The vault exhaust fans were not designated as safety class in the PFP FSAR. Should the vault be stagnant at the time of the release, due to a failure of both the supply and exhaust fans, PuO_2 particles could be released back through the supply ductwork to the environment. The supply and exhaust ductwork provide the paths of least resistance from the vault. It is thus concluded that safety class backdraft dampers or HEPA filters should be provided in the supply system ductwork to limit potential releases back through that path.

A canister rupture may result in a significant release of PuO_2 inside the storage vault storage tubes (in-floor storage concept) or inside the cubicles (cubicle storage concept). Depending on the configuration of the vault ventilation system, gross contamination of the vault atmosphere above the floor (in-floor storage concept) or outside the cubicles (cubicle concept) may occur. Entry into the vault following such an event poses a serious hazard to a facility worker, if not wearing a respirator. Sampling lines for monitoring the vault atmosphere prior to entry are designated as safety significant for the protection of facility workers.

(Recommendation: safety significant moisture detectors should be incorporated into SPS to monitor glovebox atmospheres or glovebox exhaust airstreams to minimize the chances of packaging wet material.)

The ability to safely deal with potentially overpressurized canisters is a concern that needs to be addressed.

4.3.6 Vault Overheating Due to Loss of Ventilation Flow

Modifications to the storage vault as a result of the W-460 project will alter the distribution of the heat loads in the storage vaults and will change the air flow characteristics through the storage vault. Loss of forced ventilation flow through the vault will cause the storage packages and vault structure to heat. This analysis addresses the potential safety implications associated with a long-term loss of vault ventilation.

4.3.6.1 Scenario Development. Loss of forced ventilation flow through the storage vault can be caused by equipment failures (e.g., fan failures), ventilation control system failures, or loss of power. Both the supply and exhaust systems have redundant fans and are connected to backup power (verify). The only initiator postulated to result in long-term loss of forced ventilation flow is a seismic event. A large earthquake could cause loss of both site and local power and damage to ventilation system components. Restoring ventilation flow following a seismic event could take several days, if the vault ventilation system and backup power systems are not qualified to withstand seismic forces.

This analysis only considers storage of packages containing PuO_2 within the storage vault. PuO_2 has a melting point of around 2400 °C. Unlike Pu metal, PuO_2 does not undergo phase changes that significantly affect its density when heated. Credible overheating of 3013 packages in the storage vault will not result in package ruptures. The equation given in Section 4.3.5 for canister pressurization shows that the pressure increase due to thermal loads is directly proportional to the fractional increase in the absolute temperature of the canister contents, per the ideal gas law. The magnitude of the pressure changes that can be produced by the thermal portion of the equation, over credible storage vault temperature ranges, is small in comparison to the pressure increase expected due to offgassing from the reaction of PuO_2 with residual water inside the containers. Canister ruptures due to internal pressurization therefore, is not a concern should a long-term loss of ventilation flow through the storage vault occur. Of primary safety concern is the effect of long-term loss of ventilation flow on the vault's structural integrity. The storage vaults were designated safety class in the PFP FSAR to protect the large inventory of Pu contained within them and to confine any potential releases should storage containers fail. The storage vaults are qualified to withstand the design basis earthquake (DBE). Should overheating result in degraded structural integrity, partial collapse of the vaults could result in failure of several storage packages and a release of significant quantities of PuO_2 to the environment.

At this conceptual design stage, the credibility of vault structural collapse due to long-term loss of forced ventilation flow has not been assessed. Potential vault configurations and ventilation modifications are being developed. Concrete structural integrity can be lost due to both thermal degradation of the concrete (dehydration) and thermally induced mechanical stresses. A preliminary thermal analysis recently performed for the proposed in-floor storage vault concept (for two storage tube designs) predicted that vault concrete temperatures as high as 254 °F (lower floor/basepad) and 173 °F (upper operating deck) could be reached within 2 to

2.5 days should supply and exhaust flow be lost. The analysis utilized a detailed finite-element axi-symmetric model of three 3013 cans stacked vertically in a tube. Each can was assumed to have a thermal loading of 30 W as allowed per the DOE standard. The effect of the predicted concrete temperatures on the structural integrity of the vault was not evaluated. The long-term temperature exposure limit for concrete is 150 °F. Exceeding this limit will result in loss of concrete structural integrity only during a very extended time frame. Improvements to the vault modifications have been identified to reduce potential concrete temperatures should ventilation flow be lost.

4.3.6.2 Source Term Analysis. The modified storage vault(s) will eventually hold 2300 storage packages, each containing approximately 5 kg of PuO_2. If it is conservatively assumed that a long-term loss of ventilation flow results in a partial vault collapse and significant damage to 10% of the storage containers, the release from each container could be expected to be similar to the release predicted for the ruptured canister in the previous accident analysis. The release fraction predicted for a ruptured pressurized storage package in Section 4.3.6.2 is 3.1×10^{-3}. In the hypothetical vault collapse scenario, the total release from the vault containers is:

$$(2300 \text{ canisters})(5000 \text{ g/canister})(0.1)(3.1 \times 10^{-3}) = 3600 \text{ g}.$$

Reducing this release by an order of magnitude to account for rubble factor gives a total release to the environment of 360 g.

4.3.6.3 Consequence Analysis. The onsite and offsite doses are calculated using the methodology discussed in Section 4.2. From Table 4-2, the onsite X/Q' is 4.74×10^{-4} s/m^3. The offsite X/Q' is 1.01×10^{-5} s/m^3. The receptor's breathing rate is 3.3×10^{-4} m^3/s and the inhalation ULD for the plutonium oxide powder is 1.7×10^{8} rem/g. The estimated doses to the onsite and offsite receptors are:

Onsite Dose

$$= (360 \text{ g})(4.74 \times 10^{-4} \text{ s/m}^3)(3.3 \times 10^{-4} \text{ m}^3\text{/s})(1.7 \times 10^{8} \text{ rem/g})$$
$$= 9600 \text{ rem}$$

Offsite Dose

$$= (360 \text{ g})(1.01 \times 10^{-5} \text{ s/m}^3)(3.3 \times 10^{-4} \text{ m}^3\text{/s})(1.7 \times 10^{8} \text{ rem/g})$$
$$= 200 \text{ rem}$$

Collapse of the vault could also result in a criticality by configuring the canisters and rubble in a critical geometry. The onsite and offsite consequences of a criticality are assessed in Section 4.3.4 and shown to be negligible in comparison to the doses calculated above.

4.3.6.4 Comparison to Evaluation Guidelines. The estimated onsite and offsite doses for a vault collapse, are compared against the evaluation guidelines in Table 4-10. The doses are shown to be well above both the onsite and offsite evaluation guidelines. A long-term interruption in vault ventilation flow, should such an event be capable of compromising the structural integrity of the storage vault, is concluded to be unacceptable.

4.3.6.5 Safety SSCs Required. The 2736-Z storage vaults are safety class structures. The analysis above shows that the consequences of a vault collapse are unacceptable. The modifications to the existing storage vaults to accommodate the 3013 packages produced by the SPS, therefore, must ensure that the structural integrity of the vaults can not be compromised due to a loss of forced ventilation airflow.

Detailed thermal and structural modelling of the vault's structural response to a loss of ventilation accident is required during detailed design (see Section 8.0). This analysis must consider transient effects and potential long-term concrete degradation at the elevated temperatures possible given loss of forced flow through the vault. Temperature gradients across the vault walls must also be assessed for structural effects. This analysis will determine whether significant concrete degradation is possible given a long-term loss of ventilation flow or will determine the recovery time in which restoration of active ventilation will be required to prevent structural degradation.

If thermal modelling cannot demonstrate acceptable structural response to a long-term loss of forced ventilation flow, the alternative is to designate and qualify the vault ventilation system and backup power system as safety class. This would ensure continuous cooling airflow through the storage vaults following a seismic event.

4.3.7 Seismic Event

This analysis takes credit for structures and passive components that have been qualified to withstand the effects of the safety class level DBE. Failures of non-seismically qualified active systems are postulated to estimate the potential releases from the 2736-Z and -ZB buildings during the seismic event.

4.3.7.1 Scenario Development. The 2736-Z and 2736-ZB structures are qualified for the safety class level DBE. The final exhaust filters for these buildings and the ductwork up to them are also seismically qualified. To ensure confinement of airborne radioactive particulate from the SPS, the SPS structure, exhaust ductwork up to its final HEPA filters and its HEPA filters are to be qualified for the safety class level earthquake (based on design and safety analyses performed for the prototype SPS). Similarly, the exhaust filters for the SPS in Room 638 and the ductwork up to the filters are seismically qualified to limit potential releases from the SPS and to prevent seismically induced criticalities (see Section 4.3.4). The supply and exhaust fans for 2736-ZB and the storage vaults are not qualified for seismic events, nor are the control systems for the various ventilation systems. It is unknown if the vault supply ductwork or SPS exhaust ductwork on the roof of 2736-ZB will survive a seismic event. For this analysis, it is assumed they may not survive. Failure of the ductwork on the roof of 2736-ZB can result in reduced airflow through the storage vaults and loss of exhaust flow from the SPS. The backup generator for the vaults and 2736-ZB are also not qualified for the seismic event. Localized or global loss of power is possible in a seismic event. There are no seismic switches currently in the design to shutdown the 2736-ZB or 2736-Z buildings supply fans or the dry air and compressed gas supplies to the SPS gloveboxes. Ventilation control failures caused by random equipment failures, loss of pneumatic air supplies, or random power failures in the earthquake can result in pressurization or stagnation of the SPS, storage vault, or the various other HVAC zones in the 2736-ZB and 2736-Z buildings. Conservative release scenarios for the 2736-ZB and 2736-Z buildings are developed separately below.

Since the SPS gloveboxes are seismically qualified and anchored to the floor in a manner that prevents toppling, catastrophic failure of the SPS containment structure is not postulated in the seismic event. Equipment (e.g., ductwork, water pipes, etc) over and around the glovebox will be modified (e.g., securely anchored, restrained, or removed) as necessary to prevent them from damaging the SPS containment structure in the seismic event.

Seismic motions are postulated to result in elevated particulate levels within the glovebox by causing handling equipment to dump cans or furnace trays. Seismic motions can be expected to result in plutonium oxide powder being released directly from contaminated surfaces due to vibration. Seismically induced ventilation faults (e.g., loss of exhaust without shutdown of supply, failed closed exhaust dampers, compressed gas line failures inside the glovebox) are postulated to result in pressurization of the SPS gloveboxes forcing contamination out into the 641 and 642 rooms. Similarly, ventilation faults are postulated to result in pressurization or stagnation of the 641 and 642 rooms. In the seismic event, facility workers can be expected to exit through the exterior door on the east wall of the building. This exterior door provides a release path to the environment. For the purposes of this analysis, it is assumed the pressurized release from the glovebox occurs for 24 h before dry air and utility gas supplies to the gloveboxes are shutoff. This is judged to represent a conservative recovery period following a severe seismic event. The release from the SPS is similar to that evaluated in Section 4.3.2.

The loose plutonium oxide in the SPS presents the greatest threat for release in the seismic event. Plutonium oxide contained in sealed 3013 packages (i.e., packages constructed to the DOE-STD-3013 requirements) that may be in the lag storage cart at the time of the earthquake, or in the Nondestructive Assay laboratory is not expected to be vulnerable to release in the earthquake, given the design of the 3013 packages. The 3013 packages are qualified to withstand drops from 9 m (30 ft).

Sealed, overpacked site convenience cans from the source vault may also be in temporary lag storage upstream of the SPS at the time of the earthquake, being readied for entry into the SPS. The design of the overpack containers (mechanically sealed food pack cans) makes release from the site convenience cans in an earthquake also unlikely. Drop tests have been conducted (ARH-CD-635 1976) in which food pack cans filled with nonradioactive materials (to simulate can loading) were dropped from a height of 10 ft. Although deformation occurred, in no case were any of the can seams split open. Release from the sealed, double overpacked site convenience cans in unlikely due to impacts in the seismic event. For assessment purposes, however, it is conservatively assumed that one overpacked convenience can outside the SPS is ruptured due to dropping or other mechanical impact in the seismic event. This release adds to the release from the postulated pressurized glovebox.

Due to the design of the SPS gloveboxes and the limited combustible loading in both 641 and 642 rooms and inside the gloveboxes, a post-DBE fire involving the SPS gloveboxes is not anticipated. For a discussion of the potential for glovebox fires, see Section 4.3.3. Radiological releases from other areas of the 2736-ZB building not associated with the addition of the SPS are outside the scope of this analysis.

Releases inside the storage vaults not being modified by the W-460 project are covered by the existing PFP FSAR. For the modified vault that will store the 3013 canisters produced by the SPS, the storage tubes (in-floor storage concept) or storage pedestals (cubicle storage concept) are to be seismically qualified. It is assumed that this will protect the packages from mechanical damage and prevent storage configuration failures that could constrict cooling airflow or result in criticalities. The 3013 packages in storage tubes (in-floor concept) will be constrained by the tubes and will not be subject to significant mechanical stress in the earthquake. The 3013 packages stored on pedestals inside cubicles will be restrained in baskets or harnesses to prevent canisters from falling to the floor of the cubicle. The 3013 packages, as discussed above, are qualified to withstand drops from 10 m. Therefore, it is extremely unlikely that 3013 packages would rupture in the earthquake even if they fell to the floor.

The earthquake could result in reduced cooling flow through the vault, due to loss of supply and or exhaust flow. Exhaust flow could be lost due to fan failure, loss of power, or inadvertent damper closure. Loss of supply could occur due to fan failure, loss of power, or shearing of the supply ductwork. As discussed in the previous accident analysis in Section 4.3.6, modifications to the vault will ensure that structural collapse cannot occur due to a long-term loss of ventilation flow through the vault, or design features and administrative procedures will be put in place to ensure ventilation flow is restored before significant degradation can occur. If necessary, insulating concrete can be used to protect the structural concrete from excessive temperatures and thermal stresses.

Loss of ventilation flow therefore, is not assumed to result in failure of the vault confinement boundary or structural failures that could rupture canisters in the vault. Although the vault will heat up on loss of ventilation, the temperatures expected in the vault will not be high enough to cause rupture of canisters due to over-temperature.

As discussed in Section 4.3.5, it is possible that a very small fraction of the canisters in the vault may be vulnerable to rupture due to overpressurization caused by excess adsorbed water. It is very unlikely that such a canister would rupture concurrent with or as a result of the earthquake. However, for assessment purposes, it is conservatively assumed that the heat caused by loss of ventilation flow causes enough of an increase in internal pressure, or enough creep in a canister wall to cause a canister rupture. Should the heat increase be caused by loss of exhaust flow, the release from the vault, post earthquake, would be similar to the release estimated in Section 4.3.5.

The structural response of the 291-Z-1 exhaust stack to DBE loadings was evaluated for the PFP FSAR. The dynamic analysis demonstrated that the stack had enough ductile capacity to resist the DBE loading without collapse (WHC 1996b, Section 9.4.2.1). The 291-Z-1 exhaust stack is therefore not a concern to fall into the 2736-Z or -ZB buildings and cause a release in a seismic event.

4.3.7.2 Source Term Development. The release to the environment is the sum of the release from the 2736-ZB building due to the pressurized glovebox and the dropped overpacked site convenience can and the release from the modified storage vault in the 2736-Z building.

4.3.7.2.1 Release from the 2736-ZB Building. The exterior door from Room 641 is assumed to remain ajar after operators exit the room following the seismic event. The 2736-ZB exhaust fan is assumed to shutdown as a result of the earthquake (due to equipment failure or loss of power supply). The air forced into the room by the pressurized glovebox (gloves are assumed to rupture) and the supply air to the room (assumed to remain running) causes pressurization of the 641/642 area of the building. Because of the open exterior door, all of the PuO_2 powder released to the room air is assumed to be subsequently released to the outside atmosphere, as in the glovebox pressurization accident analyzed in Section 4.3.2.

The release from the pressurized glovebox is estimated in a similar manner to the releases estimated in Sections 4.3.1 and 4.3.2. Because of shaking during the earthquake and normal PuO_2 powder transferring operations just prior to the earthquake, the glovebox atmospheres are assumed to be at the quasi-stable loading limit of 100 mg of PuO_2 powder per cubic meter of air at the time the gloveboxes pressurize and the gloves rupture. It is assumed that a furnace tray handler subsequently dumps a furnace tray of powder to the floor of the glovebox. Powder released in the powder dump is assumed to be swept out of the glovebox through the ruptured glove ports. Subsequent resuspension of the oxide powder in the glovebox is postulated to cause a continuous release from the glovebox for 24 h after the seismic event. This is a conservative time estimate for emergency response actions to close the outside door, to shutdown supply air to the room and SPS gloveboxes, and to shutdown compressed utility gas supplies to the gloveboxes.

The initial puff release into the room is the product of the quasi-stable particulate concentration (100 mg/m^3) and the total SPS air volume for gloveboxes containing loose PuO_2 (14.4 m^3 from Section 4.3.2.2). This gives a release estimate of 1.44 g.

Table 4-13 of DOE-HDBK-3010-94 (DOE 1994a) summarizes the results of experiments where various materials were poured from heights of 1 m. For 500 g quantities of UO_2, spilled from a height of 1 m, the measured respirable release fraction was 4×10^{-5}. This release fraction is judged to apply to the postulated spill of PuO_2 powder from the furnace tray. Multiplying the release fraction by the mass of powder on the furnace tray (5 kg), gives a release to the room atmosphere (and subsequent release to the environment), due to the spilled furnace tray, of 0.2 g.

As in Section 4.3.1, the maximum quantity of loose PuO_2 powder available for resuspension any given time is 20 kg (4 furnace trays at 5 kg apiece). Using the resuspension release rate of 4×10^{-6} wt. fraction/h from Section 4.3.1.2 for release from the furnace tray powder beds, the total release due to resuspension during a 24-h time frame is 1.9 g ([20,000 g][4×10^{-6}/h] [24 h]).

The total release from the 2736-ZB building is 3.5 g (1.44 + 0.2 + 1.9).

4.3.7.2.2 Release from Storage Vault. The release from the vault due to rupture of an overpressurized canister is estimated in Section 4.3.5.2. For the pressurized vault case (vault supply running, vault exhaust off), the release to the environment was estimated to be 1.8×10^{-4} g. The release is small in comparison to the release from the 2736-ZB building because the majority of the air forced through the vault flows through the safety class exhaust HEPA filters.

4.3.7.2.3 Total Release to Atmosphere. The total release to the atmosphere is the sum of the release from the 2736-ZB building and the release from the storage vault, or 3.5 g.

4.3.7.3 Consequence Analysis. The onsite and offsite consequences are estimated using the dose model described in Section 4.2. From Table 4-2, the onsite X/Q' is 4.74×10^{-4} s/m^3. The offsite X/Q' is 1.01×10^{-5} s/m^3. The receptor's breathing rate is 3.3×10^{-4} m^3/s and the inhalation ULD for the plutonium oxide powder is 1.7×10^8 rem/g. The estimated doses to the onsite and offsite receptors are:

Onsite Dose

$$= (3.5\text{ g})(4.74 \times 10^{-4}\text{ s/m}^3)(3.3 \times 10^{-4}\text{ m}^3\text{/s})(1.7 \times 10^8\text{ rem/g})$$
$$= 93\text{ rem}$$

Offsite Dose

$$= (3.5\text{ g})(1.01 \times 10^{-5}\text{ s/m}^3)(3.3 \times 10^{-4}\text{ m}^3\text{/s})(1.7 \times 10^8\text{ rem/g})$$
$$= 2.0\text{ rem}$$

4.3.7.4 Comparison to Evaluation Guidelines. The onsite and offsite doses are compared against the evaluation guidelines in Table 4-11. Both the onsite and offsite guidelines are exceeded. The majority of the dose occurs due to the pressurized release from the SPS glovebox. This release can be expelled or drawn through the open exterior door on the east side of the building. As discussed in Section 4.3.2, safety class design features are needed to prevent the release from the glovebox and/or to mitigate the release from the building.

4.3.7.5 Safety SSCs Required. The required safety class SSCs are those taken credit for in the analysis and the as yet to be determined design feature(s) to prevent or mitigate releases from a pressurized SPS glovebox. Seismically qualified SSCs taken credit for in the analysis that must be designated safety class include the following:

- The 2736-ZB structure. Safety class qualification is needed to ensure the structure will not collapse on the SPS. Structure is needed to act as confinement barrier for releases from the SPS or releases from convenience cans that could be damaged outside the SPS.

- The SPS glovebox structure and its anchors to the floor. Safety class seismic qualification of the structure prevents catastrophic failure of the SPS and ensures releases from the SPS are within the bounds of the seismic analysis. Seismic qualification of ductwork, piping, and other equipment above the SPS is needed to ensure such items do not damage the SPS in the seismic event.

- The SPS exhaust system up through HEPA filter housing in the 638 room (includes HEPA filters, HEPA filter housing, and exhaust ductwork up through the penetration in the roof). Qualifying ductwork up to penetration in the roof ensures that there is no large open leakage path to the environment from the 638 room.

- The 2736-ZB exhaust system HEPA filters, HEPA filter housings, and ductwork up to and including the exhaust filters. Safety class HEPA filters are needed to prevent significant quantities of PuO_2 released in the seismic event from being drawn unfiltered through the building exhaust system.

- The 2736-Z exhaust system HEPA filters, HEPA filter housings, and ductwork up to the exhaust filters. Qualified filters, housing and ductwork are needed to ensure potential releases from the vault are adequately mitigated. As discussed in Section 4.3.6, the vault supply system should be fitted with a safety class backflow damper or safety class HEPA filter to prevent backflow of contamination from the vault to the environment in the event a canister ruptures under high pressure.

- 2736-Z structure and storage arrays. For the in-floor storage concept, the floor, storage tubes, and other structures necessary to direct airflow properly through the vault are safety class in addition to the outer walls. For the cubicle storage concept, the cubicles, pedestals, and canister restraints are safety class in addition to the outer walls.

Options for mitigating potential releases from the SPS to the environment include: (1) adding safety class interlocks to shut off the SPS dry air supply and compressed utility gas supplies on detection of seismic movement or high pressure indication in the glovebox, (2) adding safety class interlocks to shutdown the 2736-ZB building supply system on detection of seismic movement or pressurization of the glovebox, and (3) modifying the exterior door on the east side of the 2736-ZB building to an airlock arrangement, with reliable door closers, to limit potential outleakage through that path.

Analyses will be needed to demonstrate the adequacy of the design feature(s) selected to limit releases from the SPS and through the 2736-ZB building fabric.

To protect facility workers from potential airborne PuO_2, both during the event and in subsequent reentries into the building, facility CAMs are designated as safety significant. It should be noted, however, that safety significant CAMs may not be reliable following the safety class level DBE.

4.3.7.6 Delta to PFP Seismic Risk Analysis. In a seismic event, the potential environmental releases from the SPS in the 2736-ZB building and the modified vault(s) in the 2736-Z building are only a portion of the total release that could occur from the PFP complex. This section adds the Project W-460 seismic releases to the seismic releases determined for the rest of the PFP facility in the PFP FSAR (WHC 1996b). The total onsite and offsite doses for the seismic event are compared against the appropriate risk evaluation guidelines from WHC-CM-4-46, Section 7.0

An earthquake large enough to cause the releases from the 2736-Z and -ZB buildings as postulated in the accident analysis discussed in Sections 4.3.7.1 through 4.3.7.5 is judged to be in the "Unlikely" frequency category, using the frequency ranges described in Section 7.0, "Risk" of the *Safety Analysis Manual* (WHC-CM-4-46). Such an earthquake would be expected to have a return period in the range of 1/100 to 1/10,000 yr.

The PFP FSAR analyzes two seismic scenarios that are estimated to have a frequency of around 1×10^{-4}/yr. This frequency borders on the same frequency range as the seismic event of concern in this PSE. In the first seismic scenario evaluated in the PFP FSAR, the 234-5Z and 236-Z ventilation systems are assumed to shutdown or fail as a result of the seismic event. Plutonium releases are postulated to occur from various gloveboxes, ductwork, piping and containers within the facilities due to seismic motion or seismically induced damage. A plutonium release is also postulated to occur from the 232-Z building. Releases from the 2736-Z and -ZB buildings are estimated to be negligible in the PFP seismic analysis. Because of the shut down ventilation systems in the first seismic scenario, contaminated air from inside the 234-5Z and 236-Z facilities is modelled to be released to the environment via natural ventilation--e.g., by breathing through penetrations (e.g., open doors) in the structures due to wind effects. Gravitational settling of particles within the facility is credited.

In the second seismic scenario presented in the PFP FSAR, the 234-5Z and 236-Z building supply fans are assumed to shut down but the exhaust fans are assumed to remain running following the seismic event. The exhaust duct is assumed to remain intact but the exhaust filters are assumed to fail. The "ventilation" case release is higher than the "no ventilation" because the unfiltered volumetric flow through the exhaust system with the fans running is higher than the volumetric breathing caused by wind effects in the "no ventilation" case. The calculated onsite and offsite doses from the "ventilation" case, however, are lower because of the increased dispersion caused by the elevated stack release versus the ground level release (through open doors) in the "no ventilation" case.

The PFP FSAR "no ventilation" seismic case presents the bounding release to add the Project W-460 seismic release to. The total Pu release from the PFP facility in the FSAR "no ventilation" case is estimated in the PFP FSAR to be 1.4 g (from WHC 1996b, Table 9-33). The onsite and offsite doses calculated in the FSAR for the this release are 9.7 and 0.20 rem, respectively. From Section 4.3.7.2 above, the total release from the 2736-Z and -ZB buildings in the seismic event is 3.5 g (mostly from 2736-ZB). The onsite and offsite doses due to the releases from the 2736-Z and -ZB buildings are 93 and 2.0 rem, respectively. Combining the FSAR and Project W-460 PSE estimates gives a total onsite receptor dose of 100 rem (rounding to significant digits) and a total offsite dose of 2.2 rem. On a per gram basis the releases from the 2736-Z and -ZB buildings produce larger doses than the releases estimated for the rest of the PFP complex in the FSAR because the isotopic inventory assumed for the PuO_2 in this PSE are more conservative than the plutonium isotopic inventory assumed in the seismic accident in the FSAR.

The release amounts and doses are summarized and compared against the risk evaluation guidelines for the "unlikely" frequency category (from Section 7.0 of WHC-CM-4-46) in Table 4-12. It should be noted that the risk evaluation guidelines for the unlikely frequency category are more liberal than the conservative, deterministic guidelines used to determine SSC safety classifications. The total seismic doses are compared against the risk evaluation guidelines here because the accident initiator is known with high confidence to be in the "unlikely" frequency category. The total onsite dose of 100 rem reported in Table 4-12 is above the risk evaluation guideline of 25 rem. However, the total offsite dose of 2.2 rem is below the offsite risk evaluation guideline of 5 rem. The onsite risk evaluation guideline is exceeded because of the open issue with regard to the egress door on the 2736-ZB building and interlocks to shutdown dry air and compressed gas supplies to the SPS. The onsite and offsite dose contributions from the 2736-ZB building will both be reduced substantially when the design improvements to limit the SPS release through the exterior door in the facility are developed in detailed design.

4.3.8 Extreme Wind

Buildings 2736-ZB and 2736-Z were analyzed for potential damage in the design basis 90 mi/h wind. The buildings were shown to withstand both wind and standard missile forces (WHC 1990). Added safety assurance is provided by the layout of the other buildings in the PFP complex around the 2736-ZB and 2736-Z buildings. The location of the 2736-ZB and 2736-Z buildings relative to other buildings in the PFP complex is shown in Figure 4-3. The 2736-ZB and 2736-Z buildings are sheltered from wind and from wind driven missiles from the east by the 291-Z building and from the north by the multistory 234-5Z building. Buildings 291-Z and 234-5Z have been qualified for the design basis wind (WHC 1990). The PuO_2 inventories in the 2736-ZB and 2736-Z buildings are concluded to not be at risk of being released due to missile impact or building failure in the design basis wind event. The 2736-ZB and storage vault ventilation system filters and exhaust fans are also concluded to be adequately protected from high wind.

The vault supply ductwork runs across the roof of the 2736-ZB building. This ductwork may be vulnerable to damage in high winds. Site power could also be knocked out in high winds. Failure of the vault supply ductwork could result in undersupply of airflow to the vault. This may cause the vault to heat slightly, but no significant consequence would be expected with continued vault exhaust fan operation. Should the design basis wind also knock out power to the vault exhaust fan, an overheating condition could develop. It is likely that power could be restored, however, before any structural degradation occurred. A rigorous thermal analysis will be performed during detailed design to examine the structural effects of loss of forced flow to the vault (see Section 8.0). Should this analysis determine that structural degradation could occur within a short time frame of losing vault ventilation, the ventilation system will be provided with safety class backup power and the supply ductwork will be qualified for the design basis wind and protected from missile damage.

Like the vault supply, a portion of the exhaust ductwork for the SPS will run across the roof of 2736-ZB. Should this ductwork be damaged in high winds, the SPS will lose exhaust flow and could go ambient or could possibly pressurize. This would result in a release of contamination to the 641 and 642 rooms similar to that analyzed in Section 4.3.2. Any glovebox air forced or drawn out the failed ductwork on the 2736-ZB roof would be adequately mitigated by the safety class SPS HEPA filters in the 638 room. Releases from the SPS gloveboxes into the 641 or 642 rooms rely on secondary containment provided by the 2736-ZB structure and building ventilation system. Should the high wind result in loss of power, both the glovebox and the 2736-ZB would go stagnant (ambient pressure). Modelling of the release through potentially open doors and building penetrations under loss of ventilation conditions is an issue requiring further development and is discussed further in Section 8.0.

4.3.9 Airplane Impact

Chapter 9.0, Section 9.2.7, of Revision 1 of the PFP FSAR (WHC 1996b) evaluated the potential for impacts on the PFP facility resulting from aircraft flights over and near the facility. The evaluation considered the following types of air traffic over the Hanford Site:

- Commercial air carriers
- Air taxis
- General aviation
- Military aviation
- Pesticide and herbicide aerial applicator aircraft
- Hanford bioscience surveillance aircraft
- Hanford Site radiological survey helicopter flights.

The evaluation determined that the likelihood of aircraft accidents affecting the PFP was incredible (annual probability of $\sim 10^{-8}$ or less) for all aircraft operations except in the case of the survey helicopter flights. For most aircraft flights, the relatively low frequency of the flights, their distance from the PFP and the low frequency of severe accidents resulted in the very low probability of impacting the PFP.

In the case of survey helicopter flights, they would intentionally fly over and near the facility multiple times, the flights are at low altitude and the frequency of accidents is higher for helicopters than other types of aircraft. This would result in a higher likelihood of a helicopter accident impacting PFP such that an accident was deemed credible (annual probability slightly greater than 10^{-6}). Consequently, it was determined that survey helicopter flights over and near the PFP would be restricted to prevent flights within an area represented by a 2300 ft square centered on the 291-Z-1 stack at PFP. As long as survey helicopter flights remain outside this area, an accident impacting PFP was determined to be incredible.

Given the above limit on survey helicopter flights and the determination that other aircraft flight accidents impacting PFP is incredible, the likelihood of aircraft accidents is sufficiently low that the consequences of such an accident does not need to be considered.

4.3.10 Vehicle Impact

The SPS is located in the 641/642 room area of the 2736-ZB building. This area of the building has exterior wall on the east side and borders the 2736-ZC building on the south, which houses a shipping/receiving area with a loading dock. In the hazards analysis, it was postulated that the SPS might be vulnerable to damage should a high momentum vehicle impact the eastern wall of the 2736-ZB building or a vehicle (or its load) impact the southern wall of the 2736-ZB building. In addition, there was concern that a vehicle impacting the western wall of the building could damage equipment in Rooms 600 or 602 and adversely affect building and glovebox ventilation flow.

Based on an assessment of truck operations within the PFP complex, three types of vehicle impacts into the 2736-ZB building were found to warrant consideration: high velocity vehicle impacts due to a runaway vehicle from the main road circling the facility, vehicle impacts into the eastern wall of the facility due to process trucks travelling down the alley between the 2736-ZB building and the 291-Z building, and vehicle or load impacts into the southern wall of the 2736-ZB building due to a receiving accident at the loading dock in the 2736-ZC building. These initiators are discussed in the following paragraphs.

Inside the PFP fence, a speed limit is 15 mi/h is specified. At this speed, semi-trucks and process trucks are not expected to be capable of crashing through the reinforced concrete walls of the building. Although very unlikely, an over-speed truck from the road circling the facility can be postulated if the truck operator has a seizure, heart attack, or other medical condition that causes him to lose control of the truck (e.g., to accelerate and turn in toward the facility). A runaway truck could also occur due to a mechanical failure (e.g., stuck accelerator). As is shown in Figure 4-3, the 2736-ZB building is for the most part surrounded by other buildings within the PFP complex. The 2736-ZB building is shielded on the east by the 291-Z building; on the south by the 2736-ZC, 232-Z, and 2731-ZA buildings; and on the west by the 2721-Z building. To the southeast and southwest the 2736-ZB building is shielded by the 291-Z-1 stack and the 234-ZB building, respectively. Impacts into the surrounding buildings is not likely to effect the 2736-ZB building and are beyond the scope of this analysis. The unlikely initiator for the runaway vehicle accident, combined with the protection provided by the surrounding buildings makes the possibility of a high momentum impact into the 2736-ZB very remote. The likelihood of a high velocity vehicle impacting the portions of the 2736-ZB building housing the SPS or ventilation equipment is judged to be low enough that detailed consequence analysis is not warranted at this stage in the Project W-460 design. The credibility of the runaway vehicle impacts into the 2736-ZB building will be further evaluated in accident analyses supporting detailed design.

Process trucks and laundry trucks are periodically driven down the alley between the 2736-ZB building and the 291-Z building. A loading platform is located up against the 234-5Z building (by door 125) in the alley. Trucks driven down the alley to the loading platform could conceivably impact the eastern wall of 2736-ZB (due to driver error, driver medical condition, or truck mechanical failure). At normal speeds, these trucks will not be capable of breaching the reinforced concrete wall. Such a vehicle would have little room to build up speed should a mechanical failure occur or an operator medical crisis develop of the accelerator stick. The alley is narrow so turning a process truck into the building at high speed would be difficult. A glancing blow at credible speeds would not be expected to produce wall failure. Further assessment of the vehicle weight and speed required to cause significant damage to the facility, however, is recommended during detailed design. Based on this assessment, administrative restrictions on vehicle speed (and possibly weight) can be defined to ensure the integrity of the wall. If necessary, concrete posts or other barriers can be added to provide additional protection for the eastern wall. The exterior doors on the east side of the building are likely to be vulnerable to damage even low speed impacts. The exterior doors form part of the safety class confinement boundary for the facility. Concrete posts or other barriers should be considered to protect these exterior doors.

A shipping/receiving area with a loading dock is provided in the 2736-ZC building, which is located just south of 2736-ZB (see facility layout in Figure 4-3). The configuration of this loading dock precludes damage to the south wall of the 2736-ZB building should a shipping truck be backed up in an uncontrolled manner (due to human error or medical condition). The shipping/receiving area deck is elevated 5 ft off the pavement where the shipping truck backs in. Should a truck be backed up in an uncontrolled manner the load would be transferred to and absorbed by the basemat of 2736-ZC. Because of the elevated shipping/receiving area deck, it is not credible for a truck to be driven through 2736-ZC into 2736-ZB. It is conceivable a truck impacting the loading dock could dump its load onto the elevated shipping/receiving area deck. It is unlikely however that the load (typically transportation containers) would be heavy enough or have enough momentum to carry into the south wall of the 2736-ZB building, past the crane and other equipment located in the shipping/receiving area.

5.0 CONSTRUCTION RISKS

5.1 FACILITY RISKS

No safeguards or security physical upgrades will be necessary. However, certain situations during construction may impose risk to the building structure.

The installation of the ventilation and dry air systems will require penetrations in the building walls and ceilings. The penetrations could possibly compromise the integrity of the building.

An opening will have to be created in the east wall of Room 642 to facilitate equipment access. The structural change could possible affect the seismic response since the new door and frame will be designed to maintain seismic qualification of the building.

Airlocks will be added that could possibly affect the seismic response of the building.

The full scope of the electrical modifications are not known at this time but could possibly result in building power outages, voltage spikes, or shorts due to human error.

Modifications to the fire protection system may cause other portions of the system to be inadvertently shut off resulting in loss of fire protection in another area of the building.

Modifications to the HVAC system could affect supply or exhaust trains in other areas of the building.

The increased movement of vehicles delivering components may increase risk of vehicle impacts to the buildings.

5.2 PERSONNEL RISKS

Ordinary construction hazards will exist during the installation of the Pu SPS. All reasonable precautions will be taken to protect the health and safety of employees, subcontractors, and DOE personnel. DOE health and safety standards and regulations will be followed. Personnel risks include, but are not limited to, the following:

- Heat related injuries (furnace operation and welding process)
- High pressure accidents (helium and nitrogen bottles and tubing)
- Exposure to concentrated gases (helium and nitrogen bottles/tubing leaks)

- Excessive noise (ventilation fans, construction tools, etc)
- Falls (tripping/slipping on construction debris).

5.2.1 Nuclear

It is expected that very little contamination will be in the building or ductwork during construction activities. There will be no radiological inventory involved except where existing site Pu storage containers will be moved to facilitate vault modifications. Work to modify a vault room will not occur until all radioactive material has been removed from the room. Radiation shielding for operators of the SPS will be provided on the equipment supplied. Shielding for the vaults will be determined during detail design.

Removing, packaging, and disposing of any radioactive or dangerous waste or materials found during installation will comply with appropriate safety standards and procedures.

5.2.2 Chemical

Personnel may be exposed to hazardous chemicals used in the process of decontamination.

5.3 MITIGATION

Construction risks can be reduced significantly through proper construction planning to ensure compliance with applicable industrial health and safety standards (29 CFR 1910 and 1926), WHC-CM-4-40 and WHC-CM-1-11, and the most recent industry standards applicable to chemical threshold limits and biological exposures.

6.0 SAFETY DOCUMENTATION

6.1 ADDITIONAL SAFETY DOCUMENTATION REQUIRED

The development, review, and approval of a preliminary safety analysis report in accordance with WHC-CM-4-46 is required prior to the start of construction.

6.2 CHANGES REQUIRED TO EXISTING FACILITY SAFETY ANALYSIS DOCUMENTATION

The operations related to the Pu SPS shall be added to the existing PFP Final Safety Analysis Report (WHC 1996b). Applicable operating safety requirements and supporting facility operating procedures must be reviewed and updated.

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7.0 PROJECT INTERFACES

7.1 STABILIZATION AND PACKAGING SYSTEM INSTALLATION INTERFACES

The following are requirements during SPS installation.

7.1.1 Normal Operations

The normal operations at the PFP in Buildings 2736-Z, 2736-ZA, and 2736-ZB will be affected by the construction activities associated with the SPS.

7.1.2 Electrical

The SPS will require a 3-phase, 480V power supply. The stabilization section will require a 100 amp circuit breaker panel board. The packaging section will require a subfeed from the stabilization panel board, some 208Y/120V transformers, and a 175 amp, 480V feeder.

7.1.3 HVAC System

The ventilation supply and exhaust systems in Buildings 2736-Z, 2736-ZB, and 2736-ZA will be affected as described in Section 1.3.3.

7.1.4 Fire Protection System

The fire protection system piping above the SPS will require modification to be seismically qualified. This is necessary to prevent the piping from falling and damaging the SPS confinement barrier, and potentially dumping water directly into the SPS gloveboxes (which could cause a criticality), in a seismic event.

7.2 VAULT MODIFICATIONS INTERFACES

The modifications to a vault will require all of the existing storage canisters to be moved from that vault and relocated to another vault.

7.3 RISKS TO INTERFACING FACILITIES

Based on the PHA and accident analysis presented in Chapter 4, no unacceptable risks to interfacing facilities result from the SPS installation and operation have been identified.

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8.0 ITEMS REQUIRING FURTHER RESOLUTION

During the completion of this PSE, the following items were identified that require further development:

- **Storage Vault Structural Response To Loss Of Ventilation Flow.** Detailed thermal and structural modelling of the vault's structural response to a loss of ventilation accident is required for the final vault design modification developed for storage of the 3013 canisters. The thermal analysis should consider transient effects and potential long-term concrete degradation at the elevated temperatures possible given loss of forced flow through the vault. Temperature gradients across the vault walls must also be assessed for structural effects. This analysis will determine whether significant concrete degradation is possible given a long-term loss of ventilation flow or will determine the recovery time in which restoration of active ventilation will be required to prevent significant structural degradation.

  If thermal modelling cannot demonstrate acceptable structural response to a long-term loss of forced ventilation flow, the vault ventilation system and backup power system will require designation and qualification as safety class SSCs to ensure continuous cooling airflow through the vaults. The safety class qualification has to consider the potential effects of the design basis earthquake, design basis wind, and design basis ashfall.

- **Determination of Design Features to Mitigate Pressurized Glovebox Releases.** Further analyses are required to determine the appropriate safety class design features to mitigate potential releases from the SPS gloveboxes. Mitigative options include: (1) safety class interlocks to shut off the SPS dry air supply and compressed utility gas supplies on detection of high pressure indication in the glovebox, (2) safety class interlocks to shutdown the 2736-ZB building supply system on detection of pressurization of the glovebox, (3) modifying the exterior door on the E side of the 2736-ZB building to an airlock arrangement, with reliable door closers, to limit potential outleakage through that path, (4) qualifying and designating the building exhaust system active components to safety class requirements to ensure reliable confinement in the event of an upset. Room exhaust flow may have to be set high enough to maintain confinement across the open exterior door.

- **Modelling of Releases From Storage Vaults Under Stagnant and Pressurized Conditions.** Further modelling of potential releases from the storage vaults under stagnant or pressurized conditions is required to determine the need for safety class backdraft dampers or HEPA filters in the supply duct. The analysis is also needed to determine the potential contamination spread to other areas of the facility due to release through the storage vault door and other penetrations, which in turn will determine the safety classification and functional requirements for the vault door, the 2736-Z and 2736-ZB ventilation systems and external doors on the 2736-Z and 2736-ZB buildings.

- **Criticality Analyses of SPS and Storage Vault Operations.** A Criticality Safety Evaluation Report (CSER) must be prepared and reviewed by Hanford criticality specialists as well as the PFP Criticality Representative, and issued prior to operation of the system. The CSER must contain an assessment of the operation and equipment to determine the locations and conditions where a criticality is possible and the conditions that could cause a criticality. The CSER must provide defensible limits for these locations or operational conditions. The CSER analysis must consider both normal and abnormal operations or situations such as:

  - Load in, load out and other locations in which containers of plutonium oxide might accumulate in quantities in excess of criticality limits (caused by human error or canister or tray handling system errors).

  - Inadvertently loading in containers containing plutonium metal ("buttons") which may result in criticality limits based on PuO_2 being exceeded.

  - Gradual accumulation of plutonium around equipment that is used to transfer powders (e.g., oxide tipping station).

  - Locations in which plutonium powder might be spilled as a result of a process upset or operator error (especially in those areas that might also have containers of plutonium).

  - Failure of the furnace water walls (if water cooling system used) or the supply to the water walls so that the furnace trays become filled with liquid as well as plutonium.

  - Operator error in which the container is filled to the top with high density plutonium powder rather than filled to a specific mass limit.

  - And, failure of the steam coils in the storage vault HVAC system resulting in a water mist in the vicinity of plutonium storage locations.

- **Analysis of Vehicle Impacts into the 2736-ZB Building Walls.** Further analysis of potential vehicle impacts into the 2736-ZB building should be performed during detailed design. The SPS is to be located near the eastern exterior wall of the building and could be vulnerable to damage in a vehicle impact. The walls of the building are relied on to contain releases from the SPS. The vehicle weight and speed required to penetrate the walls of the 2736-ZB building should be determined to assess the need for design features and administrative controls to mitigate vehicle impacts. The likelihood of runaway vehicles impacting the structure at higher speeds also needs to be developed during the detailed design phase. All vehicles used inside the PFP fence (e.g., laundry trucks, process trucks, forklifts, etc) should be considered in the analysis. The construction and egress doors in the eastern wall of the building may be particularly vulnerable to vehicle impacts. The doors form part of the safety class confinement boundary for the facility. Impacts into these doors could also result in damage to the SPS and a PuO_2 release. Detailed design should consider features to protect the doors from vehicle impacts.

- **Controls to Prevent Building Damage Due to Crane Falls.** Cranes will possibly be used to deliver SPS components from delivery trucks onto the loading dock or to a location near the new door installed on the east side of the 2736-ZB building. The crane(s) will be working in the vicinity of or over the storage vault building. A crane may also be used to stage materials on the roof that are required for the ventilation system modifications. There is no significant source term in the SPS area during the construction phase but some measure of protection should be provided for the storage vaults. Controls will have to be developed to protect the vaults during construction activities. Crane operations at PFP, other than those associated with Project W-460, are beyond the scope of this analysis and are controlled in accordance with existing Hanford Site programs.

- **Hydrogen Burn Potential in the Stabilization Furnaces.** Should sweep air through the furnaces be lost while stabilizing PuO_2 powders, a concern has been raised that hydrogen could build up inside the furnaces and be ignited. Hydrogen is produced due to the reaction of PuO_2 and adsorbed water as discussed in Section 4.3.5. Further assessment of the water desorption and PuO_2/H_2O reaction rates at elevated temperatures are needed to determine the credibility of furnace hydrogen deflagrations.

- **Verification of Seismic Qualification of Existing Ventilation Ductwork.** Seismic qualification of the 2736-ZB and 2736-Z building exhaust ductwork and final HEPA filters, as assumed in the accident analyses presented in Section 4.3.7, should be verified during detailed design.

- **Effects of Project W-460 Modifications on Seismic Qualification of the 2736-Z and 2736-ZB Buildings and Exhaust Ductwork.** Project W-460 will add a construction door to the 2736-ZB building. Another modification will involve tying the SPS exhaust system into the existing 2736-ZB building ductwork. The storage vaults in the 2736-Z building will also be modified with new storage arrays to support the 3013 containers. The 2736-Z building, the 2736-ZB building, and the exhaust duct for the 2736-ZB building were designated safety class in the PFP FSAR and are required to be seismically qualified. Analyses are required during detailed design on the W-460 project to demonstrate that the project modifications will not compromise the seismic qualification of the safety class 2736-Z building, 2736-ZB building, or 2736-ZB exhaust system.

- **Fire Analysis.** Section 4.3.3 presents an analysis of an SPS Glovebox Fire. This analysis was done without the benefit of a formal Fire Hazards Analysis (FHA). The project has committed to performing an FHA during the Definitive Design stage of the project. The results of the FHA will then be reviewed and appropriately coordinated with fire accident and consequence analysis.

REFERENCES

DOCUMENTS

ARH-CD-635 1976, *Evaluation of Food Pack Cans as Plutonium Storage Containers*, Atlantic Richfield Hanford Company, Richland, Washington.

BNWL-1732 1973, *Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents*, Battelle-Pacific Northwest Laboratory, Richland, Washington.

BNFL 1996, SDD/Pu SPS @ RF/707, Rev. 1, *System Design Document for the Plutonium Stabilization and Packaging System*, BNFL Inc., Denver, Colorado.

Carter, R. D., Keil, G. R., Ridgway, K. R., 1969, *Criticality Handbook*, Volume II, ARH-600, Volume 2, Atlantic Richfield Hanford Company, Richland, Washington.

DOE 1976, DOE 76-4519, *Job Safety Analysis*, U.S. Department of Energy, Washington D.C.

DOE 1989, *General Design Criteria*, DOE Order 6430.1A, U.S. Department of Energy, Washington, D.C.

DOE 1994a, DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, U.S. Department of Energy, Washington, D.C.

DOE 1994b, DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

DOE 1996, DOE-STD-3013-96, *Criteria for Preparing and Packaging Plutonium Metals and Oxides for Long-Term Storage*, U.S. Department of Energy, Washington, D.C.

Elder, J. D., Graf, J. M., Dewart, J. M., Buhl, T. E., Wenzel, W. J., Walker, L. J., Stoker, A. K., 1986, *A Guide to Radiological Accident Considerations for Siting and Design of DOE Nonreactor Nuclear Facilities*, LA-10294-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Koelling, J. J., Hansen, G. E., Byers C. C., 1976, *Fission and Explosive Energy Release of* PuO_2, PuO_2 - UO_3 *Assemblies*, LA-UR-77-72, Los Alamos National Laboratory, Los Alamos, New Mexico.

Marks, L. S., 1951, *Mechanical Engineers Handbook*, McGraw-Hill Book Company, New York, New York.

Paxton, H. C., Pruvost, N. L., 1986, *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, ^{233}U*, LA-10860-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

PNL-4154 1982, *Accident Generated Particulate Materials and Their Characteristics — A Review of Background Information*, Pacific Northwest Laboratory, Richland, Washington.

WHC 1990, WHC-SD-CP-DA-032, *PFP/FSAR Milestone Analysis Items*, Westinghouse Hanford Company, Richland, Washington.

WHC 1996a, WHC-SD-CP-FDC-005, *Plutonium Stabilization and Handling (PuSH) Functional Design Criteria (FDC)*, Westinghouse Hanford Company, Richland, Washington.

WHC 1996b, WHC-SD-CP-SAR-021, Rev. 1, *Plutonium Finishing Plant Final Safety Analysis Report*, Westinghouse Hanford Company, Richland, Washington.

Woodcock, E. R., 1996, *Potential Magnitude of Criticality Accidents*, United Kingdom Atomic Energy Authority Report, AHSB(RP)R-14.

29 CFR 1910, *Occupational Safety and Health Standards*, Code of Federal Regulations, as amended.

29 CFR 1926, *Safety and Health Regulations for Construction*, Code of Federal Regulations, as amended.

FLUOR DANIEL HANFORD CONTROLLED MANUALS

WHC-CM-1-10, *Safety Manual*, Fluor Daniel Hanford, Richland, Washington.

WHC-CM-1-11, *Industrial Hygiene Manual*, Fluor Daniel Hanford, Richland, Washington.

WHC-CM-4-40, *Industrial Hygiene Manual*, Flour Daniel Hanford, Richland, Washington.

WHC-CM-4-46, *Safety Analysis Manual*, Fluor Daniel Hanford, Richland, Washington.

Table 2-1. Safety Class and Safety Significant SSCs. (6 Sheets)

SSC	Safety Classification	Rationale	Safety Function	Applicable Accident Analysis
2736-ZB Building Structure	Safety Class	Structure previously designated safety class in PFP FSAR. Seismic qualification necessary to ensure building doesn't collapse in earthquake or high wind causing unacceptable release from SPS, or causing criticality by piling too much Pu together in the presence of failed water sources. Structure also forms part of confinement boundary for releases inside building.	Prevent damage to SPS--must survive DBE and DBW forces and impacts from credible wind driven missiles. Confine radiological releases from SPS or from ruptured canisters elsewhere inside the building.	4.3.2 "Loss of Glovebox Confinement" 4.3.3 "Glovebox Fire" 4.3.4 "Criticality" 4.3.7 "Seismic Event" 4.3.8 "Extreme Wind"
2736-Z Building Structure	Safety Class	Structure previously designated safety class in PFP FSAR. Seismic qualification necessary to ensure building doesn't collapse in earthquake or high wind causing an unacceptable release from the canisters in vault storage, or that collapse doesn't result in criticality configuration of vault inventory. Structure also forms portion of confinement system (along with ventilation system ductwork and filters) for releases inside the vault.	Protect storage canisters from damage; structure must withstand DBE forces, DBW, and impacts from credible wind driven missiles; structural integrity must also be maintained on loss of forced ventilation flow through the vaults. Maintain critically safe configuration of storage canisters. Confine radiological releases from vault canisters.	4.3.4 "Criticality" 4.3.5 "Package Failures in Storage Vault" 4.3.7 "Seismic Event" 4.3.8 "Extreme Wind"
2736-Z Building floor and storage tube configuration (in-floor storage concept)	Safety Class	Required to remain intact during seismic event to prevent large releases from vault canisters and to maintain critical safe configuration of vault inventory.	Prevent damage to canisters; must survive DBE forces, and loss of cooling ventilation flow. Maintain critical safe geometry of storage array.	4.3.7 "Seismic Event" 4.3.4 "Criticality"

Table 2-1. Safety Class and Safety Significant SSCs. (6 Sheets)

SSC	Safety Classification	Rationale	Safety Function	Applicable Accident Analysis
2736-Z Building storage cubicles and canister holders (cubicle storage concept)	Safety Class	Same as above	Same as above	Same as above
SPS glovebox structure and floor anchors	Safety Class	Structural integrity must be maintained in seismic event to prevent large releases from the glovebox to the 641/642 room and to prevent critical geometries of plutonium oxide powder from being formed.	Contain radioactive material. Contain fissile material in critically safe geometry. Note: SPS must be protected from damage due to the failure of overhead ductwork or piping; supports for overhead ductwork or piping should be seismically qualified.	4.3.7 "Seismic Event"
SPS exhaust system HEPA filters, HEPA filter housing and ductwork up to 2736-ZB roof penetration	Safety Class	Required to mitigate the release of PuO_2 powder through the exhaust system during normal operations and during upset conditions. An unfiltered release through the SPS vent system could result in dose consequences exceeding the offsite evaluation guideline.	Remove radioactive particulates from SPS exhaust airstream.	4.3.1 "Unfiltered Release Through Glovebox Ventilation System" 4.3.7 "Seismic Event"
2736-ZB Building final HEPA filters, HEPA filter housing, and ductwork up to the HEPA filter housing	Safety Class	Required to mitigate potential releases of PuO_2 through the building exhaust system; consequence of unfiltered release through system would exceed offsite EG, based on consequences determined in Sections 4.3.2, 4.3.3, and 4.3.7.	Remove radioactive particulates from building exhaust airstream.	4.3.2 "Loss of Glovebox Confinement" 4.3.3 "Glovebox Fire" 4.3.7 "Seismic Event"
2736-Z Building exhaust system HEPA filters, HEPA filter housing and ductwork up to HEPA filter housing	Safety Class	Required to mitigate potential releases of PuO_2 powder through the vault exhaust system; storage canisters in the vault may rupture due to overpressure; unfiltered release from storage vault could exceed the offsite EG, based on the consequence analyses reported in Section 4.3.5.	Mitigate particulate releases through exhaust system ductwork.	4.3.5 "Package Failures in Storage Vault" 4.3.7 "Seismic Event"

Table 2-1. Safety Class and Safety Significant SSCs. (6 Sheets)

SSC	Safety Classification	Rationale	Safety Function	Applicable Accident Analysis
Vault ventilation supply backdraft damper or supply filters	Safety Class	Needed to prevent or mitigate releases through supply path should canister rupture while vault exhaust fan is shutdown. Exhaust fan is not qualified to safety class requirements.	Prevent or mitigate particle releases through supply path.	4.3.5 "Package Failures in Storage Vault"
Construction door on E wall of 2736-ZB	Safety Class	Forms part of safety class confinement boundary for the facility (along with the building structure and exhaust filters).	Door should be sealed shut following construction. Functional requirement is that door remain in place and closed in DBE and DBW.	4.3.2 "Loss of Glovebox Confinement" 4.3.3 "Glovebox Fire" 4.3.4 "Criticality" 4.3.7 "Seismic Event" 4.3.8 "Extreme Wind" 4.3.10 "Vehicle Impact"
Cutting tools and electrical equipment inside the SPS material preparation area	Safety Class	Spark proof tools and electrical equipment are required to prevent ignition of hydrogen potentially released from convenience cans when they are opened. Consequences of hydrogen deflagration could exceed the offsite EG.	Prevent ignition sources.	4.3.3 "Glovebox Fire"
Facility CAMs and vault air sampling system	Safety Significant	Airborne Pu poses significant hazard to facility workers. Safety significant designation assigned per criterion 13 from Table 1, Section 9.0 of WHC-CM-4-46.	Alert facility workers when airborne Pu hazard exists.	4.3.2 "Loss of Glovebox Confinement" 4.3.5 "Package Failure in Storage Vault"
Furnace cooling jacket, if water cooling used	Safety Significant	Spill of cooling water inside SPS could result in a criticality; consequences of a criticality could exceed the onsite EG of 5 rem.	Contain cooling water.	4.3.4 "Criticality"

Table 2-1. Safety Class and Safety Significant SSCs. (6 Sheets)

SSC	Safety Classification	Rationale	Safety Function	Applicable Accident Analysis
Moisture detection in SPS gloveboxes (recommended)	Safety Significant	Should moist air infiltrate into the SPS, wet PuO_2 could be sealed up in a final storage container. The container could pressurize and rupture resulting in injury and significant radiological exposure to facility workers; releases inside the vault are confined by the safety class vault structure and safety class vault exhaust system HEPA filters; moisture detector provides defense-in-depth protection against package ruptures in the storage vault; safety significant designation assigned per criteria 12 and 13 from Table 1, Section 9.0 of WHC-CM-4-46.	Provide indication of "wet" air inside the SPS gloveboxes".	4.3.5 "Package Failures in Storage Vault"
Dryer on SPS supply air	Safety Significant	See above	Supply dry air meeting the dew point requirement to the SPS.	See above
Criticality alarms	Safety Significant	Safety significant designation assigned per criterion 13 from Table 1, Section 9.0 of WHC-CM-4-46.	Detect criticality.	4.3.4 "Criticality"
SPS glovebox ventilation kicker fan and controls	Safety Significant	Should Pu escape from the SPS into the 641/642 it presents a significant hazard to operators; safety significant designation assigned per criteria 12 and 13 from Table 1, Section 9.0, of WHC-CM-4-46.	Maintain negative pressure in the SPS in the event both facility exhaust fans shut down.	4.3.2 "Loss of Glovebox Confinement"
SPS glovebox confinement boundary (e.g., windows, gloveports, sphincter seals, entry isolation doors and their controls)	Safety Significant	See above	Ensure confinement of radioactive materials.	4.3.2 "Loss of Glovebox Confinement"

Table 2-1. Safety Class and Safety Significant SSCs. (6 Sheets)

SSC	Safety Classification	Rationale	Safety Function	Applicable Accident Analysis
SPS glovebox pressure indication and alarms	Safety Significant	Positive pressure inside the glovebox can result in the spread of Pu from the gloveboxes to the 641/642 room; this presents a significant hazard to SPS operators; safety significant designation assigned per criteria 12 and 13 from Table 1, Section 9.0, of WHC-CM-4-46.	Indicate positive pressure in glovebox. Positive pressure indication will result in the evacuation of workers from room 641/642 and the manual shutdown of dry air and compressed gas supplies to the SPS.	4.3.2 "Loss of Glovebox Confinement"
SPS dump valves and interlocks to glovebox pressure transducers	Safety Significant	See above	Open on detection of increasing pressure in glovebox to ensure confinement is not lost.	4.3.2 "Loss of Glovebox Confinement"
Regulators and pressure relief valves (PRVs) on compressed dry air supply and compressed utility gas supplies to SPS	Safety Significant	Failure to regulate compressed gas supplies could result in failure of the SPS glovebox confinement system and the release of large quantities of PuO_2 to the 641/642 room; ultimate mitigation of release to the environment is provided by safety class building structure and exhaust system HEPA filters (see Section 8.0 for open issue regarding controls to shut down gas supplies to the SPS on detection of high pressure).	Regulate compressed gas supply pressures within operating parameters specified for the SPS.	4.3.2 "Loss of Glovebox Confinement"

Table 2-1. Safety Class and Safety Significant SSCs. (6 Sheets)

SSC	Safety Classification	Rationale	Safety Function	Applicable Accident Analysis
SPS fire suppression system (includes overheat detection system).	Safety Significant	Safety Significant designation assigned to protect the integrity of the SPS should a fire occur inside the SPS.	Extinguish internal fires.	4.3.3 "Glovebox Fire" Note: The Glovebox Fire accident analysis assumes the limited combustible loading in the SPS design precludes significant conflagrations that might involve the SPS structure. The Safety Significant designation was conservatively assigned pending completion of an FHA to further assess the potential for significant fires.
Restraints for SPS fire suppression system compressed gas bottles.	Safety Significant	Fire suppression system gas bottles pose potential missile threat to SPS if not restrained (if located in same room with SPS). Safety Significant designation applied to ensure the integrity of the Safety Significant SPS confinement boundary.	Prevent toppling of compressed gas bottles in seismic event (or due to other interactions) which could cause supply valve to break off.	4.3.2 "Loss of Glovebox Confinement" 4.3.7 "Seismic Event"

Other SSC safety classifications to be determined based on further analyses discussed in Section 8.0

Table 3-1. 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 (1)
< 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.

1. Time since separation.

Table 4-1. Preliminary Hazards Analysis Form.

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material At Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat	Freq Cat	Remarks

Table 4-2. Atmospheric Dispersion Coefficients for Releases from the 2736-Z and 2736-ZB Buildings.

Receptor	X/Q' (s/m^3)
Maximum Onsite Individual (550 m WNW)	4.74 E-4[1]
Maximum Offsite Individual (12,500 m W)	1.01 E-5[2]

1. From Table 9-39 of WHC-SD-CP-SAR-021, Plutonium Finishing Plant Final Safety Analysis Report, Rev. 1. X/Q' includes building wake and plume meander.
2. From Table 9-40 of WHC-SD-CP-SAR-021, Plutonium Finishing Plant Final Safety Analysis Report, Rev. 1. X/Q' includes building wake and plume meander.

Table 4-3. Unmitigated Dose Consequences for Unfiltered Release Through the Plutonium Stabilization and Packaging System Glovebox Ventilation System.

Receptor Location	Effective Dose Equivalent, rem	Guidelines[1], rem
Onsite (550 m WNW)	49	5
Offsite (12,500 m W)	1.0	0.5

1. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-4. Unmitigated Dose Consequences for Pressurized Plutonium Stabilization and Packaging System Glovebox Accident.

Receptor Location	Effective Dose Equivalent, rem	Guidelines[1], rem
Onsite (550 m WNW)	43	5
Offsite (12,500 m W)	0.90	0.5

1. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-5. Unmitigated Dose Consequences for Plutonium Stabilization and Packaging System Glovebox Fire.

Receptor Location	Effective Dose Equivalent, rem	Guidelines[1], rem
Onsite (550 m WNW)	33	5
Offsite (12,500 m W)	0.70	0.5

1. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-6. Critical Masses and Dimensions.

Geometry	Reflection	Pu density g/cc	% Pu-240	Critical Mass[1] & Dimensions
Sphere	Full	2	0	8.5 kg, 4.3 L
		4	0	10.5 kg, 2.6 L
		6	0	10.5 kg, 1.8 L
	1" H_2O	2	0	13 kg, 6.5 L
		4	0	15.5 kg, 3.9 L
		6	0	15 kg, 2.5 L
	none	2	0	20 kg, 10 L
		4	0	23 kg, 5.8 L
		6	0	23 kg, 3.8 L
	1" H_2O	2	10	23 kg, 11.5 L
		4	10	22 kg, 5.5 L
		6	10	21 kg, 3.5 L
Slab	Full	2	0	8 kg/ft^2, 1.7 in. deep
		4	0	12 kg/ft^2, 1.3 in. deep
		6	0	14 kg/ft^2, 0.9 in. deep
	1" H_2O	2	0	14 kg/ft^2, 3 in. deep
		4	0	23 kg/ft^2, 2.3 in. deep
		6	0	28 kg/ft^2, 1.7 in. deep
	none	2	0	22 kg/ft^2, 4.2 in. deep
		4	0	33 kg/ft^2, 3.8 in. deep
		6	0	44 kg/ft^2, 3 in. deep
	1" H_2O	2	10	19 kg/ft^2, 4.1 in. deep
		4	10	28 kg/ft^2, 3 in. deep
		6	10	33 kg/ft^2, 2.3 in. deep

1. Critical mass is based on assumption that the remainder of the volume is filled with water. For example, a critical mass of 8.5 kg in 4.3 L with plutonium density of 2g/cm^3 means that there is 0.05 kg or 0.05 L of water mixed in with the powder.

Table 4-7. Critical Mass - Dry vs. Wet Powder for Spherical Volumes, 0 wt% ^{240}Pu.

Plutonium Density, g/cm^3	Reflection	Critical Mass, kg	
		Dry Powder	Wet Powder
2	None	600	20
4	None	150	23
6	None	50	23
2	1 in.	300	23
4	1 in.	100	22
6	1 in.	40	21
2	Full	120	8.5
4	Full	45	10.5
6	Full	22	10.5

Table 4-8. Dose Consequences Due to Criticality Resulting in 10^{18} Fissions.

Receptor Location	Effective Dose Equivalent, rem	Thyroid Dose, rem
Onsite (550 m WNW)	0.73	2.4
Offsite (12,500 m W)	0.05	1.6

Table 4-9. Dose Consequences for Package Failure in Storage Vault.

Receptor Location	Effective Dose Equivalent, rem	Guidelines[1], rem
Onsite (550 m WNW)	4.8 E-3	5
Offsite (12,500 m W)	1.0 E-4	0.5

1. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-10. Dose Consequences for Vault Collapse Due to Overheating.

Receptor Location	Effective Dose Equivalent, rem	Guidelines[1], rem
Onsite (550 m WNW)	9600	5
Offsite (12,500 m W)	200	0.5

1. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-11. Dose Consequences for Releases from 2736-Z and 2736-ZB in a Seismic Event.

Receptor Location	Effective Dose Equivalent, rem	Guidelines[1], rem
Onsite (550 m WNW)	93	5
Offsite (12,500 m W)	2.0	0.5

1. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-12. Summary of PFP Seismic Releases and Doses.

Source of Release	Release Quantity (g of Pu)	Onsite Dose (rem)	Offsite Dose (rem)
2736-Z and -ZB Buildings (Project W-460)	3.5	93	2.0
Remainder of PFP and 232-Z Facility[1]	1.4	9.7	0.2
Totals	4.9	103	2.2
Risk Evaluation Guidelines for "Unlikely" Frequency Category[2]		25	5

1. From PFP FSAR Seismic "no ventilation" case
2. Guidelines are from WHC-CM-4-46, Nonreactor Facility Safety Analysis Manual, Fluor Daniel Hanford, Richland, Washington.

Table 4-13. Evaluation of Plutonium Stabilization and Packaging System Project Impact on PFP FSAR Analyzed Accidents. (3 sheets)

Section Number	PFP FSAR Analyzed Accident	Potential Impact on Probability/Frequency	Potential Impact on Consequences	Applicable SPS Accident
9.2.1A	Explosion - Product Concentrator	NONE	NONE	
9.2.1B	Explosion - Filtrate Evaporator	NONE	NONE	
9.2.1C	Deflagration in Glovebox HA-21I	NONE	NONE	
9.2.1D	Explosion - Laboratory Waste Concentrator	NONE	NONE	
9.2.1E	Explosion - Hydrogen in Fluorinator	NONE	NONE	
9.2.1F	Explosion - Flammable Gas (Propane)	NONE	NONE	
9.2.1G	Explosion - Slag and Crucible System Deentrainer	NONE	NONE	
9.2.2A	Fire - Remote Mechanical C Line Fire	NONE	NONE	
9.2.2B	Fire - 234-5Z Roof	NONE	NONE	
9.2.2C	Fire - Glovebox HA-21I	Frequency of general glovebox fires is increased by addition of SPS	Consequences of SPS glovebox fire may be higher than FSAR analyzed case	Fire in SPS Glovebox (see Section 4.3.3)
9.2.2D	Fire - Waste Drum	NONE	NONE	
9.2.3	Criticality	Frequency of facility criticality increased by addition of SPS	Consequences of SPS criticality or storage vault criticality could be higher than FSAR analyzed case	Criticality (see Section 4.3.4)
9.2.4.2.1	Seismic Event - 234-5Z	NONE	NONE	
9.2.4.2.2	Seismic Event - 236-Z PRF	NONE	NONE	
9.2.4.2.3	Seismic Event - Product Handling 234-5Z and 236-Z	NONE	NONE	

Table 4-13. Evaluation of Plutonium Stabilization and Packaging System Project Impact on PFP FSAR Analyzed Accidents. (3 sheets)

Section Number	PFP FSAR Analyzed Accident	Potential Impact on Probability/Frequency	Potential Impact on Consequences	Applicable SPS Accident
9.2.4.2.4	Seismic Event - Vaults	NONE	NONE	
9.2.4.2.5	Seismic Event - Other (234-5Z and 236-Z)	NONE	NONE	
9.2.4.2.6	Seismic Event - 2736-Z Complex	NONE	Release from SPS and modified vaults could be higher than analyzed FSAR case	Seismic Event (see Section 4.3.7)
9.2.4.2.7	Seismic Event - 242-Z	NONE	NONE	
9.2.4.2.8	Seismic Event - 232-Z	NONE	NONE	
9.2.4.2.9	Seismic Event - 291-Z	NONE	NONE	
9.2.4.2.10	Seismic Event - 241-Z	NONE	NONE	
9.2.4.2.11	Seismic Event - Criticality	Addition of SPS may increase likelihood of criticality marginally over the FSAR case.	Seismic induced criticality in SPS or modified vault could add to criticality consequences analyzed in the FSAR	Criticality (see Section 4.3.4)
9.2.4.2.12	Seismic Event - Fire	NONE--facility fire	Consequences of SPS fire could add to post DBE fire consequences determined in the FSAR.	Fire in SPS Glovebox (See Section 4.3.3)
9.2.4.2.13	Seismic Event - Separation of Walls and Floor in 234-5Z	NONE	NONE	
9.2.5	Strong Wind - HNO_3 Storage Tank Rupture	NONE	NONE	
9.2.6.1	Flood - External	NONE	NONE	
9.2.6.2	Flood - Internal	NONE	NONE	

Table 4-13. Evaluation of Plutonium Stabilization and Packaging System Project Impact on PFP FSAR Analyzed Accidents. (3 sheets)

Section Number	PFP FSAR Analyzed Accident	Potential Impact on Probability/Frequency	Potential Impact on Consequences	Applicable SPS Accident
9.2.6.3	Flood - Glovebox	NONE	NONE	
9.2.7.1	Aircraft Accident - Commercial Aircraft and Contract Aerial Applicator	NONE--commercial aircraft impact into the PFP complex is incredible based on PFP FSAR	NONE	
9.2.7.2	Aircraft Accidents - Radiological Survey Helicopter Overflights	NONE--frequency reported in FSAR to be incredible if flight controls are implemented	NONE--consequences not analyzed in PFP FSAR	
9.2.8	Toxic Chemical Releases	NONE	NONE	

Figure 1-1. Plutonium Stabilization and Packaging System Location Drawing.

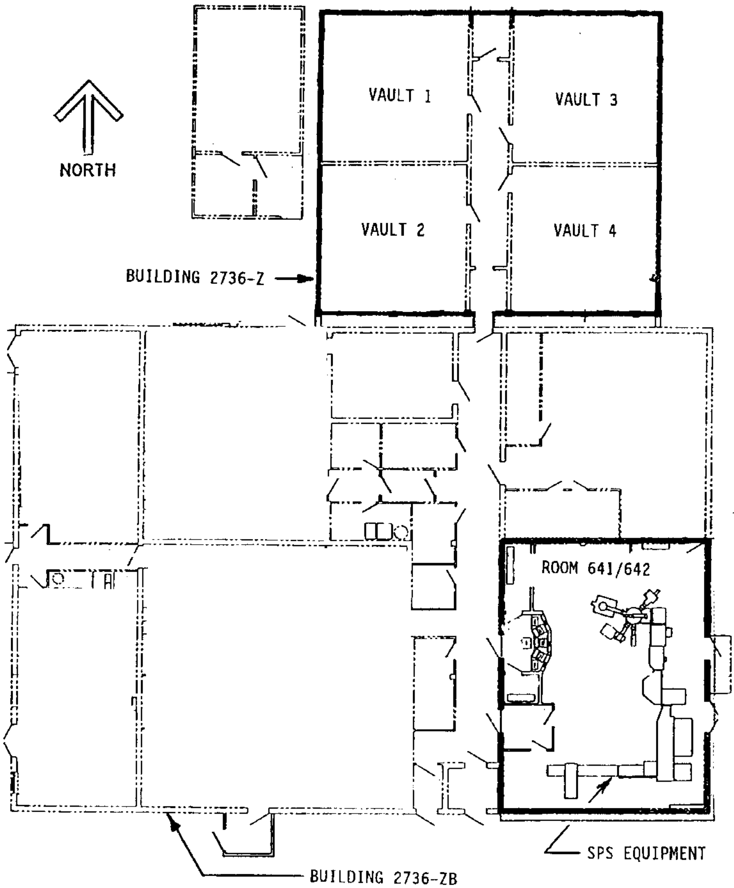


Figure 4-1. Accident Selection Process Flow Sheet.

HAZARD ANALYSIS (PHA IN THIS CASE)	This hazard analysis utilized the PHA approach for identifying hazards and accident sequences.
↓	
Preliminary list of Accidents or abnormal occurrences classified by consequence and frequency	Consequence and Frequency are qualitatively evaluated.
↓	
Sort by "CATEGORY" and "TYPE"	"CATEGORY" relates to the initiating event - Internal or External. "TYPE" relates to the accident phenomena - (fire, explosion, etc)
↓	
Perform conservative and simplistic calculation of consequences for determination of LEVEL OF SIGNIFICANCE	LEVEL OF SIGNIFICANCE implies a potential consequence that approaches evaluation guidelines. Evaluation Guidelines are established for the purpose of identifying and evaluating safety-class structures, systems, and components.
↓	
Pick "REPRESENTATIVE" (bounding) accident or accidents for each "TYPE"	"REPRESENTATIVE" accidents are those that bound the consequences for a group of similar accidents. "SIMILAR" means accidents of the same type challenging the same or analogous barriers. "ANALOGOUS" barriers reflect the same prevention/mitigation/design philosophy but may be located in a different part of the facility or project.
↓	
Review list of remaining accidents and identify "UNIQUE" accidents	"UNIQUE" accidents have potential consequences that may approach the "Evaluation Guidelines" and challenge different barriers from the "REPRESENTATIVE" for that accident type.

Figure 4-2. 3013 Storage Containers.
(Dimensions are in millimeters)

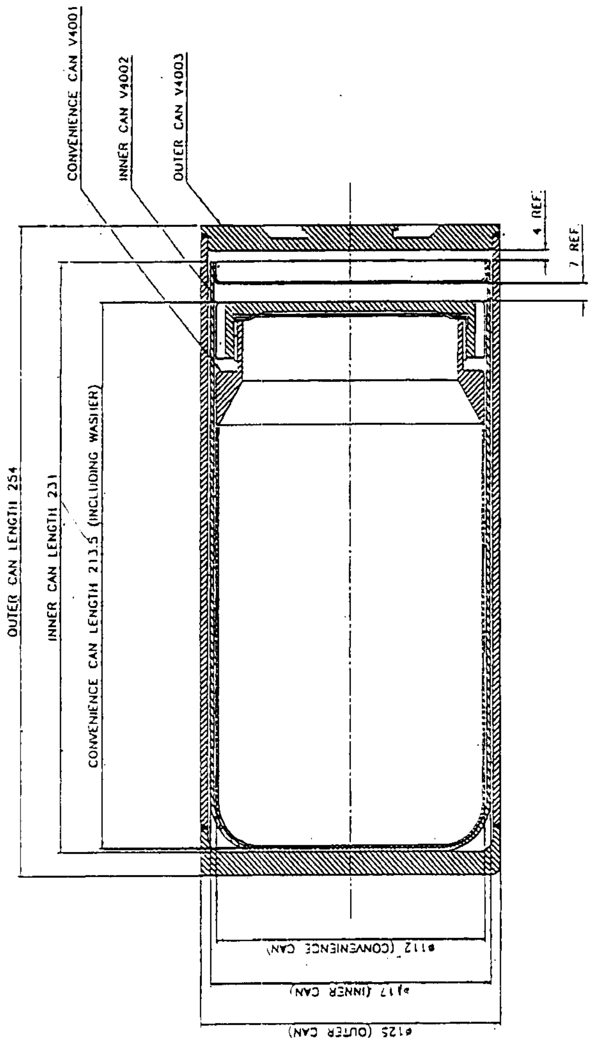
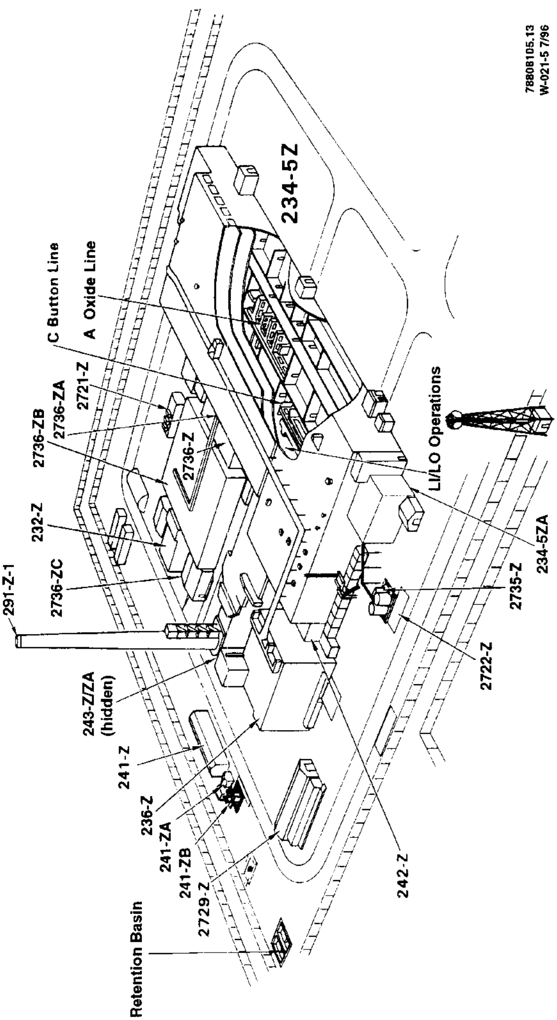


Figure 4-3. Plutonium Finishing Plant Layout.



APPENDIX A

SPS PRELIMINARY HAZARDS ANALYSIS

Appendix A

SPS Preliminary Hazards Analysis

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
1.0.op	1.0 Front End Operations										
1.1.a.op	1.1 Vault Storage to SPS Machine	Transfer from vault to cart	1.1.1 Drop canister inside vault	Human error	Pu oxide inside canister	Damaged outer can	Cans are small and relatively easy to handle Inner can is bagged and then overpacked into two other sealed cans Inner cans have been shown to survive 3 m falls without releasing powder (pfp sar)	Procedures and training	S0	F3	S0 based on three barriers precluding release. Inner can has slipfit lid which is taped. Inner can is also bagged and the bag heat sealed. Two overpack cans are mechanically sealed.
1.1.b.op	1.1 Vault Storage to SPS Machine	Transfer to SPS machine	1.1.2 Drop canister off cart	Human error	Pu oxide inside canister	Damaged outer can	Cart design plus above	Procedures and training	S0	F3	S0 based on three barriers precluding release. Inner can has slipfit lid which is taped. Inner can is also bagged and the bag heat sealed. Two overpack cans are mechanically sealed.
1.1.c.op	1.1 Vault Storage to SPS Machine	Transfer from vault to SPS machine	1.1.3 Expose other facility workers to direct ionizing radiation	Failure to adhere to radiation control procedures (ALARA). Facility workers do not maintain safe distance between containers and themselves.	Na (ionizing radiation source)	Increased worker exposures		Radiological control program Training Procedures	S1	F3	New shielded cart may be used
1.1.d.op	1.1 Vault Storage to SPS Machine	Transfer from vault to SPS machine	1.1.4 Violation of double contingency	Use of unapproved cart Operator puts too many canisters on cart	NA	Violation of double contingency requirement Criticality may occur if two contingencies violated	Cart design prevents critical geometries	Criticality controls Procedures	S1	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.0.op	2.0 SPS Operations										
2.1.a.op	2.1 SPS Gloveboxes (general)	Confine radiological material inside glovebox or to the ventilation system	2.1.1 Loss of confinement	Glovebox breach Damage to glovebox due to internal impact Explosion Fire External impact Seismic event Ventilation upsets Instrument purge gas leaks Inadvertent dry fire suppression activation Dry air supply control failure	Loose contamination in the glovebox plus Pu oxide in open containers	Release of contamination to the room atmosphere if confinement lost (e.g., hole too big for exhaust system) Operator exposures	Robust glovebox design Glovebox exhaust system Seismically qualified gloveboxes and supports Glovebox fire suppression system Dump valves minimize potential for glovebox pressurization Controls on supply and exhaust system Pressure indication in glovebox Fire suppression system alarms CAMs in room Room ventilation system mitigates potential release to the environment	Operator training and procedures Feed control minimizes likelihood of receiving containers with explosive/ Combustible materials Housekeeping limits combustible loading in glovebox	S2	F3	S2 ranking based on unfiltered release through building ventilation system Seismic initiator F2 or lower
2.1.b.op	2.1 SPS Gloveboxes (general)	Shielding	2.1.2 Loss or degradation of shielding Shielding inadequate for radiation source term in the glovebox	Human error in maintenance Pu accumulation over time in the box Higher than expected activity in source material	NA (no release, hazard is ionizing radiation)	Increased operator exposures	Design of the glovebox Area radiation monitors	Maintenance procedures Control of feed material Radiation control program (surveys) Housekeeping limits accumulation in glovebox	S1	F3	
2.1.c.op	2.1 SPS Gloveboxes (general)	Safety handle radioactive material	2.1.3 Spill of Pu material within the box	Operator drops canister Canister handling equipment damages or spills canister	Pu material within the canister (0.5 kg to 5 kg)	Release of Pu inside box requiring actions to clean it up; increased operator dose	Glovebox structure and glovebox exhaust system Design of automated handling equipment	Operator training and procedures	S2	F3	S2 ranking based on unfiltered release through exhaust stack also results in increased operator doses due to clean out requirements

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.1.d.op	2.1 SPS Gloveboxes (general)	Criticality prevention	2.1.4 Criticality	Too many canisters too close together Moderator (water) present with sufficient number of canisters	NA (primary hazard is ionizing radiation)	Operators exposed to high doses Release of fission product gases Release of Pu oxide powder disturbed in event to glovebox atmosphere	Criticality controls, including: Criticality detection in the gloveboxes, alarms in the rooms Criticality drains in gloveboxes Can handlers designed to only hold 1 can at a time Dry fire protection system for glovebox instead of water System designed in manner that prevents critical mass from coming together in a seismic event Spacing of storage spaces and equipment inside gloveboxes precludes criticality Design precludes ingress of water during seismic events Canister handling equipment interlocks preclude buildup of cans in areas of the machine	Criticality control procedures on spacing and number of containers in given area	S1	F3	check to see if criticality drains have been removed from design
2.2	Receipt area Major equipment: Glovebox Can opener Can handler Entry airlock	Receive incoming containers of Pu oxide from transfer trolley Record container numbers Open outer containers Frisk containers Remove inner container Bag out clean outer containers and packaging material for disposal Transfer containers into mat. prep. glovebox									

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.2.a.op	2.2 Receipt area		2.2.1 Drop canister on floor of room 641 in transferring from cart to glovebox	Human error	Outer canister surface contamination and Fraction of Pu material inside double over packed inner canister	Damaged storage package; potential minor release of Pu material from storage package should outer and inner overpacks rupture	Room CAMs will detect unlikely release from canisters Site convenience can is over packed in two mechanically sealed food pack cans Convenience can (inner can) slip lid is taped on Convenience can is over packed in bag to limit contamination spread to food pack cans Multiple barriers substantially limit potential release from canister assembly	Operator training/ procedures Results of drop tests on slip lid fit convenience cans provide confidence convenience can will not leak Pu material should the inner and outer overpacks rupture	S0 S1	F3 F1	S0, F3 for drop which results in no significant leak S1, F2 for canister drop resulting in minor contamination spread to the room
2.2.b.op	2.2 Receipt area		2.2.2 Loss of glovebox confinement during load in	Human error Ventilation upset Entry device seal failures	Loose contamination inside receipt glovebox [assumed to be very low]	Small spread of contamination to room	Room CAMs Glovebox exhaust system	Operator training and procedures Inner canisters are frisked for contamination not opened until passed through airlock into material preparation area	S1	F3	Receipt glovebox will have very low levels of contamination because cans that are found to be contaminated are bagged and passed on to the next glovebox before opening. Unknown if cans will be loaded in through airlock, sphincter seal, or if they will be bagged in.
2.2.c.op	2.2 Receipt area		2.2.3 Drop of inner overpack can inside glovebox after opening outer overpack can or drop of convenience can after opening inner overpack	Human error or malfunction of canister handler or canister opener	Fraction of material inside dropped package that could escape through a rupture	Minor release inside glovebox	Glovebox exhaust system (includes fans, filters, CAMs and other instrumentation) Convenience can lid is taped on and can is bagged and heat sealed	Operator training and procedures Convenience can drop tests	S2	F3	S2 ranking based on drop of bagged convenience can and unfiltered release through SPS ventilation system
2.2.d.op	2.2 Receipt area		2.2.4 Mishandling of contaminated cans/bags loaded out from glovebox	Human error Failure of frisking operation	Surface contamination	Worker exposure Minor release to room	Room CAMs Room ventilation system mitigates release to environment	Operator training and procedures	S1	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.2.e.op	2.2 Receipt area		2.2.5 Air flow reversal from material preparation glovebox	Ventilation imbalance Entry airlock failure	Loose contamination in mat prep glovebox	Contamination spread to "clean" receipt glovebox Increased worker exposure	Glovebox ventilation system controls Interlock controls on airlock doors	Operator training and procedures	S1	F3	
2.2.f.op	2.2 Receipt area		2.2.6 Load in wrong container/material (Pu nitrate, scrap metal, metal button, Pu fluorides)	Human error	see remarks	see remarks	Assay unit	Controls on material originally put in vault Metals inventory will be oxidized or packaged before SPS operates Packages containing Pu metals will be different size than Pu oxide containing packages Labeling of containers Other Pu materials in PFP will be stabilized or disposed before SPS operates Containers ID'd (bar code checked) after loading in Container assayed in mat prep glovebox	--	--	Item for further development. Expectation is that only Pu oxides will be received. To be developed further in definitive design
2.2.g.op	2.2 Receipt area		2.2.7 Fire in glovebox	Electrical equipment ignites packaging materials in glovebox	Loose contamination on packaging material and on other surfaces in the glovebox	Elevated release inside glovebox Degradation of glovebox integrity	Glovebox heat detection Dump valves limit potential pressurization Fire suppression system SPS ventilation system Robust glovebox design Room ventilation system	Housekeeping procedures to limit combustible loading	S1 S2	F3 F2	S1 for anticipated fire S2 if fire spreads to other gloveboxes (less likely)

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.2.h.op	2.2 Receipt area		2.2.8 Pressurized glovebox	Ventilation upsets Fire: electrical equipment ignites packaging materials in glovebox	Loose contamination on packaging material and on other surfaces in the glovebox	Spread of contamination to room atmosphere	Room CAMs ventilation system instrumentation Dump valves	training and procedures	S1	F3	
2.2.i.op	2.2 Receipt area		2.2.9 Criticality	Too many canisters too close together Moderator (water) present with sufficient number of canisters	NA (primary hazard is ionizing radiation)	Operators exposed to high doses Release of fission product gases Release of Pu oxide powder disturbed in event to glovebox atmosphere	Criticality controls, including: Criticality detection in the gloveboxes, alarms in the rooms Criticality drains in gloveboxes Can handlers designed to only hold 1 can at a time Dry fire protection system for glovebox instead of water System designed in manner that prevents critical mass from coming together in a seismic event Spacing of storage spaces and equipment inside gloveboxes precludes criticality Design precludes ingress of water during seismic events Canister handling equipment interlocks preclude buildup of cans in areas of the machine	Criticality control procedures on spacing and number of containers in given area	S1	F3	check to see if criticality drains have been removed from design

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.3	SPS Material Preparation Area - First Section Major equipment: Can handlers Entry and exit isolation doors Container opener Powder dispensing station Size reducing station Convenience can transfer port decontamination station Compactor station Material transfer ports	Receive inner container through entry air lock Assay container Open container Transfer container and contents to dispensing station Decontaminate canisters for loadout Compact containers coming from dispensing station Bag out containers for disposal									
2.3.a.op	2.3 SPS Material Preparation Area - First Section		2.3.1 Radioactive material spill inside glovebox (e.g., canister spill)	Contents of canister spilled during opening or handling operation External impact on glovebox	Contents of canister (0.5 to 2.5 kg Pu oxide)	Release of Pu inside glovebox	Glovebox confinement system (box, ventilation, inlet and outlet ventilation filters) Canister handling system controls and instrumentation Glovebox secured to floor	Operator training and procedures	S2	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.3.b.op	2.3 SPS Material Preparation Area - First Section		2.3.2 Criticality inside glovebox	Too many cans simultaneously too close together Flooding with water in combination with multiple cans Flooding with other moderators (e.g., hydraulic oil)	Number of cans in material prep area	Operator exposed to high doses Release of fission product gases Release of pu oxide powder disturbed in event to glovebox atmosphere	Criticality controls, including: Criticality drains in gloveboxes Can handlers designed to only hold 1 can at a time Dry fire protection system for glovebox minimizes potential for water intrusion System designed such that only two cans can contact each other in a seismic event Design precludes ingress of water during seismic events Interlocks preclude buildup of cans in areas of the machine	Criticality control procedures on spacing and number of containers in given area	S1	F3	
2.3.c.op	2.3 SPS Material Preparation Area - First Section		2.3.3 Fire inside glovebox	Plastic bags, cleanup rags, other fuel sources ignited by electrical equipment Pyrophoric metal shavings/turnings ignited Overheated furnace	Loose Pu oxide in glovebox and on packing packaging materials Pu material contained in entire machine (if fire spreads/ consumes other gloveboxes)	Pu released to room and through building vent system Soot and water vapor released challenging building vent system Building damage	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Pyrophoric material controls Visual checks to detect insertion of metal shavings/turnings	S1 S2	F3 F2	S1/F# for fire not spreading to other gloveboxes S2/F2 for fire postulated to spread to other areas of the machine containing more loose Pu material
2.3.d.op	2.3 SPS Material Preparation Area - First Section		2.3.4 Canister Explosion	Can containing hydrogen is ignited upon opening or by handling activity	Pu oxide material in can (0.5 to 5 kg) plus glovebox contamination	Pu release inside glovebox Potential glovebox damage Potential glovebox loss of confinement/spread of contamination to room	Stout glovebox design Glovebox ventilation system Room ventilation system Dump valves	Feed source controls limits potential for receiving cans containing combustibles or reactive chemicals	S2	F2	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.3.e.op	2.3 SPS Material Preparation Area - First Section		2.3.5.a Pressurized glovebox	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose contamination in box	Pu release from glovebox into room	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.3.f.op	2.3 SPS Material Preparation Area - First Section		2.3.5.b Pressurized glovebox	Chemical reaction	Loose contamination in box	Pu release into room (plus toxic fumes/gases depending on reaction)	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox Controls on feed source minimize likelihood of reactive compounds being processed. Limit on combustibles in gloveboxes. No solvents or reactive chemicals stored in gloveboxes Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.3.g.op	2.3 SPS Material Preparation Area - First Section		2.3.5.c Pressurized glovebox	Imbalance between dry air supply and exhaust	Loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.3.h.op	2.3 SPS Material Preparation Area - First Section		2.3.6 Stagnant glovebox	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose contamination in glovebox	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.3.i.op	2.3 SPS Material Preparation Area - First Section		2.3.7 Excess vacuum in glovebox	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose contamination in glovebox	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.3.j.op	2.3 SPS Material Preparation Area - First Section		2.3.8 Contamination spread to other (cleaner) gloveboxes	Ventilation upset Open isolation doors Internal pressurization due to pneumatic air leaks	Loose contamination in glovebox	Increased personnel exposure (ionizing radiation)	Isolation doors Ventilation balance	Operator training and procedures Surveys	S1	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4	Material Preparation Area Second section Major equipment: Glovebox Entry and exit isolation doors Container opener Powder dispensing station Size reduction station Convenience can transfer port Scale	Transfer through isolation door Open overpack(s) Open convenience can Pour canister contents into screened hopper Transfer material with screw conveyer to furnace tray Control tray filling by weight Size reduction of large oxide pieces Transfer tray to transfer area through isolation door Transfer outer cans and site convenience cans back to the first section for bag out and disposal Overpack Pu metal/other containing packages									
2.4.a.op	2.4 Material Preparation Area Second section		2.4.1 Radioactive material spill inside the glovebox	Contents of canister spilled during opening or handling operation External impact on glovebox Also Release from powder dispensing station during filling of furnace trays Spill from furnace tray Release from size reduction equipment	Material being transferred to furnace trays Material on furnace tray if tray dumped by handling equipment	Release of Pu inside glovebox	Glovebox confinement system (box, ventilation, inlet and outlet ventilation filters) Canister handling system controls and instrumentation Glovebox secured to floor	Operator training and procedures	S2	F3	how do you open 3013 cans needing rework? Intrinsically dusty process poses potential for glovebox air contamination levels higher than in other sections of SPS

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.b.op	2.4 Material Preparation Area Second Section		2.4.2 Criticality inside glovebox	Too many cans simultaneously too close together Flooding with water in combination with multiple cans Flooding with other moderators (e.g., hydraulic oil) Overload furnace trays (e.g., control failures in powder dispensing station) Dump pu powder elsewhere besides weighed furnace tray; critical mass accumulation in glovebox Too much material in screw feeder (e.g., plugging, failure in control logic) Stack furnace trays containing pu oxide too close together Water intrusion with overloaded tray(s) Cans containing metal or other pu material, sent through system for repacking, exceeds combined oxide metal limits	NA	Large worker exposure to ionizing radiation	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls
2.4.c.op	2.4 Material Preparation Area Second Section		2.4.3 Fire inside glovebox	Plastic bags, cleanup rags, other fuel sources ignited by electrical equipment Pyrophoric metal shavings/turnings ignited Overheated furnace	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Pu released to room and through building vent system Soot and water vapor released challenging building vent system Building damage	Dry fire protection system for glovebox glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Pyrophoric material controls Visual checks to detect insertion of metal shavings/turnings	S1 S2	F3 F2	Loose Pu material available for release in section 2 greater than in section 1

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.d.op	2.4 Material Preparation Area Second Section		2.4.4 Canister explosion inside the glovebox	Can containing hydrogen is ignited upon opening or by handling activity	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Pu release inside glovebox Potential glovebox damage Potential glovebox loss of confinement/spread of contamination to room	Stout glovebox design Glovebox ventilation system Room ventilation system Dump valves	Feed source controls limits potential for receiving cans containing combustibles or reactive chemicals	S2	F2	
2.4.e.op	2.4 Material Preparation Area Second Section		2.4.5.a Pressurized glovebox	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, screw conveyer, open cans, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Loose Pu material available for release greater in section 2 than 1

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.f.op	2.4 Material Preparation Area Second Section		2.4.5.b Pressurized glovebox	Chemical reaction	Loose contamination in box	Pu release into room (plus toxic fumes/gases depending on reaction)	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox Controls on feed source minimize likelihood of reactive compounds being processed. Limit on combustibles in gloveboxes. No solvents or reactive chemicals stored in gloveboxes Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.4.g.op	2.4 Material Preparation Area Second Section		2.4.5.c pressurized glovebox	Imbalance between dry air supply and exhaust	Loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Operator training and procedures	S2	F3	
2.4.h.op	2.4 Material Preparation Area Second Section		2.4.6 stagnant glovebox	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.i.op	2.4 Material Preparation Area Second Section		2.4.7 excess vacuum in the glovebox	Imbalance between exhaust and dry air supply loss of dry air supply	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.4.j.op	2.4 Material Preparation Area Second Section		2.4.8 contamination spread to other (cleaner) gloveboxes	Ventilation upset Open isolation doors Internal pressurization due to pneumatic air leaks	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Increased personnel exposure (ionizing radiation)	Isolation doors Ventilation balance	Operator training and procedures Surveys	S1	F3	
2.4.k.op	2.4 Material Preparation Area Second Section		2.4.9 Inadvertently open and process material contained in canister intended to be overpacked and passed through the system	Human error	Potentially metallic Pu in canister Other	Contamination from burning Pu Fire in glovebox (particularly if metal put in furnace)	Screened funnel prevents metal from being added to furnace tray (metal in larger pieces than powder)	Operator training and procedures controls on handling metal	S1	F2	
2.5	2.5 Transport Area Major equipment: Glovebox Canister handlers Tray handlers Isolation doors Television monitoring system	Transports unopened convenience cans of metal through to tipping/filling/dispense area Transport trays of powder to the furnaces Transport trays to loi sampling area Transport cans back to material preparation glovebox Transport empty trays from tipping/filling/dispense area to the powder dispense area									

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.5.a.op	2.5 Transport Area		2.5.1 Radioactive material spill inside the glovebox	Above contents of canister spilled during opening or handling operation External impact on glovebox Spill from furnace trays (multiple)	Material being transferred on trays and in cans	Release of Pu inside glovebox	Glovebox confinement system (box, ventilation, inlet and outlet ventilation filters) Canister handling system controls and instrumentation Glovebox secured to floor	Operator training and procedures	S2	F3	
2.5.b.op	2.5 Transport Area		2.5.2 Criticality inside glovebox	Furnace trays containing pu oxide too close together Water intrusion with overloaded tray(s) Cans containing metal or other pu material, sent through system for repacking, exceeds combined oxide metal limits Spilling powder from multiple furnace trays exceeds safe mass limits	NA	Large worker exposure to ionizing radiation	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls
2.5.c.op	2.5 Transport Area		2.5.3 Fire inside glovebox	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Training and procedures	S1 S2	F3 F2	S1/F3 based on small fire S2/F2 based on fire that involves multiple SPS gloveboxes

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.5.d.op	2.5 Transport Area		2.5.4.a Pressurized glovebox	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Loose Pu material available for release greater in section 2 than 1
2.5.e.op	2.5 Transport Area		2.5.4.b Pressurized glovebox	Imbalance between dry air supply and exhaust	Loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Training and procedures	S2	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.5.f.op	2.5 Transport Area		2.5.5 Stagnant glovebox	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.5.g.op	2.5 Transport Area		2.5.6 Excess vacuum in the glovebox	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.6	Furnace Area Major equipment: Glovebox Tray handlers Furnaces with entry doors Gas cooling supply to furnace	Move trays of pu oxide powder into stabilization furnaces Heat trays of pu oxide powder at required temperature and for required time to remove moisture Heat trays of pu to ensure that pu contained in trays has been fully oxidized Move trays of pu oxide powder that has been stabilized to the transfer area									
2.6.a.op	2.6 Furnace Area		2.6.1 Radioactive material spill inside the glovebox	Above contents of canister spilled during opening or handling operation External impact on glovebox Spill from furnace trays (multiple)	Material being transferred on trays	Release of Pu inside glovebox	Glovebox confinement system Tray handler Glovebox secured to floor	Operator training and procedures	S2	F3	confirm that water cooling is not used. get details of how gas cooling works!!!

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.b.op	2.6 Furnace Area		2.6.2 Radioactive material spill inside furnace	Spill from furnace trays (multiple)	Material being transferred on trays	Operation of furnace with oxide powder on heating coils may result in coil failure Difficulty in cleaning up spill resulting in increased personnel exposure	Design of the tray handler Furnace tray rack design glovebox ventilation system and HEPA filters Furnace exhaust ventilation and sintered metal filter	Personnel training and procedures	S2	F3	S2 rating based on unfiltered release through either glovebox ventilation system or furnace exhaust
2.6.c.op	2.6 Furnace Area		2.6.3 Criticality inside glovebox	Furnace trays containing Pu oxide too close together Water intrusion with overloaded tray(s) Spilling powder from multiple furnace trays exceeds safe mass limits	NA	Large worker exposure to ionizing radiation release of fission Product gasses Release of Pu oxide powder disturbed by criticality to the glovebox atmosphere	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls chemical reactions possible in furnace with compounds contaminating the Pu oxide?? what about wrong material such as Pu nitrate, fluorides, organic solvents???
2.6.d.op	2.6 Furnace Area		2.6.4 Fire inside glovebox	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short Overheat of furnaces coupled with combustible materials being present	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system Robust glovebox design Glovebox ventilation system Room ventilation system Room fire suppression system	Fire loading limits Training and procedures	S1 S2	F3 F2	S1/F3 based on small fire S2/F2 based on fire that involves multiple SPS gloveboxes

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.e.op	2.6 Furnace Area		2.6.5.a Pressurized glovebox	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.6.f.op	2.6 Furnace Area		2.6.5.b Pressurized glovebox	Chemical reaction	Loose contamination in box	Pu release into room (plus toxic fumes/gases depending on reaction)	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization	Worker training and procedures emergency response procedures Housekeeping controls limit Pu accumulation in glovebox Controls on feed source minimize likelihood of reactive compounds being processed. Limit on combustibles in gloveboxes. No solvents or reactive chemicals stored in gloveboxes Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

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2.6.g.op	2.6 Furnace Area		2.6.5.c pressurized glovebox	Imbalance between dry air supply and exhaust	loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Training and procedures	S2	F3	
2.6.h.op	2.6 Furnace Area		2.6.5.d Pressurized glovebox	Furnace dry air high flow (failure of control valve)	Loose Pu oxide powder in furnace	Spread of contamination into glovebox(s)	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	chance for gross contamination of glovebox and furnace. creates cleanup problem. Possible challenge to ventilation filters through plugging??? blow up the furnace???

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.i.op	2.6 Furnace Area		2.6.6 Stagnant glovebox	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.6.j.op	2.6 Furnace Area		2.6.7 Excess vacuum in the glovebox	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.6.k.op	2.6 Furnace Area		2.6.8.a Loss of glovebox integrity	Overheated stabilization furnace(s) from loss of cooling, temperature control failure	Loose Pu oxide powder in glovebox (material in trays, etc.)	Release of contamination into room	Furnace temperature controls and indicators Furnace insulation Glovebox heat detection Room CAMs Room ventilation system Glovebox ventilation system Dump valves	Operator training and procedures	S2	F2	S2 rating based on unfiltered release is there a possibility of fire system actuation from furnace overheating box? compounds the confinement issue due to postulated loss of glovebox integrity.

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.l.op	2.6 Furnace Area		2.6.8.b Loss of glovebox integrity	Furnace door left open during heating cycle	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of contamination into room	Furnace door interlocks Glovebox heat detection Room CAMs Room ventilation system Glovebox ventilation system Dump valves	Operator training and procedures	S2	F3	S2 rating based on unfiltered release
2.6.m.op	2.6 Furnace Area		2.6.9.a Inadequate stabilization of Pu oxide (related only to this portion of the system)	Furnace temperature too low (control failure or human error) Furnace dwell time too short (control failure or human error) Failed furnace heating coil	Trays of Pu oxide in furnace	Unstabilized pu oxide sent on for packaging (eventually resulting in can swelling during long term storage) Possible process upset if discovered	LOI furnace Furnace temperature controls and indication CAMs monitor vault atmosphere for canister failures (subsequent consequence control)	LOI test Operator training and operating procedures	S0	F3	this is a process upset condition resulting in reduced throughput as long as the LOI test identifies that a problem exists if problem goes undetected, could result in release to vault (S1 consequence)
2.6.n.op	2.6 Furnace Area		2.6.9.b Inadequate stabilization of Pu oxide (related only to this portion of the system)	Failure of furnace dry air supply (assuming plant instrument air supply) (valve failed closed or inadvertently left closed)	Trays of Pu oxide in furnace	??Pu not fully stabilized (lack of full oxidation) ??Furnace integrity threatened (leak tight furnace designed for air supply)	LOI furnace	LOI test Operator training and operating procedures	S0	F3	
2.7	LOI test area Major equipment: LOI glovebox LOI sampling station Sample desiccator LOI furnace	Furnace trays delivered from transport area after stabilization Samples taken manually from each furnace tray Samples LOI tested Samples returned to next batch Empty trays visually inspected and sent back to powder dispensing station Desiccator allows cooling of sample in dry environment outside furnace (200 C to ambient)									

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2.7.a.op	2.7 LOI test area		2.7.1 Radioactive material spill inside the glovebox	Spill from furnace trays (multiple) during handling Spill of material during sampling External impact on glovebox causes spill	Material being transferred on trays Material transferred to crucible	Release of Pu inside glovebox	Glovebox confinement system (glovebox filter, exhaust system fans and filters) Tray handler Glovebox secured to floor	Operator training and procedures	S2	F3	S2 ranking based on unfiltered release to environment
2.7.b.op	2.7 LOI test area		2.7.2 Radioactive material spill inside LOI furnace	Spill from crucible during load in	Material being transferred in crucible (30 g)	Operation of furnace with oxide powder on heating coils may result in coil failure Difficulty in cleaning up spill resulting in increased personnel exposure	Glovebox ventilation system and HEPA filters	Personnel training and procedures	S1	F3	
2.7.c.op	2.7 LOI test area		2.7.3 Criticality inside glovebox	Furnace trays containing Pu oxide too close together due to tray handling system error Water intrusion with overloaded tray(s) in sample area Spilling powder from multiple furnace trays exceeds safe mass limits	NA	Large worker exposure to ionizing radiation Release of fission product gasses Release of Pu oxide powder disturbed by criticality to the glovebox atmosphere	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls on throughput, spacing, and mass accumulation	S1	F2	frequency ranking without controls chemical reactions possible in LOI furnace with compounds contaminating the Pu oxide?? what about wrong material such as Pu nitrate, fluorides, organic solvents???

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.7.d.op	2.7 LOI test area		2.7.4 Fire inside glovebox	Combustible materials left from cleanup, insulation on wiring ignited by spontaneous combustion or electrical short Overheat of furnace coupled with combustible materials present	Loose Pu oxide powder in glovebox (material in trays and crucibles)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system Robust glovebox design Glovebox ventilation system Room ventilation system Room fire suppression system	Fire loading limits Training and procedures	S1 S2	F3 F2	S1/F3 based on small fire S2/F2 based on fire that involves multiple SPS gloveboxes
2.7.e.op	2.7 LOI test area		2.7.5.a Pressurized glovebox	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, crucibles, etc)	Spread of contamination from the glovebox to the room Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2,7.f.op	2.7 LOI test area		2.7.5.b Pressurized glovebox	Furnace dry air high flow (failure of control valve) Desiccator dry air high flow (failure of control valve	Loose Pu oxide powder in furnace Loose Pu oxide powder in desiccator	Minor spread of contamination into glovebox(s)	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S1	F3	LOI furnace filter may become plugged? blow up the furnace???
2.7.g.op	2.7 LOI test area		2.7.6 Stagnant glovebox	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.7.h.op	2.7 LOI test area		2.7.7 Excess vacuum in the glovebox	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.7.i.op	2.7 LOI test area		2.7.8 Loss of glovebox integrity	Overheated LOI furnace, temperature control failure Furnace damaged or knocked over	Loose Pu oxide powder in glovebox (material in trays, crucibles)	Release of contamination into room	Furnace temperature controls and indicators Furnace insulation Glovebox heat detection Room CAMs Room ventilation system Glovebox ventilation system Dump valves Furnace secured to bottom of glovebox	Operator training and procedures	S2	F2	S2 rating based on unfiltered release is there a possibility of fire system actuation from furnace overheating box? compounds the confinement issue due to postulated loss of glovebox integrity.
2.7.j.op	2.7 LOI test area		2.7.9 Inadequate stabilization of Pu oxide	LOI test fails to detect inadequate stabilization see 2.5.9 for furnace faults leading to inadequate stabilization	Quantity of Pu represented by LOI sample	Unstabilized Pu oxide sent on for packaging (eventually resulting in can swelling during long term storage) Process upset if discovered	Stabilization furnace temperature controls and indication, timers, etc. LOI furnace instrumentation (thermocouple readings, amp gauges) allows operator to discover furnace faults CAMs monitor vault atmosphere for canister failures (subsequent consequence control)	Operator training and operating procedures	S1	F2	S1 rating based on potential worker exposure in vault (during inspection, load in, etc) and unfiltered release through vault vent system

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.8	Tipping/Dispense/Fill area Major equipment: Oxide Tipping Glovebox Seismic Displacement Absorber Furnace Tray Elevator/Transpose Unit Furnace Tray Tipper Convenience Can Transfer Unit Material Transport Port Dispense/Fill Glovebox Convenience Can Post In Sphincter Seal Convenience Can Handler Convenience Can magazine Can loading station Cap removal/replacement station Can fill station Cap monitoring station Can orientation device Convenience can post out unit	Load in empty convenience cans with their caps Transfer oxides in furnace trays to tray tipper Fill convenience can Weigh can Transfer to capping station and Cap can Transfer to cap monitoring station and measure can height Transfer to can orientation station Transfer into gaslock for entry into can weigh and cap insertion area									

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.8.a.op	2.8 Tipping/Dispense/Fill area		2.8.1 Radioactive material spill inside the glovebox	Spill from furnace trays due to can handler failures, elevator/transpose unit failures, and tipper failures Spill during filling of can Overfill convenience can at fill station if furnace tray contains 5 kgs of low bulk density powder Overfill convenience canister at fill station due to double-batched furnace tray Spill at cap removal/replacement station Spill at cap monitoring station Spill from can when orienting horizontally at orientation station for entry into gaslock (cap not properly in place)	Material being transferred on trays and in cans	Release of Pu into glovebox atmosphere	Glovebox and glovebox confinement system Can handler controls and instrumentation Furnace tray handler controls and instrumentation Television monitoring station allows operator surveillance	Operator training and procedures	S2	F3	S2 ranking based on unfiltered release to the environment through SPS ventilation system
2.8.b.op	2.8 Tipping/Dispense/Fill area		2.8.2 Criticality inside glovebox	Furnace trays or convenience cans containing pu oxide too close together due to handler errors Water intrusion with overloaded tray(s) Cans containing metal or other pu material, sent through system for repacking, exceeds combined oxide metal limits Spilling powder from multiple furnace trays or convenience cans exceeds safe mass limits (caused by handler failures)	NA	Large worker exposure to ionizing radiation	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.8.c.op	2.8 Tipping/Dispense/Fill area		2.8.3 Fire inside glovebox	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Training and procedures	S1 S2	F3 F2	S1/F3 based on small fire S2/F2 based on fire that involves multiple SPS gloveboxes
2.8.d.op	2.8 Tipping/Dispense/Fill area		2.8.4 Pressurized glovebox	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Loose Pu material available for release greater in section 2 than 1

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.8.e.op	2.8 Tipping/Dispense/Fill area		2.8.5 Stagnant glovebox	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.8.f.op	2.8 Tipping/Dispense/Fill area		2.8.6 Excess vacuum in the glovebox	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.8.g.op	2.8 Tipping/Dispense/Fill area		2.8.7 Too much Pu (mass) tipped from furnace tray into convenience can	Failure at weighing station in material prep area Double batch on furnace tray	Pu material in convenience can	3013 canister violating mass limit 3013 canister violating storage wattage limit Pressurization of 3013 package in storage vault; potential rupture of 3013 package in vault	Powder dispensing station scale (initiating failure) Can fill station scale Convenience can weigh station (in can weigh and cap insertion area) CAM monitoring in vault (for can ruptures) Vault ventilation system may prevent over pressurization 3013 package designed to withstand high pressures	Operator training	S2	F3	

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2.8.h.op	2.8 Tipping/Dispense/Fill area		2.8.8 Furnace tray sent back to material prep area with Pu material still in it	Failures in weighing at tray fill station or the convenience can fill station	Pu material added to convenience can on next cycle	Too much material in furnace tray on next cycle; exceed mass limit in convenience can on next cycle. Or process upset, if detected	Powder dispensing station scale (initiating failure) Can fill station scale Convenience can weigh station (in can weigh and cap insertion area) CAM monitoring in vault (for can ruptures) Vault ventilation system may prevent over pressurization 3013 package designed to withstand high pressures	Operator training	S2	F3	
2.8.i.op	2.8 Tipping/Dispense/Fill area		2.8.9 Contamination spread to can weigh and cap insertion area	Gas lock failure Loss of helium supply to gas lock	Contamination in glovebox air	Contaminated 3013 packages Increased worker exposures in cleaning up	Gas lock control system and interlocks Helium supply instrumentation	Operator training and operating procedures	S1	F3	S1 rating based on increased worker exposure from cleanup activities
2.8.j.op	2.8 Tipping/Dispense/Fill area		2.8.10 Loss of glovebox confinement	Sphincter seal failure Error during load in of convenience can	Contamination in glovebox atmosphere	Release of small quantities of contamination to room atmosphere	Glovebox ventilation system Room ventilation system Room CAMs Sphincter seal design	Operator training and operating procedures	S1	F3	S1 rating based on small quantity of material released

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2.9	Can Weigh and Cap Insertion Area Major equipment: Can weigh and cap insertion glovebox Gas lock Convenience can turntable Weigh scale and barcode reader Convenience can pusher Inner can post in sphincter seal Inner can cap magazine Inner can storage magazine Material transfer port Inner can rotating sphincter seal Stub collection chute	Post in caps through glovebox sphincter seal Remove convenience can from gas lock (transferred in from previous glovebox) Weigh and id convenience can Align convenience can to rotating sphincter seal Push convenience can into inner can inside rotating sphincter seal Push cap into inner can Pass convenience can/inner can assembly into inner can handling area Bag out stubs cut off with laser welder									
2.9.a.op	2.9 Can Weigh and Cap Insertion Area		2.9.1 Radioactive material spill inside the glovebox	Cap not installed correctly on convenience can	Material that falls out of can as it is oriented horizontally	Contamination spread in glovebox	Can height measurement equipment Glovebox ventilation system Glovebox confinement function	Operating procedures and operator training	S1	F3	S1 based on added exposure for cleanup F3 based on no controls
2.9.b.op	2.9 Can Weigh and Cap Insertion Area		2.9.2 Loss of confinement	Rotating sphincter seal failure Inner can post in sphincter failure Improper can insertion into sphincter seal Can not inserted into sphincter seal to maintain confinement Filter missing from inner can cap	Airborne contamination present in glovebox	Release of contamination to room	Glovebox ventilation Room CAMs Room ventilation system	Operator training and operating procedures	S1	F3	S1 based on low contamination level expected in glovebox

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2.9.c.op	2.9 Can Weigh and Cap Insertion Area		2.9.3 Wrong atmosphere in glovebox	Helium supply shut off Wrong gas supplied	NA	Possible failure to detect bad welds due to no helium present Depending on the wrong gas, results could be quite variable	Oxygen monitoring on outlet of glovebox	Procedures governing bottle replacement	S0	F3	S0 based on bad inner weld not detected and later causing problems wrong gasses could result in significant consequences. explosive gasses could create significant damage to glovebox due to laser ignition source or other ignition sources
2.9.d.op	2.9 Can Weigh and Cap Insertion Area		2.9.4 Pressurized Glovebox	Loss of ventilation exhaust Excessive helium flow rate	Airborne contamination present in glovebox	Release of contamination to room	Robust glovebox construction and low leak rate Room CAMs Room ventilation system Glovebox ventilation system controls and alarms	Operator training and operating procedures	S1	F3	S1 based on low contamination level expected in glovebox
2.9.e.op	2.9 Can Weigh and Cap Insertion Area		2.9.5 Stagnant glovebox	Concurrent failure of ventilation exhaust and helium supply	Airborne contamination present in glovebox	Release of contamination to room	Room CAMs Room ventilation system Glovebox ventilation system controls and alarms	Operator training and operating procedures	S1	F3	S1 based on low contamination level expected in glovebox

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2.10	Inner Can Handling Area Major Equipment: Inner can handling fume hood Inner can rotating sphincter seal Inner can storage magazine Laser welding/cutting tool Laser generator Inner can handling unit	Laser weld inner can cap to inner can Cut stub from inner can Hold and remove sealed cans inside sphincter seal Pass sealed can to inner can handling area Move inner can into outer can, pass assembly to outer can weld/monitor area Load in empty inner cans Load in empty inner can into rotating sphincter seal (pushing cutoff cap stub out of rotating sphincter seal)									
2.10.a.op	2.10 Inner Can Handling Area		2.10.1 Loss of confinement in fume hood	Loss of exhaust flow due to equipment failures, loss of power, closed dampers, etc.	Fumes normally exhausted through fume hood Radiological contamination in fume hood	Welder fumes and helium leak into room Minor contamination spread to room if contaminated canisters have been handled	Room ventilation system Room CAMs	Operator training and procedures	S1	F3	no protection for facility worker for toxic fumes emitted
2.10.b.op	2.10 Inner Can Handling Area		2.10.2 Leak of air into can weigh and cap insertion station (see above)	Rotating sphincter seal failure Can not in rotating sphincter	Fumes normally exhausted through fume hood Radiological contamination in fume hood	Welder fumes and helium leak into room Minor contamination spread to room if contaminated canisters have been handled	Room ventilation system Room CAMs	Operator training and procedures	S1	F3	no protection for facility worker for toxic fumes emitted

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2.10.c.op	2.10 Inner Can Handling Area		2.10.3 Drop or damage can assembly during transport to outer can weld and monitoring area	Failure of can handling equipment	NA	Programmatic impact May have to send inner can/convenience can assembly back through process	--	--	--	--	
2.10.d.op	2.10 Inner Can Handling Area		2.10.4 Laser beam impinges on SPS wall or equipment instead of canister	Fiberoptic cable not installed. Laser not aimed properly Can not in place when laser on	Loose Pu oxide in glovebox	Laser may burn hole in SPS boundary Equipment damage Fire Operator injury (burns, blindness)	Interlocks with panels over windows, flap over inner can storage magazine and the software for initiating inner can leak testing prevent personnel from viewing the laser light and its reflections SPS vent system maintains confinement despite hole burned in SPS boundary	Operator training and procedures	S1	F3	Fire not expected due to low combustible loading in SPS S1 ranking assigned due to the potential for operator injury, intrusion of moist air into the system, and release of small quantities of Pu to room
2.11	Outer Can Weld and Monitoring Area Major Equipment: Can turntable/trolley and outer can handler Laser generator Mass spectrometer Vacuum pump Inner can leak detection unit Outer can helium fill/lid fitment unit Outer can welder Bar code reader Outer can leak detection unit Lag storage trolley	Leak check inner can Evacuate outer can Inert outer can with helium Install outer can lid Weld outer can lid Check outer can for surface contamination Leak check outer can Place outer can in lag storage trolley									

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2.11.a.op	2.11 Outer Can Weld and Monitoring Area		2.11.1 Failure to detect leaky inner canister	Failure of detection equipment Loss of vacuum pump Leaky seal on inner canister during leak test; sweep air dilutes helium readings	NA	Leaky inner canister stored in vault Possible moisture intrusion into 3013 package during storage; violation of 3013 storage requirements	Instrumentation on vacuum pump (e.g., flow, temp., pressure)	Operator training and procedures	S0 S1	F3 F1	S1/F1 ranking for pressurized/ruptures 3013 package in storage vault (two independent leak tests would have to fail)
2.11.b.op	2.11 Outer Can Weld and Monitoring Area		2.11.2 Spread of Pu to leak testing equipment and to vacuum pump	Failed weld on inner can	Pu oxide from convenience can that has migrated or been released into the inner can plenum	Contaminated mass spec head Contaminated vacuum pump Spread of contamination to room Operator exposure on cleanup Contaminated outer can	Inner can helium leak test	Operator training and procedures	S1	F3	intrinsic nature of leak test spreads contamination it's trying to prevent the spread of
2.11.c.op	2.11 Outer Can Weld and Monitoring Area		2.11.3 Failure to evacuate outer can before adding helium	Vacuum pump failure not detected Failure to seal before evacuating outer can	NA	Air/helium mixture in outer can when capped making subsequent leak test less reliable	Vacuum pump instrumentation	Operator training and procedures	S0 S1	F3 F1	violation of storage requirements for canister leakage of contamination to vault during storage
2.11.d.op	2.11 Outer Can Weld and Monitoring Area		2.11.4 Failure to backfill with helium	Loss of helium supply Control failure	NA	No helium in outer can to detect potential leaks with	Instrumentation on vacuum pump (e.g., flow, temp., pressure)	Operator training and procedures	S0 S1	F3 F1	
2.11.e.op	2.11 Outer Can Weld and Monitoring Area		2.11.5 Failure to seal outer can	Various laser welder failures	NA	Leaky outer canister	Helium leak testing equipment (mass spec)	Outer can helium leak test	S0 S1	F3 F1	no spread of contamination to vault unless convenience can, inner can also leak
2.11.f.op	2.11 Outer Can Weld and Monitoring Area		2.11.6 Failure to detect contamination on outside of 3013 package	No swab performed due to control or operator failure Failure of counting equipment	Contamination on outside of can	Operator contamination when canister handled Spread of contamination to room atmosphere	Frisk portals Room ventilation system Room CAMs	Operator training and procedures Personnel exit surveys	S1	F3	

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2.11.g.op	2.11 Outer Can Weld and Monitoring Area		2.11.7 Failure to properly decontaminate contaminated outer can	Operator error	Contamination on outside of can	Operator contamination when canister handled Spread of contamination to room atmosphere	Frisk portals Room ventilation system Room CAMs	Operator training and procedures Personnel exit surveys	S1	F3	
2.11.h.op	2.11 Outer Can Weld and Monitoring Area		2.11.8 Contamination spread during bagout of inner canisters that fail leak test	Improper bagging Dropped canister after bagout	Pu in bag	Contamination spread to room	frisk portals Room ventilation system Room CAMs	Operator training and procedures	S1	F2	
2.11.i.op	2.11 Outer Can Weld and Monitoring Area		2.11.9 Criticality	Double contingency violation Too many canisters in lag storage placed too close together due to human error or automatic loader error Fire suppression system activation (during fire, or due to spurious failure) with sufficient number of 3013 packages stored in room	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages)	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
2.11.j.op	2.11 Outer can weld and monitoring area		2.11.10 Misdirected laser beam impinges on SPS or equipment instead of outer can	Fiberoptic cable not installed Laser not aimed properly Can misaligned	Loose Pu in glovebox	Laser may burn hole in SPS boundary Burns to operators Equipment failure Glovebox fire	Interlocks to prevent operators from viewing laser light or reflections	Operates training and procedures	S1	F3	Glovebox fire not expected S1 ranking based on the potential for operator injury
3.0.op	3.0 Storage Vault Operations (3013 cans)										
3.1.a.op	3.1 SPS Machine to NDA lab	Transfer from SPS to NDA lab	3.1.1 Movement of radioactive materials near workers	Normal operation requires movement of material from processing area to NDA lab	NA	Direct radiation exposures to facility workers	Shielded lag storage trolley Interlocks prevent trolley from being moved from Outer Can Weld and Monitoring area until shielding door on cart is closed	ALARA controls for workers to maintain safe distance if shielded cart not used Radiation protection program	S1	F3	

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3.1.b.op	3.1 SPS Machine to NDA lab	Transfer from SPS to NDA lab	3.1.2 Canisters dropped from cart or cart dumped over during transfer	Human error Seismic event	Material in canister (canister and overpacks not assumed to fail)	Damaged 3013 packages	3013 package design	operation procedures	S0	F3	
3.1.c.op	3.1 SPS Machine to NDA lab	Transfer from SPS to NDA lab	3.1.3 Criticality during transfer	Double contingency violation Too many cans on cart	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages) Cart designed to maintain critically safe configuration if tipped over	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
3.2.a.op	3.2 NDA Lab	NDA of 3013 packages	3.2.1 Direct radiation from canisters in lag storage	Normal operation is to have radioactive material in the lab	NA	Direct radiation exposures to facility workers	--	ALARA program radiation protection			
3.2.b.op	3.2 NDA Lab	NDA of 3013 packages	3.2.2 Criticality	Too many canisters stored in NDA area in unsafe configuration Fire water break or activation in NDA area with sufficient canisters present	NA	Worker exposure to large amounts ionizing radiation	Criticality alarms Critically safe storage racks?	Criticality control program	S1	F3	check on storage configuration or administrative criticality controls for this area
3.3.a.op	3.3 NDA Lab to Storage Vault	Transfer to storage vault from NDA lab	3.3.1 Movement of radioactive materials near workers	Normal operation requires movement of material from processing area to NDA lab	NA	Direct radiation exposures to facility workers	Shielded lag storage trolley Interlocks prevent trolley from being moved from Outer Can Weld and Monitoring area until shielding door on cart is closed	ALARA controls for workers to maintain safe distance if shielded cart not used Radiation protection program	S1	F3	
3.3.b.op	3.3 NDA Lab to Storage Vault	Transfer to storage vault from NDA lab	3.3.2 Canisters dropped from cart or cart dumped over during transfer	Human error Seismic event	Material in canister (canister and overpacks not assumed to fail)	Damaged 3013 packages	3013 package design	Operation procedures	S0	F3	

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3.3.c.op	3.3 NDA Lab to Storage Vault	Transfer to storage vault from NDA lab	3.3.3 Criticality during transfer	Double contingency violation Too many cans on cart	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages) Cart designed to maintain critically safe configuration if tipped over	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
3.4.a.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.1 Movement of radioactive materials near workers	Normal operation requires movement of material from processing area to NDA lab	NA	Direct radiation exposures to facility workers	Shielded lag storage trolley Interlocks prevent trolley from being moved from Outer Can Weld and Monitoring area until shielding door on cart is closed	ALARA controls for workers to maintain safe distance if shielded cart not used Radiation protection program	S1	F3	
3.4.b.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.2 Canisters dropped from cart or cart dumped over during transfer	Human error Seismic event	Material in canister (canister and overpacks not assumed to fail)	Damaged 3013 packages	3013 package design	Operation procedures	S0	F3	
3.4.c.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.3 Criticality during transfer	Double contingency violation Too many cans on cart	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages) Cart designed to maintain critically safe configuration if tipped over	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
3.4.d.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.4 Dropped canister	Human error	Pu in can (can not assumed to fail)	Damaged can or storage tube Can stuck in tube Damaged storage rack	Winch for tube storage concept Canister designed to withstand drop	Operator training and procedures	S0	F3	programmatic impact
3.4.e.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.5 Direct radiation from storage canisters	Normal operation	NA	Worker exposure	Shielding in vault	ALARA program	S1	F3	

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3.4.f.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.6 Criticality	Violation of criticality specifications	NA	Worker exposure to ionizing radiation in large quantities	storage vault configuration	criticality prevention procedures	S1	F3	
3.4.g.op	3.4 SPS Machine to Storage Vault	Transfer to Storage Vault from SPS Load in 3013 canister into storage vault	3.4.7 Radioactive contamination in vault	Leaky 3013 package(s)	Portion of material in 3013 package vault	Worker exposure Small release to environment through ventilation system Potential spread of contamination to other areas of facility	3013 package design	Two leak tests provide confidence in integrity of packages Stabilization process limits potential for canister rupture	S2	F3	
3.5.a.op	3.5 Storage Vault	Long term storage	3.5.1 Contamination in Vault from leaking 3013 packages	Canister rupture due to inadequate pu oxide stabilization in sps Canister rupture due to overloading canisters (too much pu in container results in over pressure due to helium production by decay) Inner and outer overpacks on some canisters not sealed properly and not detected	Portion of material in ruptured or leaking packages	Small airborne release through ventilation system Worker exposures during entries into vault Potential spread of contamination to other areas of the facility Additional personnel exposures due to cleanup	Vault air monitored with CAMs Vault ventilation system Robust 3013 package design	Leak tests Stabilization process in SPS Mass of Pu added to convenience cans measured in SPS system	S2	F3	
3.5.b.op	3.5 Storage Vault	Long term storage	3.5.2 Canister/Vault Overheating	Long term loss of ventilation flow due to equipment failures Long term loss of power	Material in 3013 storage packages	Degradation of concrete structure (concrete dehydration) Concrete structure compromised due to thermal stress induced cracking Failure of 3013 packages due to overpressure or overtemperature	Temperature monitoring Backup power? Ventilation system design (redundant fans?) Ventilation system instrumentation	Recovery procedures for loss of ventilation or loss of power (avoidance of long term loss of ventilation)	S2	F3	S2 for canister ruptures catastrophic failure of structure beyond design basis and thus not postulated

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3.5.c.op	3.5 Storage Vault	Long term storage		Several packages stored in vault that exceed wattage limit	Material in 3013 storage packages	Failure of 3013 packages due to overpressure or overtemperature	Ventilation system Design of tube racks or cubicles	SPS system monitors quantity of material added to convenience cans to limit wattage	S2	F2	localized overheating in vault High wattage canisters unlikely to be loaded in a cluster are thermocouples located throughout the vault?
4.0.is	4.0 SPS Interfacing Systems (including facility interfaces to the SPS)										
4.1.a.is	4.1 SPS glovebox dry air supply system	Provides sufficient flow through glovebox for heat removal	4.1.1 Loss of or inadequate supply airflow	Loss of power Compressor failure Inadvertently valved out Failure of pressure control Plugged line	Loose Pu in glovebox	Overheated gloveboxes; potential pressurization Potential degradation of glovebox integrity (failed seals, etc). Release of pu material to room atmosphere	Glovebox heat detection Furnaces are insulated Alarms on supply failure	Maintenance on supply system	S2	F3	S2 category assigned based on potential unfiltered release through building ventilation system
4.1.b.is	4.1 SPS glovebox dry air supply system	Control flow to maintain negative pressure in gloveboxes	4.1.2 Glovebox pressurization due to oversupply	Regulator failure Human error in setting up system	Loose Pu in glovebox	Release of Pu material to room atmosphere	Dump valves Glovebox pressure indication Ventilation system instrumentation and controls Regulator on dry air supply PRV on supply	Operator training and response	S2	F3	confirm existence of interlocks (are they in SPS machine design or are they to be provided by PFP HVAC) PRV location? (box or supply) Are there pressure gauges in system

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4.1.c.is	4.1 SPS glovebox dry air supply system	Supply dry air to facilitate Pu oxide stabilization	4.1.3 Loss of dry air supply	Loss of power Compressor failure Supply inadvertently valved out Failure of pressure regulation system Plugged line Failure of dryer	Pu material in vault canisters	Swelled/potentially ruptured canisters in storage vault	LOI test Moisture detection in plant air supply system	--	S1	F3	
4.2.a.is	4.2 SPS glovebox exhaust system	Maintain negative pressure in the gloveboxes (confinement)	4.2.1 Pressurization of glovebox if exhaust lost and supply not shutoff.	Exhaust fan failure Inadvertently closed damper Plugged filter	Loose contamination in glovebox	Release of Pu material from the gloveboxes to room atmosphere (subsequent release through stack)	Room ventilation system and filters Building structure CAMs in room Glovebox pressure indication Backup exhaust fan Dump valves	Operator training and response Routine maintenance on vent system	S2	F3	S2 based on unfiltered release through stack
4.2.b.is	4.2 SPS glovebox exhaust system	Maintain negative pressure in the gloveboxes (confinement)	4.2.2 Loss of exhaust and supply (stagnant gloveboxes)	Loss of power Control failures	Loose contamination in glovebox	Migration of Pu material from the gloveboxes to room atmosphere (subsequent release through stack)	Room ventilation system and filters Building structure CAMs in room SPS alarms on lack of negative pressure Backup fan	Operator training and response Routine maintenance on vent system	S2	F3	S2 based on unfiltered release through stack

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4.2.c.is	4.2 SPS glovebox exhaust system	Maintain negative pressure in the gloveboxes (confinement)	4.2.3 Recirculation loop caused by kicker fan	Loss of primary loss and failure of isolation damper to close when backup (new) exhaust fan turns on	Loose contamination in glovebox	Migration of Pu material to room atmosphere Release of Pu through penetrations in building (function of room/building ventilation system has been defeated) Gloveboxes are probably under positive pressure because of dry air supply flow	HVAC instrumentation (flow indication, pressure indication, damper positions indication, etc) Glovebox pressure indication Room CAMs	Operator training and procedures	S2	F3	fix potential for recirculation loop
4.2.d.is	4.2 SPS glovebox exhaust system	Limits release of radiological material from SPS operations by filtering exhaust before exit out the stack	4.2.4 Unfiltered release through stack	Failed filter Failed filter seals	Loose contamination in glovebox	Unmitigated release of Pu material through stack	Stack CAM detects unfiltered release DP instrumentation across filter	Operator training and response Routine maintenance on vent system	S2	F3	S2 based on unfiltered release through stack
4.2.e.is	4.2 SPS glovebox exhaust system	Heat removal	4.2.5 Insufficient airflow	Exhaust fan failure Closed damper Plugged filter Imbalance between supply and exhaust	Loose contamination in glovebox	Potential damage to glovebox integrity (seal failures)	Temperature in gloveboxes are monitored Flow indicators on exhaust Backup fan	Operator training and procedures	S1	F3	
4.3.a.is	4.3 Glovebox fire protection system (dry fire suppression system)	Extinguish non-metal fires inside the glovebox	4.3.1 Fire suppression system fails to activate during a glovebox fire	Detectors fail to detect fire Bottle or line failure	Loose contamination in glovebox Combustibles in gloveboxes (source of toxic gases)	Potential damage to glovebox integrity Potential spread of fire to other gloveboxes	heat Sensors in the glovebox Gloveboxes design minimizes potential for significant fires Soot from small fires mitigated by glovebox and room ventilation system filters	Visual detection by operators Operators can extinguish fire with MgO_2 Fire protection program for testing and maintenance of fire suppression system Combustible loading administratively controlled	S2	F2	S2 ranking based on assumption fire could involve the entire line of gloveboxes. Pu release through building ventilation system assumed to be unfiltered. F3 for small fires Large fire will plug ventilation system filters with water and soot

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4.3.b.is	4.3 Glovebox fire protection system (dry fire suppression system)	Extinguish non-metal fires inside the glovebox	4.3.2 Fire suppression system activates and over pressurizes gloveboxes during fire	Vent system flow capacity insufficient to maintain confinement on activation of fire suppression system	Loose contamination in glovebox Combustibles in gloveboxes (source of toxic gases)	Spread of contamination from glovebox	Heat sensors in the glovebox Gloveboxes design minimizes potential for significant fires Soot from small fires mitigated by glovebox and room ventilation system filters	Visual detection by operators Operators can extinguish fire with MgO_2 Fire protection program for testing and maintenance of fire suppression system Combustible loading administratively controlled	S2	F3	
4.3.c.is	4.3 Glovebox fire protection system (dry fire suppression system)	Extinguish non-metal fires inside the glovebox	4.3.3 Spurious fire suppression activation (no fire)	Vent system flow capacity insufficient to maintain confinement on activation of fire suppression system	Loose contamination in glovebox	Pressurization of glovebox	CAMs in room detect release from gloveboxes room ventilation system filters the release before discharge to the environment alarm on system actuation	visual detection by operators	S2	F3	S1 based on release through small penetrations in glovebox

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4.4.a.is	4.4 Electrical System	Supplies power to utilities, SPS operating equipment, and control instrumentation	4.4.1 Global or local loss of power Faults that cause erroneous equipment operations	Site supply failures outside facility (natural phenomena, etc.) In-facility failures, (e.g., shorts, overloads, switchgear failures, etc.) Facility fires not associated with SPS operations	Loose contamination in glovebox	Loss of ventilation flow in SPS or vault (see dry air supply and exhaust, vault ventilation system) Loss of instrumentation Potential spread of contamination from gloveboxes to room; operator exposures Canister handling failures resulting in Pu spills inside gloveboxes adding to loose contamination available for release Operating problems leading to increased worker exposure upon recovery Failure to adequately stabilize some oxide material; subsequent swelling/rupture of canisters in vault	Gloveboxes designed to minimize leakage Ductwork to filters is seismically qualified Room CAMs connected to backup power Glovebox pressure indication warns operator of potential loss of confinement UPS Backup power	Operator detection and response	S1	F3	S1 ranking based on assumed complete loss of power. Pu assumed to be released from stagnant building through cracks, penetrations, and seals. Is vent system connected to backup power? What is UPS connected to? What is backup diesel generator connected to?
4.4.b.is	4.4 Electrical System	Supplies power to utilities, SPS operating equipment, and control instrumentation				Combinations of faults that are undesired (loss of power to select systems/components)	--	--	--	--	Beyond scope of this evaluation. Various combinations of faults with the electrical system should be addressed during the definitive design phase.
4.5.a.is	4.5 Criticality drains	Prevent criticality by assuring significant quantities of moderators are drained from gloveboxes	4.5.1 Drains fail to drain when water present	Plugged drain Flowrate of water into box exceeds drain capacity	NA (ionizing radiation exposure)	Significant exposure to operators	Criticality alarms inside gloveboxes No significant supplies of water inside gloveboxes Glovebox design prevents intrusion of water from external sources	Emergency response by operators	S1	F2	

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4.5.b.is	4.5 Criticality drains	Prevent criticality by assuring significant quantities of moderators are drained from gloveboxes	4.5.2 Criticality in drain storage location	Powder goes down drain with water; collects in critical configuration inside tank, pipe, etc.	Pu powder that might go down the drain	Possible significant exposure to personnel in the facility	Criticality alarms No significant supplies of water in gloveboxes Glovebox design prevents entry of water from external water sources Screens on drains	Operator emergency response	S1	F2	
4.6.a.is	4.6 Furnace Cooling Gas Supply System	Maintain furnace shell temperature below 50 C	4.6.1 Loss of cooling	Loss of supply Loss of power	Loose contamination in glovebox	Exceed glovebox operating temperature limit Glovebox integrity compromised Potential loss of confinement due to seal failures and heat load which pressurizes box Personnel hazard due to high temperature Extremely hot shell could cause a fire	Temperature measurement within the glovebox Controls on cooling loop Glovebox design Glovebox ventilation system removes part of the excess heat Dump valves	Operator procedures and training	S1 S2	F3 F3	S1 based on overheating causing seal failures S2 if overheating causes glovebox fire
4.7.a.is	4.7 Plant instrument air supply system	Supplies air to pneumatic actuators (which open isolation doors and operate can handlers) Purge can handlers to minimize contamination of internal mechanisms	4.7.1 Loss of air supply	Line break Compressor failure Power loss Valved out	Loose contamination within glovebox	Operational upset, inability to run canisters through the process Contamination spread between gloveboxes	Alarms on low pressure air	Operator procedures and training	S0	F3	Operational concern only for inability to operate equipment Maintenance for repair or clean up will increase personnel exposure

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4.7.b.is	4.7 Plant instrument air supply system	Provide air with low humidity to stabilization furnaces Provide air with low humidity to LOI furnaces Provide air with low humidity to LOI desiccator	4.7.2 High moisture content in air	Failure of dryer	Pu oxide stabilized inside the furnaces over the time period of the malfunction Pu oxide LOI tested during time period of malfunction Pu oxide run through desiccator during the time period of the malfunction	Understabilized Pu oxide sent on to final packaging without detection (potentially) Subsequent pressure buildup in 3013 canisters in storage; potential rupture of canister and release of contamination from the vault ventilation system	Moisture detection in instrument/plant air supply 3013 cans designed to withstand high pressures CAMs monitor vault atmosphere	Operator training and procedures	S2	F2	common cause failure may make it difficult to detect unstabilized Pu oxide
4.7.c.is	4.7 Plant instrument air supply system	Provide required air flow to furnace to sweep moisture released from Pu oxide out of furnace plenum and to provide assured supply of oxygen for oxidation of partially oxidized Pu	4.7.3 Undersupply of instrument air	Upstream line break Compressor failure Valved out Power loss	Pu oxide in trays in furnace	Operational upsets Pu oxide insufficiently stabilized Swelling of canisters in vault	LOI furnace	LOI test	S0 S1	F3 F3	S0 based on immediate effect S1 base on release to vault at future date due to ruptured canisters assume furnace is nearly leak tight so that suction from exhaust not adequate to pull sufficient air into furnace from glovebox
4.7.d.is	4.7 Plant instrument air supply system	Provide required air flow to furnace to sweep moisture released from Pu oxide out of furnace plenum and to provide assured supply of oxygen for oxidation of partially oxidized Pu	4.7.4 Oversupply of instrument air to stabilization furnace (oversupply to gloveboxes covered in 4.7.6)	Failure of control valve Incorrect setting of control valve (human error)	Pu oxide in trays in furnace	Furnace unable to maintain correct temperature (inadequate stabilization - see 4.7.3) Pressurized furnace (potential for destruction) Pu oxide disturbed and dispersed into glovebox atmosphere	Furnace ventilation exhaust Control valve design Glovebox design Glovebox ventilation system	Operator training and operating procedures	S1	F3	S1 based on increased operator exposure due to cleanup

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4.7.e.is	4.7 Plant instrument air supply system	Supplies air to pneumatic valves and dump valves	4.7.5 Loss of instrument air supply	Line break Compressor failure Valved out Power loss	Loose contamination within glovebox	Operational upsets Contamination spread between gloveboxes Loss of confinement Pressurized glovebox	Alarms on low supply pressure	Operator training and procedures	S2	F3	do dump valves fail as is on loss of air supply or do they fail open?
4.7.f.is	4.7 Plant instrument air supply system	Contain air	4.7.6 Loss of containment	Line breach Regulator failure Actuator cylinder seal failure	Loose contamination in glovebox Powder in cans creating additional contamination	Pressurize gloveboxes Possible movement of contamination between glovebox areas Migration of contamination in glovebox to room atmosphere Gross contamination of glovebox areas requiring cleanup	Glovebox design (robust construction and PRV) Glovebox ventilation exhaust design minimizes pressurization CAMs in room with alarms	Operator training and emergency response	S2	F3	Possible S2 consequence if room ventilation filter is failed S1 consequence if building ventilation system operating properly
4.8.a.is	4.8 Laser Welder chilled water system	Cool laser welder	4.8.1 Loss of coolant	Loss of supply Valved out Line leak upstream Loss of temperature control	NA	Damage to the laser; production upset	Unknown	Visual observation	S0	F3	Cooling is performed in room remote from gloveboxes so criticality due to this water source not a concern. Is there an interlock that prevents laser use if chilled water is lost?

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4.8.b.is	4.8 Laser Welder chilled water system	contain Water	4.8.2 Loss of containment	Line leak into the glovebox	NA (ionizing radiation exposure problem)	Potential spread of moderator to other boxes Spread of contamination within the machine; spread of contamination to the room Spread of contamination to the criticality drain system Double contingency violation; potential criticality	Design minimizes likelihood of water leak into the box Criticality alarms Design of gloveboxes minimizes potential water leakage to room Criticality drains	Operator visual detection	S1	F2	F2 for leak into glovebox S1 ranking based on assumed criticality or spread of Pu to room
4.9.a.is	4.9 Laser gas supplies	--	4.9.1 --	--	--	--	--	--	--	--	entries TBD in definitive design. No significant hazards anticipated.
4.10.a.is	4.10 Helium gas Supply (canister backfill)	Supply helium to inert gaslock and the can weigh and cap insertion glovebox Supply helium cover gas for inner and outer cans for leak detection purposes	4.10.1 Loss of supply	Line break Valved out Line plug Bottle empty	Pu oxide powder in inner can	Failure to detect leaky inner and outer canisters; Potential moisture intrusion into inner can and subsequent pressurization of canisters in storage vault	Helium flow and pressure are monitored Inner can leak detection unit Outer can leak detection unit Canister design minimizes chances for canister rupture	Operator training and procedures	S1	F2	S1 ranking based on assumed rupture of canister and unfiltered flow through vault ventilation system. Release limited by multiple canister barriers.
4.10.b.is	4.10 Helium gas Supply (canister backfill)	Supplies inerting gas for welding	4.10.2 Loss of supply	Line break Valved out Line plug Bottle empty	Pu oxide powder in inner can	Bad welds; inner and outer canisters may leak	Helium leak detectors (inner and outer can leak detection units)	--	S1	F2	

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4.10.c.is	4.10 Helium gas Supply (canister backfill)	Supplies inerting gas for glovebox and welding area	4.10.3 High velocity object	Failure of bottle restraints allows bottle to fall and break main supply valve Bottle dropped during replacement of empty bottles Random bottle or piping failure	Contamination contained in gloveboxes	Contamination released to room due to impact of high pressure gas propelled bottle Possible personnel injury Possible damage to other equipment/systems in immediate vicinity	Fall prevention restraints required on all high pressure gas bottles Carts used to move bottles have restraints to prevent tip off	Operator training and operating/maintenance procedures	S2	F2	S2 ranking based on bottle striking and damaging glovebox. F2 ranking based on probability of random direction of motion
4.11.a.is	4.11 Transport Glovebox Television Monitoring System	Provide operators with the ability to visually monitor the operation of the automated can/tray handler	4.11.1 Degraded or unintelligible picture	Bad cables Failed camera Loss of power Failed electronics	Pu oxide powder in trays being transported Pu metal in canisters being transported through	Dump trays of Pu being transported onto glovebox floor (criticality and contamination concern) Dump trays of Pu being transported to furnaces onto furnace floor (criticality and contamination concern) Inability to observe furnace door status (process failure/stoppage) Inability to observe tray entry and exit from furnace (process stoppage)	Criticality alarms CAMs in the room and exhaust stack Filtered glovebox exhaust Handler control system (minimizes chance of spill/criticality due to reliability of system to perform correctly without observation)	Operator training and procedures	S1	F2	S1 rating based on spill consequence from criticality (operator exposure) or spills in glovebox requiring additional exposure for cleanup
4.12.a.is	4.12 Ventilation Supply to Room 641 and 642	Provide airflow for maintaining correct negative pressure in rooms housing SPS	4.12.1 Insufficient supply flow	Failure of supply fan Ventilation supply damper fails closed	Pu oxide contamination in glovebox atmosphere	Excessive negative dP relative to glovebox Possible movement of Pu oxide contamination imor room from glovebox (air flow reversal)	Ventilation system has backup supply fan Ventilation system controls shutdown system on low flow indication Room CAMs Supply fan loss of pressure alarm	Operator training and procedures	S1	F3	S1 based on intact glovebox

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.12.b.is	4.12 Ventilation Supply to Room 641 and 642	Provide airflow for maintaining correct negative pressure in rooms housing SPS	4.12.2 Excessive supply air flow	Controller failure on supply fan	NA	Pressurized rooms	Control system on ventilation		S0	F3	
4.12.c.is	4.12 Ventilation Supply to Room 641 and 642	Provide airflow for maintaining correct negative pressure in rooms housing SPS	4.12.3 Excessive supply air flow	Failure of exhaust fan Exhaust damper fails in closed position	Pu oxide contamination in glovebox atmosphere	Pressurized glovebox and pressurized room Movement of contamination to room from glovebox Movement of contamination in room to the environment via various building penetrations	Control system on ventilation system Glovebox pressure alarms Building structure Low resistance paths are filtered Room CAMs	Operator training and procedures	S2	F3	Glovebox assumed to be more pressurized than room in this accident S2 based on unfiltered release
4.13.a.is	4.13 Ventilation Exhaust from Room 641 and 642	Provides filtered path for air flow from room and negative pressure in room	4.13.1 Loss of filtration	HEPA seal failures Human error during maintenance or installation Long term plugging of HEPA filter Impact by objects entrained in air flow Wrong train placed in service during maintenance Smoke/water vapor pluggs HEPA filter from fire-filter blowout	Contamination in room Pu oxide contamination in glovebox atmosphere	Unfiltered release of contamination in room to environment Significant release to environment if glovebox confinement concurrently fails	dP Alarms across filter Exhaust CAMs	Periodic filter testing Operator training and procedures	S2 S0	F2 F3	S2 based on consequences from glovebox failure

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.13.b.is	4.13 Ventilation Exhaust from Room 641 and 642	Provides filtered path for air flow from room and negative pressure in room	4.13.2 Loss of flow (building ventilation system)	Exhaust damper fails closed Exhaust fan fails Power failure Filter plugging	Pu oxide contamination in glovebox atmosphere	Pressurized glovebox relative to room (see 4.12.3)	Redundant exhaust fans Backup power supply Automatic transfer of power supply Kicker fan and controls for glovebox Dump valves Automatic shutdown of supply and exhaust fan on loss of flow Room CAMs Building structure	Operator training and procedures	S2	F3	See remarks for 4.12.3
4.13.c.is	4.13 Ventilation Exhaust from Room 641 and 642	Provides filtered path for air flow from room and negative pressure in room	4.13.3 Excessive exhaust flow rate	Fully open damper (failure of damper controls)	Pu oxide contamination in glovebox atmosphere	High negative pressure in room Release of Pu oxide from glovebox	Control system for ventilation Room CMAs Pressure alarms for ventilation system	Operator training and procedures	S1	F3	May or may not result in glovebox being positive to room - see 4.12.1
4.14.a.is	4.14 Building ventilation system (general)	Provides ventilation flow to building, confinement function to room	4.14.1 No flow	Loss of power Control system shutdown of supply and exhaust fans	Pu oxide contamination in glovebox atmosphere	Loss of room negative pressure (confinement) Loss of glovebox exhaust and negative pressure (confinement) Migration of Pu oxide into room	Kicker fan High ventilation pressure alarms Backup supply and exhaust fans Packup power supply CAMS in room Glovebox filters Building structure (and airlocks)	Operator training and procedures	S1	F3	Expected state of ventilation system if kicker fan required to be on S1 based on glovebox intact but some leakage
4.15.a.is	4.15 Fire suppression system in Room 641 and 642	Suppress fires in rooms with water	4.15.1 Failure to extinguish fire	Failure of sprinkler system to activate Failure of water supply	Pu oxide in gloveboxes	Damage to gloveboxes Damage to building structure	Design of fire system	Operator training and procedures	S2	F3	Fire presumed in this accident

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4.15.b.is	4.15 Fire suppression system in Room 641 and 642	Prevent release of water when no fires are present	4.15.2 Fire system releases water into room when not required	Spurious actuation Piping leak	NA	Possible flooding of room Potential for criticality	Glovebox is well sealed Construction of building not water tight Alarms on fire system when actuation occurs	Operator training and procedures	S1	F3	S1 based on criticality
4.15.c.is	4.15 Fire suppression system in Room 641 and 642	Remain in position as designed	4.15.3 Sprinkler system falls to floor	Hanger failure Seismic event causing hanger failure	Pu oxide in gloveboxes	Loss of glovebox confinement Possible water intrusion into glovebox Possible criticality	Design of hangers and building structure Building ventilation system (in case of no seismic event)		S2	F2	This is a "3/1" type of problem S2 based on glovebox breach
4.16.a.is	4.16 Container assay nitrogen dewar system	Cool container assay monitor Contain nitrogen	4.16.1 Leak of nitrogen from system	Equipment failure	Nitrogen in dewar	Cryogenic or asphyx-iation hazard to operators	Dewar pressure boundary design	Operator training and procedures	S1	F3	It is assumed cooling is external to SPS so nitrogen not potential pressurization source.
5.0.is	5.0 Final Storage Vault Utilities										
5.1.a.is	5.1 Ventilation system	Remove heat generated by the Pu storage canisters in the vault Protect structural integrity of the vault that could be compromised due to overheating	5.1.1 Loss of sufficient ventilation	Ventilation upsets Loss of power Equipment failures	Material made available for release from canister ruptures	Overheating and pressurization of canisters; potential rupture of canisters Dehydration of concrete; decreased margin of safety in vault structural capacity	Ventilation system controls and alarms Redundant supply and exhaust fans Backup power diesel generator 3013 cans may be sufficiently robust to withstand heat up without breach Local power loss causing loss of vault supply or exhaust will set off alarms Instrumentation in vault ventilation system will indicate loss of ventilation flow	Operator action to restore power	S2	F2	vault steady state temperature may or may not exceed structural limits at steady state represents a threat to vault capability to withstand DBE Thermal analysis being performed to determine if vault structural damage is possible 3013 canisters may exceed design limits for temperature

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5.1.b.is	5.1 Ventilation system	Provides confinement of particles that might leak from canisters	5.1.2.a Loss of confinement	Pressurized vault due to imbalance between supply and exhaust Loss of supply and exhaust (stagnant case)	Contamination present in vault	Migration of particles from vault to 2736-ZB building; facility worker exposures	Vent system controls and alarms Zone Ventilation in areas where contamination may spread limits release to environment CAMs in rooms of 2736-ZB	Manual surveillances for contamination	S1	F3	
5.1.c.is	5.1 Ventilation system	Provides confinement of particles that might leak from canisters	5.1.2.b Loss of confinement	Loss of filtration	Contamination present in vault	Unfiltered release to environment	Stack CAM HEPA filters in series	--	S1	F3	very limited contamination expected in vault
6.0.ex	6.0 External Events (events external to the operational area but not related to natural phenomena)										
6.1.a.ex	6.1 SPS Machine	Stabilize Pu	6.1.1 External Impact on Gloveboxes or Turntable	Transfer cart impacts machine due to human error Gas bottles breach and become missiles striking machine	Loose Pu oxide inside machine	Loss of glovebox confinement; release of radiological material to the room Process upset if turntable damaged	Robust construction of glovebox/turntable prevents significant damage due to cart impacts Room CAMs if gloveboxes breached Glovebox ventilation system Room ventilation system and filters Bottle restraints Pressurized gasses presumably stored away from machine	Operator training and procedures Pressurized gas bottle handling standards	S2	F2	S2/F2 for gas bottle impact causing release to room

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6.1.b.ex	6.1 SPS Machine	Stabilize Pu	6.1.2 Floods initiated in other portions of the facility spreading to SPS room	Actuation of fire system in other portions of the building Fire water main break Other water supply line breaks	Fissile material in machine and lag stored around the machine Loose Pu material that could be spread	Criticality leading to high radiation doses to operators Spread of Pu oxide outside glovebox, perhaps outside the room or building	Gloveboxes and lag storage cart elevated off the floor Building is single story at ground level (SPS machine not in a basement room) Water can't build up to glovebox height. No water supplies to glovebox portion of machine Design of building would likely allow water to flow outside instead of accumulating to significant depths inside the building Criticality drains in gloveboxes Drains in other parts of facility Actuation of fire water systems or breaks in fire water lines are indicated by instrumentation and alarms.	Operator visual detection Operator training and procedures Criticality control program	S2	F1	confirm criticality drains will be used See PFP SAR regarding internal water floods
6.1.c.ex	6.1 SPS Machine	Stabilize Pu	6.1.3 Fire spreading to SPS room from other portions of the facility		Loose contamination on packaging material and on other surfaces in the glovebox	Elevated release inside glovebox Degradation of glovebox integrity	Glovebox heat detection Dump valves limit potential pressurization Fire suppression system SPS ventilation system Robust glovebox design Room ventilation system	Housekeeping Procedures to limit combustible loading	S1 S2	F3 F2	S1 for anticipated fire S2 if fire spreads to other gloveboxes (less likely)

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6.1.d.ex	6.1 SPS Machine	Stabilize Pu	6.1.4 Loss of facility power	Site supply failures outside facility (natural phenomena, etc.) In-facility failures, (e.g., shorts, overloads, switchgear failures, etc.) Facility fires not associated with SPS operations	Loose contamination in glovebox	Loss of ventilation flow in SPS or vault (see dry air supply and exhaust, vault ventilation system) Loss of instrumentation Potential spread of contamination from gloveboxes to room; operator exposures Canister handling failures resulting in Pu spills inside gloveboxes adding to loose contamination available for release Operating problems leading to increased worker exposure upon recovery Failure to adequately stabilize some oxide material; subsequent swelling/rupture of canisters in vault	Gloveboxes designed to minimize leakage Ductwork to filters is seismically qualified Room CAMs connected to backup power Glovebox pressure indication warns operator of potential loss of confinement UPS Backup power	Operator detection and response	S1	F3	S1 ranking based on assumed complete loss of power. Pu assumed to be released from stagnant building through cracks, penetrations, and seals. Is vent system connected to backup power? What is UPS connected to? What is backup diesel generator connected to?
6.2.a.ex	6.2 Storage Vaults	Store stabilized Pu	6.2.1 Floods initiated in other portions of the facility spreading to vault area	Fire water system actuation Fire water line breaks Breaks of other water supplies	Fissile material in vault	Postulated criticality	Canisters stored up off the floor of the vault Racks or storage tubes maintain separation of canisters should the vault flood Storage racks or tubes will be designed to provide critically safe configuration even if the vault is flooded or water mist is present between canister arrays	Criticality control program	S1	F1	

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6.2.b.ex	6.2 Storage Vaults	Store stabilized Pu	6.2.2 Fire spreading to vault corridor from other portions of the facility	Combustible materials ignited elsewhere in the facility; fire spreads to vault corridor		Loss of power to vault ventilation system Compromise structural integrity of a portion of the building or vault due to thermal stress or concrete dehydration Limited fire in vault if fire spreads to vault	Facility fire protection system Fire doors Air locks between vault and office areas Vault door prevents spread of fire to the inside of the vault Vault is constructed of noncombustible material Limited combustibles in vault	Emergency response procedures Fire prevention program Fire station	S1	F2	S1/F2 for loss of ventilation flow in vault due to loss of power; 3013 packages not expected to rupture due to loss of ventilation flow or small fire in vault. structural collapse due to facility fire beyond scope of this analysis--See PFP FSAR.
6.2.c.ex	6.2 Storage Vaults	Store stabilized Pu	6.2.3 Loss of facility power due to various external causes	Site supply failures outside facility (natural phenomena, etc.) Facility fires not associated with SPS operations	Loose contamination in glovebox	Loss of ventilation flow in SPS or vault (see dry air supply and exhaust, vault ventilation system) Loss of instrumentation Potential spread of contamination from gloveboxes to room; operator exposures Canister handling failures resulting in Pu spills inside gloveboxes adding to loose contamination available for release Operating problems leading to increased worker exposure upon recovery Failure to adequately stabilize some oxide material; subsequent swelling/rupture of canisters in vault	Gloveboxes designed to minimize leakage Ductwork to filters is seismically qualified Room CAMs connected to backup power Glovebox pressure indication warns operator of potential loss of confinement UPS Backup power	Operator detection and response	S1	F3	S1 ranking based on assumed complete loss of power. Pu assumed to be released from stagnant building through cracks, penetrations, and seals. Is vent system connected to backup power? What is UPS connected to? What is backup diesel generator connected to?

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6.3.a.ex	6.3 2736-Z and ZB Buildings	Houses SPS machine and storage vaults	6.3.1 Aircraft Crashes into 2736-Z or ZB collapsing roof or walls causing release of Pu oxide	Aircraft mechanical failure during overflight Human error during overflight	Pu in storage vault or SPS	Destruction of building structure and release of Pu oxide	--	--	S3	F0	See PFP FSAR
6.3.b.ex	6.3 2736-Z and ZB Buildings	Houses SPS machine and storage vaults	6.3.2 Vehicle Impact into 2736-Z or ZB results in structural damage to building and SPS gloveboxes	Vehicle strikes facility, goes through wall opening and impacts SPS	Pu in storage vault or SPS	Release of Pu oxide from glovebox damaged by impact Possible fuel fire	Robust building structure Limited area to build up velocity	Operator training and procedures	S2	F3	See PFP FSAR
6.3.c.ex	6.3 2736-Z and ZB Buildings	Houses SPS machine and storage vaults	6.3.3 Tall structures falling into building	--	--	--	--	--	--	--	See PFP FSAR
6.3.d.ex	6.3 2736-Z and ZB Buildings	Houses SPS machine and storage vaults	6.3.4 Effects of Military Activities	--	--	--	--	--	--	--	See PFP FSAR
6.3.e.ex	6.3 2736-ZB and 2736-Z Buildings	House SPS machine and operations House storage vaults	6.3.5 Range Fire Out of scope SPS and vault modifications do not change baseline compared to original facility	--	--	--	--	--	--	--	beyond scope of this analysis.

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7.0.np	7.0 Natural Phenomena										
7.1.a.np	7.1 2736-ZB and 2736-Z Buildings	House SPS machine and operations House storage vaults	7.1.1 Seismic Event	NA	Pu oxide powder in glovebox Stabilized Pu oxide in canisters in SPS room and storage vaults	Loss of power leading to loss of ventilation for gloveboxes and vaults Damage to facility Damage to gloveboxes Spilling of Pu oxide within glovebox Shaking of contamination of equipment/glovebox surfaces Possible criticality initiator due to material geometry rearrangement Various equipment failures Fires Fire/other water line breaks Spread of Pu oxide powder from facility through compromised ventilation systems or damaged structure	Seismically qualified buildings and vaults SPS machine anchoring seismically qualified Seismic displacement absorber on SPS machine	Emergency response procedures	S2	F2	Adds source term to PFP FSAR seismic accident analysis 3/1 interactions should be looked at in detail in definitive design

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7.1.b.np	7.1 2736-ZB and 2736-Z Buildings	House SPS machine and operations House storage vaults	7.1.2 High Wind	High velocity projectile caused by wind strikes the building structure and penetrates wall damaging glovebox	Pu oxide in gloveboxes Pu oxide in canisters in room and vaults	Damage to building Loss of power	2736-Z and 2136-ZB buildings designed to withstand DBW and credible wind driven missiles		S2	F3	S2 category based on damage to glovebox and release to environment S1 for loss of power causing contamination spread from glovebox exposing operators see also PFP FSAR high wind accident analysis
7.1.c.np	7.1 2736-ZB and 2736-Z Buildings	House SPS machine and operations House storage vaults	7.1.3 Lightening	NA	Pu oxide in gloveboxes	Damage to building Loss of power Equipment failures	Lightening protection system Stout building design	--	S1	F3	S1 for equipment failures causing worker injury or exposures contamination spread to environment due to loss of ventilation expected to be minor
7.1.d.np	7.1 2736-ZB and 2736-Z Buildings	House SPS machine and operations House storage vaults	7.1.4 External Floods	--	--	No consequence. External floods cannot flood building (including severe rain) (see PFP FSAR).	--	--	--	--	See PFP FSAR
7.1.e.np	7.1 2736-ZB and 2736-Z buildings	House SPS machine and operations House storage vaults	7.1.5 Ashfall	N/A	Pu oxide in gloveboxes Pu oxide in canisters in room and vault	Loss of power Potential roof damage	2736-Z and 2736-ZB buildings are designed to withstand ashfall loading Backup generator	Operator action to shovel off roof, to change out critical filters and to shutdown operations	S1	F2	S1 for loss of power to glovebox ventilation system causing release to room and operator exposures Roof collapse not expected in design basis ashfall event
7.1.f.np	7.1 2736-ZB and 2736-Z buildings	House SPS machine and operations House storage vaults	7.1.6 Range fire		Pu oxide in gloveboxes Pu oxide in canisters in room and vaults	Damage to building (potential) Loss of power	Concrete building design	Groundskeeping Hanford Fire department Little vegetation inside PFP fence	S1	F3	S1 for loss of power causing loss of ventilation flow through gloveboxes. Pu release to room causing operator exposures

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
8.0.a.ws	8.0 Worker hazards (industrial hazards) (general to all locations, unless otherwise specified)										
8.1.a.ws	8.1 Worker Hazards - General		8.1.1 Exposure to hazardous materials (e.g. solvents, fumes, decontamination chemicals)	Operator exposed to decontamination chemicals Operator exposed to cleaning solvents or solvent fumes		Operator injury		Hazardous material training and Procedures Use of MSDS	S1	F3	Occupational hazard
8.1.b.ws	8.1 Worker Hazards - General		8.1.2 Operator injury from moving equipment inside glovebox	Operator caught in moving tray elevators, can handlers, belts, pulleys		Operator injury	Shields and guards	Operator training and procedures	S1	F3	Occupational hazard
8.1.c.ws	8.1 Worker Hazards - General		8.1.3 Operator injuries from moving equipment outside the glovebox	Operator hit by moving cart Operator struck by or pinched in can turntable		Operator injury	Guards? Interlocks?	Operator training and procedures	S1	F3	Occupational hazard
8.1.d.ws	8.1 Worker Hazards - General		8.1.4 Operator burns due to exposure to heat sources (e.g., hot furnace trays, furnaces, etc.) inside gloveboxes	Exposure to hot stabilization trays Exposure to hot furnaces Exposure to hot surfaces created during welding operation		Operator injury	Glovebox heat detection	Operator training and procedures	S1	F3	Occupational hazard
8.1.e.ws	8.1 Worker Hazards - General		8.1.5 Operator injury due flying missile (i.e.,, failed gas storage bottle)	Pressurized gas bottle knocked over and supply valve broken off		Operator injury	Bottle restraints Special bottle handling carts	High pressure gas safety procedures	S1	F3	Occupational hazard
8.1.f.ws	8.1 Worker Hazards - General		8.1.6 Operator exposure to asphyxiants (from bottled gases)	Excessive concentration of helium or nitrogen gas due to line breaks		Operator injury	Room ventilation system	Operator training and procedures	S1	F3	Occupational hazard
8.1.g.ws	8.1 Worker Hazards - General		8.1.7 Operator exposure to heat and toxic fumes	Fires inside or outside glovebox		Operator injury	Wet fire suppression system outside glovebox Dry fire suppression system inside glovebox Glovebox heat detection	Housekeeping	S1	F3	Occupational hazard

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
8.1.h.ws	8.1 Worker Hazards - General		8.1.8 Operator injury due to electrical shock	Human error in equipment hookup Electrical shorts Insulation failures due to abrasion, radiation hardening, improper installation		Operator injury	Equipment design	Operator training and procedures Maintenance procedures	S1	F3	Occupational hazard
8.1.i.ws	8.1 Worker Hazards - General		8.1.9 Operator exposure to excessive noise	Operator in room containing rotating equipment such as supply fans, exhaust fans Frequent exposure to loud alarms		Operator injury		Plant health and safety procedures	S1	F3	Occupational hazard
8.1.j.ws	8.1 Worker Hazards - General		8.1.10 Slips, trips, falls, back injuries	Poor housekeeping Human error Poor labeling of hazardous areas Design that requires difficult body positioning		operator Injury	Equipment design	Operator training and procedures Plant health and safety procedures	S1	F3	Occupational hazard
8.1.k.ws	8.1 Worker Hazards - General		8.2.11 Operator injury due to dropped objects	Human error Improper storage of Pu oxide 3013 cans Maintenance activities		Operator injury		Operator training and procedures Criticality prevention specifications	S1	F3	Occupational hazard
8.1.l.ws	8.1 Worker Hazards - General		8.2.12 Operator injury during glovebox work--internal contamination caused by cuts	human error sharp objects in glovebox operator gets caught in moving equipment		Operator injury Internal contamination	Equipment design Guards and shields	Operator training and procedures	S1	F3	Occupational hazard
8.2.a.ws	8.2 Worker Safety - Vault operations		8.2.1 operator injury operating hoist (dropped load, pinch in moving parts, etc.)	human error equipment failure		Operator injury	Equipment design	Operator training and procedures	S1	F3	Occupational hazard

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
8.3.a.ws	8.3 Worker Safety - Laser operation		8.3.1 Operator exposure to YAG laser light operator burn due to welding equipment	improperly aimed welding head human error failure of fiber-optic cable		operator injury (burns or eye damage)	Equipment design Shields/guards	Maintenance and inspection Operator training and procedures	S1	F3	Occupational hazard
9.0.ch	9.0 Construction Hazards (threats to building and existing processes)										
9.1.ch	9.1 Construction of new pad and building for dry air system compressors and dryer	--	--	--	--	No effect on existing safety systems other than penetrations are made through existing building wall which shouldn't compromise building integrity	--	--	--	--	
9.2.ch	9.2 Modifications to 2736-ZB, including: Opening in east wall of Room 642 to allow access for equipment installation Add a couple of airlocks between areas Reconfigure Rooms 626 through 631 to contain operations office Add new airlock outside the building (security access)		Compromise seismic integrity of structure due to openings in load bearing walls	Change the response of load bearing walls to seismic forces	Very little contamination in building or ductwork expected during construction activities After startup, material at risk is Pu oxide in process at the time of a seismic or high wind event	Partial structural collapse in DBE after startup; release of Pu from facility No effect on vault ventilation system expected due to reconfiguration of building rooms	New door and frame will be designed to maintain seismic qualification of structure	Analysis of modification before performed USQ process ECN reviews	NA	NA	
9.3.ch	9.3 Electrical modifications		Power outages to other various 2736-ZB safety systems	Incorrect isolation of circuits during construction activities Voltage spikes or shorts caused by new electrical work (due to human error) Power line severed	Radiological material in 2736-Z or -ZB	Loss of ventilation flow through vault(s) Contamination spread within facility Loss of various instrumentation Operator exposures Operator injury		Construction planning Labelling on electrical bus			constructions risks to be further developed in definitive design or the FSAR

ID	Operational Area/System	Operation(s)/ Function(s)	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
9.4.ch	9.4 Fire protection modifications		Fire water to portion of 2736-ZB or -Z inadvertently shut off during work on another section of the 2736-ZB or -Z fire protection system	Human error		Loss of fire protection in some areas away from modification work					
9.5.ch	9.5 HVAC modifications Add HEPA filter plenum to Room 639 Add ductwork across roof Two roof penetrations Add backup exhaust fan on roof Tie into existing 2736-ZB exhaust stack		May effect ventilation supply to storage vaults in 2736-Z (e.g. damage or crush existing supply ductwork If crane used, crane could drop load onto or fall into vault or other portion of the facility	Human error Crane failure or human error	Vault contents	Overheat storage vault if supply affected Crane damage may result in radiological release to environment	Vault ventilation system instrumentation to indicate loss of supply flow	Crane rigging manual Construction plan	S2	F3	
9.6.ch	9.6 Vault modifications, including: Convert to modular pedestal storage or in floor tube storage		Increase heat load in other vaults because contents of vault being modified will need to be moved	Inadequately analyzed storage conditions Human error	Portion of Pu oxide in current storage canisters	Possible canister rupture and Pu oxide release	Vault ventilation system Vault storage rack configuration prevents storage of too many canisters Criticality alarms	Criticality control program prevents criticality in vault where extra canisters are being held	S2	F1	This accident is outside the scope of the project. It is assumed that current storage configuration is appropriate for storage of the required number of canisters
9.7.ch	9.7 New office trailer construction		Trailer location could require relocation of various utilities, causing temporary shutdown of some systems Trucks carrying modules could impact PFP buildings or utilities Electrical power could be inadvertently shut off to some systems	Human error Equipment failures		Loss of ventilation flow to storage vaults or through NDA lab	Various instrumentation	Operator observation			

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

References: System Design Document for the Plutonium Stabilization and Packaging System, ID: SDD/Pu SPS @RfF/707; Revision 1 (06/28/96), BNFL, Inc.
System Specification for the Plutonium Stabilization and Packaging System, ID: SS/Pu SPS @RF/707; Revision 1 (06/28/96), BNFL Inc.
Plutonium Finishing Plant Final Safety Analysis Report, WHC-SD-CP-SAR-021, Rev. 1 (not issued), FDNW

APPENDIX B

S2 & S3 ACCIDENT TABLES

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Table B-1

S2 Accidents Resulting in Unfiltered Release from Glovebox Ventilation System

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - RESULTS IN UNFILTERED RELEASE FROM GLOVEBOX VENTILATION SYSTEM									
2.6.b.op	2.6.2 Radioactive material spill inside furnace results in unfiltered release from glovebox ventilation system - Furnace Area	Spill from furnace trays (multiple)	Material being transferred on trays	Operation of furnace with oxide powder on heating coils may result in coil failure Difficulty in cleaning up spill resulting in increased personnel exposure	Design of the tray handler Furnace tray rack design glovebox ventilation system and HEPA filters Furnace exhaust ventilation and sintered metal filter	Personnel training and procedures	S2	F3	S2 rating based on unfiltered release through either glovebox ventilation system or furnace exhaust
2.8.a.op	2.8.1 Radioactive material spill inside the glovebox results in unfiltered release from glovebox ventilation system-Tipping/Dispense/Fill area	Spill from furnace trays due to can handler failures, elevator/transpose unit failures, and tipper failures Spill during filling of can Overfill convenience can at fill station if furnace tray contains 5 kgs of low bulk density powder Overfill convenience canister at fill station due to double-batched furnace tray Spill at cap removal/replacement station Spill at cap monitoring station Spill from can when orienting horizontally at orientation station for entry into gaslock (cap not properly in place)	Material being transferred on trays and in cans	Release of Pu into glovebox atmosphere	Glovebox and glovebox confinement system Can handler controls and instrumentation Furnace tray handler controls and instrumentation Television monitoring station allows operator surveillance	Operator training and procedures	S2	F3	S2 ranking based on unfiltered release to the environment through SPS ventilation system
4.2.d.is	4.2.4 Unfiltered release through stack results in unfiltered release from glovebox ventilation system - SPS glovebox exhaust system	Failed filter Failed filter seals	Loose contamination in glovebox	Unmitigated release of Pu material through stack	Stack CAM detects unfiltered release DP instrumentation across filter	Operator training and response Routine maintenance on vent system	S2	F3	S2 based on unfiltered release through stack

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
				INTERNAL INITIATOR - LOSS OF GLOVEBOX CONFINEMENT					
2.1.a.op	2.1.1 Loss of confinement - SPS Gloveboxes (general) results in unfiltered release from building	Glovebox breach Damage to glovebox due to internal impact Explosion Fire External impact Seismic event Ventilation upsets Instrument purge gas leaks Inadvertent dry fire suppression activation Dry air supply control failure	Loose contamination in the glovebox plus Pu oxide in open containers	Release of contamination to the room atmosphere if confinement lost (e.g., hole too big for exhaust system) Operator exposures	Robust glovebox design Glovebox exhaust system Seismically qualified gloveboxes and supports Glovebox fire suppression system Dump valves minimize potential for glovebox pressurization Controls on supply and exhaust system Pressure indication in glovebox Fire suppression system alarms CAMs in room Room ventilation system mitigates potential release to the environment	Operator training and procedures Feed control minimizes likelihood of receiving containers with explosive/ Combustible materials Housekeeping limits combustible loading in glovebox	S2	F3	S2 ranking based on unfiltered release through building ventilation system Seismic initiator F2 or lower
2.1.c.op	2.1.3 Spill of Pu material within the box - SPS Gloveboxes (general) results in unfiltered release from building	Operator drops canister Canister handling equipment damages or spills canister	Pu material within the canister (0.5 kg to 5 kg)	Release of Pu inside box requiring actions to clean it up; increased operator dose	Glovebox structure and glovebox exhaust system Design of automated handling equipment	Operator training and procedures	S2	F3	S2 ranking based on unfiltered release through exhaust stack Also results in increased operator doses due to cleanout requirements
2.2.c.op	2.2.3 Drop of inner overpack can inside glovebox after opening outer overpack can results in unfiltered release from building - Receipt area Drop of convenience can after opening inner overpack results in unfiltered release from building - Receipt area	Human error or malfunction of canister handler or canister opener	Fraction of material inside dropped package that could escape through a rupture	Minor release inside glovebox	Glovebox exhaust system (includes fans, filters, CAMs and other instrumentation) Convenience can lid is taped on and can is bagged and heat sealed	Operator training and procedures Convenience can drop tests	S2	F3	S2 ranking based on drop of bagged convenience can and unfiltered release through SPS ventilation system

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.1.a.is	4.1.1 Loss of or inadequate supply airflow results in unfiltered release from building	Loss of power Compressor failure Inadvertently valved out Failure of pressure control Plugged line	Loose Pu in glovebox	Overheated gloveboxes; potential pressurization Potential degradation of glovebox integrity (failed seals, etc). Release of pu material to room atmosphere	Glovebox heat detection Furnaces are insulated Alarms on supply failure	Maintenance on supply system	S2	F3	S2 category assigned based on potential unfiltered release through building ventilation system
4.12.c.is	4.12.3 Excessive supply air flow results in unfiltered release from building	Failure of exhaust fan Exhaust damper fails in closed position	Pu oxide contamination in glovebox atmosphere	Pressurized glovebox and pressurized room Movement of contamination to room from glovebox Movement of contamination in room to the environment via various building penetrations	Control system on ventilation system Glovebox pressure alarms Building structure Low resistance paths are filtered Room CAMs	Operator training and procedures	S2	F3	Glovebox assumed to be more pressurized than room in this accident S2 based on unfiltered release
4.13.a-2.is	4.13.1 Loss of filtration causes unfiltered release to environment	HEPA seal failures Human error during maintenance or installation Long term plugging of HEPA filter Impact by objects entrained in air flow Wrong train placed in service during maintenance Smoke/water vapor plugs HEPA filter from fire-filter blowout	Contamination in room Pu oxide contamination in glovebox atmosphere	Unfiltered release of contamination in room to environment Significant release to environment if glovebox confinement concurrently fails	dP Alarms across filter Exhaust CAMs	Periodic filter testing Operator training and procedures	S2	F2	S2 based on consequences from glovebox failure

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.13.b.is	4.13.2 Loss of flow (building ventilation system) results in unfiltered release from building	Exhaust damper fails closed Exhaust fan fails Power failure Filter plugging	Pu oxide contamination in glovebox atmosphere	Pressurized glovebox relative to room (see 4.12.3)	Redundant exhaust fans Backup power supply Automatic transfer of power supply Kicker fan and controls for glovebox Dump valves Automatic shutdown of supply and exhaust fan on loss of flow Room CAMs Building structure	Operator training and procedures	S2	F3	See remarks for 4.12.3
INTERNAL INITIATOR - LOSS OF CONFINEMENT BY GLOVEBOX PRESSURIZATION									
2.3.d.op	2.3.4 Canister Explosion results in loss of confinement - SPS Material Preparation Area - First Section	Can containing hydrogen is ignited upon opening or by handling activity	Pu oxide material in can (0.5 to 5 kg) plus glovebox contamination	Pu release inside glovebox Potential glovebox damage Potential glovebox loss of confinement/spread of contamination to room	Stout glovebox design Glovebox ventilation system Room ventilation system Dump valves	Feed source controls limits potential for receiving cans containing combustibles or reactive chemicals	S2	F2	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.3.e.op	2.3.5.a Pressurized glovebox results in loss of confinement - SPS Material Preparation Area - First Section	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose contamination in box	Pu release from glovebox into room	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.3.f.op	2.3.5.b Pressurized glovebox results in loss of confinement - SPS Material Preparation Area - First Section	Chemical reaction	Loose contamination in box	Pu release into room (plus toxic fumes/gases depending on reaction)	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox Controls on feed source minimize likelihood of reactive compounds being processed. Limit on combustibles in gloveboxes. No solvents or reactive chemicals stored in gloveboxes Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.3.g.op	2.3.5.c Pressurized glovebox results in loss of confinement - SPS Material Preparation Area - First Section	Imbalance between dry air supply and exhaust	Loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.4.d.op	2.4.4 Canister explosion inside the glovebox results in loss of confinement - Material Preparation Area Second Section	Can containing hydrogen is ignited upon opening or by handling activity	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Pu release inside glovebox Potential glovebox damage Potential glovebox loss of confinement/spread of contamination to room	Stout glovebox design Glovebox ventilation system Room ventilation system Dump valves	Feed source controls limits potential for receiving cans containing combustibles or reactive chemicals	S2	F2	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.e.op	2.4.5.a Pressurized glovebox results in loss of confinement - Material Preparation Area Second Section	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, screw conveyer, open cans, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Loose Pu material available for release greater in Section 2 than 1
2.4.f.op	2.4.5.b Pressurized glovebox results in loss of confinement - Material Preparation Area Second Section	Chemical reaction	Loose contamination in box	Pu release into room (plus toxic fumes/gases depending on reaction)	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox Controls on feed source minimize likelihood of reactive compounds being processed. Limit on combustibles in gloveboxes. No solvents or reactive chemicals stored in gloveboxes Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.g.op	2.4.5.c pressurized glovebox results in loss of confinement - Material Preparation Area Second Section	Imbalance between dry air supply and exhaust	Loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Operator training and procedures	S2	F3	
2.5.d.op	2.5.4.a Pressurized glovebox results in loss of confinement - Transport Area	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Loose Pu material available for release greater in section 2 than 1

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.5.e.op	2.5.4.b Pressurized glovebox results in loss of confinement - Transport Area	Imbalance between dry air supply and exhaust	Loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Training and procedures	S2	F3	
2.6.e.op	2.6.5.a Pressurized glovebox results in loss of confinement - Furnace Area	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.f.op	2.6.5.b Pressurized glovebox results in loss of confinement - Furnace Area	Chemical reaction	Loose contamination in box	Pu release into room (plus toxic fumes/gases depending on reaction)	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization	Worker training and procedures emergency response procedures Housekeeping controls limit Pu accumulation in glovebox Controls on feed source minimize likelihood of reactive compounds being processed. Limit on combustibles in gloveboxes. No solvents or reactive chemicals stored in gloveboxes Housekeeping controls limit Pu accumulation in glovebox	S2	F3	
2.6.g.op	2.6.5.c Pressurized glovebox results in loss of confinement - Furnace Area	Imbalance between dry air supply and exhaust	loose contamination in box	Pu release from glovebox into room	Glovebox designed to minimize leakage CAMs in room to detect contamination spread from box Room ventilation system confines release to room and filters release to the environment Dump valves prevent glovebox pressurization Vent system instrumentation minimizes likelihood of pressurization	Training and procedures	S2	F3	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.h.op	2.6.5.d Pressurized glovebox results in loss of confinement - Furnace Area	Furnace dry air high flow (failure of control valve)	Loose Pu oxide powder in furnace	Spread of contamination into glovebox(s)	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Chance for gross contamination of glovebox and furnace. Creates cleanup problem. Possible challenge to ventilation filters through plugging??? Blow up the furnace???

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.7.e.op	2.7.5.a Pressurized glovebox results in loss of confinement - LOI test area	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, crucibles, etc)	Spread of contamination from the glovebox to the room Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.8.d.op	2.8.4 Pressurized glovebox results in loss of confinement - Tipping/Dispense/Fill area	Pneumatic air/instrument purge leak combined with loss of exhaust Compressed air regulator failure Fire suppression activation	Loose Pu oxide powder in glovebox (material in trays, etc)	Spread of contamination to other gloveboxes	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S2	F3	Loose Pu material available for release greater in section 2 than 1
4.1.b.is	4.1.2 Glovebox pressurization due to oversupply results in loss of confinement	Regulator failure Human error in setting up system	Loose Pu in glovebox	Release of Pu material to room atmosphere	Dump valves Glovebox pressure indication Ventilation system instrumentation and controls Regulator on dry air supply PRV on supply	Operator training and response	S2	F3	confirm existence of interlocks (are they in SPS machine design or are they to be provided by PFP HVAC) PRV location? (box or supply) Are there pressure gauges in system

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.2.a.is	4.2.1 Pressurization of glovebox if exhaust lost and supply not shutoff results in loss of confinement	Exhaust fan failure Inadvertently closed damper Plugged filter	Loose contamination in glovebox	Release of Pu material from the gloveboxes to room atmosphere (subsequent release through stack)	Room ventilation system and filters Building structure CAMs in room Glovebox pressure indication Backup exhaust fan Dump valves	Operator training and response Routine maintenance on vent system	S2	F3	S2 based on unfiltered release through stack
4.3.c.is	4.3.3 Spurious fire suppression activation (no fire) causes pressurization of glovebox and loss of confinement	Vent system flow capacity insufficient to maintain confinement on activation of fire suppression system	Loose contamination in glovebox	Pressurization of glovebox	CAMs in room detect release from gloveboxes room ventilation system filters the release before discharge to the environment alarm on system actuation	visual detection by operators	S2	F3	S1 based on release through small penetrations in glovebox
4.7.e.is	4.7.5 Loss of instrument air supply could potentially cause glovebox pressurization and loss of confinement	Line break Compressor failure Valved out Power loss	Loose contamination within glovebox	Operational upsets Contamination spread between gloveboxes Loss of confinement Pressurized glovebox	Alarms on low supply pressure	Operator training and procedures	S2	F3	Do dump valves fail as is on loss of air supply or do they fail open?
4.7.f.is	4.7.6 Plant instrument air failures cause pressurization of glovebox and loss of confinement	Line breach Regulator failure Actuator cylinder seal failure	Loose contamination in glovebox Powder in cans creating additional contamination	Pressurize gloveboxes Possible movement of contamination between glovebox areas Migration of contamination in glovebox to room atmosphere Gross contamination of glovebox areas requiring cleanup	Glovebox design (robust construction and PRV) Glovebox ventilation exhaust design minimizes pressurization CAMs in room with alarms	Operator training and emergency response	S2	F3	Possible S2 consequence if room ventilation filter is failed S1 consequence if building ventilation system operating properly

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - LOSS OF CONFINEMENT BY GLOVEBOX MECHANICAL DAMAGE									
2.3.a.op	2.3.1 Radioactive material spill inside glovebox (e.g., canister spill) and release to room due to external impact to glovebox - SPS Material Preparation Area - First Section	Contents of canister spilled during opening or handling operation External impact on glovebox	Contents of canister (0.5 to 2.5 kg Pu oxide)	Release of Pu inside glovebox	Glovebox confinement system (box, ventilation, inlet and outlet ventilation filters) Canister handling system controls and instrumentation Glovebox secured to floor	Operator training and procedures	S2	F3	
2.4.a.op	2.4.1 Radioactive material spill inside the glovebox and release to room due to external impact to glovebox - Material Preparation Area Second section	Contents of canister spilled during opening or handling operation External impact on glovebox Also Release from powder dispensing station during filling of furnace trays Spill from furnace tray Release from size reduction equipment	Material being transferred to furnace trays Material on furnace tray if tray dumped by handling equipment	Release of Pu inside glovebox	Glovebox confinement system (box, ventilation, inlet and outlet ventilation filters) Canister handling system controls and instrumentation Glovebox secured to floor	Operator training and procedures	S2	F3	How do you open 3013 cans needing rework? Intrinsically dusty process poses potential for glovebox air contamination levels higher than in other sections of SPS
2.5.a.op	2.5.1 Radioactive material spill inside the glovebox and release to room due to external impact on glovebox - Transport Area	Above contents of canister spilled during opening or handling operation External impact on glovebox Spill from furnace trays (multiple)	Material being transferred on trays and in cans	Release of Pu inside glovebox	Glovebox confinement system (box, ventilation, inlet and outlet ventilation filters) Canister handling system controls and instrumentation Glovebox secured to floor	Operator training and procedures	S2	F3	
2.6.a.op	2.6.1 Radioactive material spill inside the glovebox and release to room due to external impact on glovebox - Furnace Area	Above contents of canister spilled during opening or handling operation External impact on glovebox Spill from furnace trays (multiple)	Material being transferred on trays	Release of Pu inside glovebox	Glovebox confinement system Tray handler Glovebox secured to floor	Operator training and procedures	S2	F3	Confirm that water cooling is not used. Get details of how gas cooling works!!!

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.k.op	2.6.8.a Loss of glovebox integrity due to overheating	Overheated stabilization furnace(s) from loss of cooling, temperature control failure	Loose Pu oxide powder in glovebox (material in trays, etc.)	Release of contamination into room	Furnace temperature controls and indicators Furnace insulation Glovebox heat detection Room CAMs Room ventilation system Glovebox ventilation system Dump valves	Operator training and procedures	S2	F2	S2 rating based on unfiltered release Is there a possibility of fire system actuation from furnace overheating box? Compounds the confinement issue due to postulated loss of glovebox integrity.
2.6.l.op	2.6.8.b Loss of glovebox integrity due to overheating	Furnace door left open during heating cycle	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of contamination into room	Furnace door interlocks Glovebox heat detection Room CAMs Room ventilation system Glovebox ventilation system Dump valves	Operator training and procedures	S2	F3	S2 rating based on unfiltered release
2.7.a.op	2.7.1 Radioactive material spill inside the glovebox and release to room due to external impact on glovebox - LOI test area	Spill from furnace trays (multiple) during handling Spill of material during sampling External impact on glovebox causes spill	Material being transferred on trays Material transferred to crucible	Release of Pu inside glovebox	Glovebox confinement system (glovebox filter, exhaust system fans and filters) Tray handler Glovebox secured to floor	Operator training and procedures	S2	F3	S2 ranking based on unfiltered release to environment
4.10.c.is	4.10.3 High velocity object striking glovebox results in loss of confinement due to glovebox damage	Failure of bottle restraints allows bottle to fall and break main supply valve Bottle dropped during replacement of empty bottles Random bottle or piping failure	Contamination contained in gloveboxes	Contamination released to room due to impact of high pressure gas propelled bottle Possible personnel injury Possible damage to other equipment/systems in immediate vicinity	Fall prevention restraints required on all high pressure gas bottles Carts used to move bottles have restraints to prevent tip off	Operator training and operating/maintenance procedures	S2	F2	S2 ranking based on bottle striking and damaging glovebox. F2 ranking based on probability of random direction of motion

Table B-2

S2 Accidents Resulting from Loss of Glovebox Configuration

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.15.c.is	4.15.3.b Sprinkler system falls on glovebox creating breach	Hanger failure Seismic event causing hanger failure	Pu oxide in gloveboxes	Loss of glovebox confinement Possible water intrusion into glovebox Possible criticality	Design of hangers and building structure Building ventilation system (in case of no seismic event)		S2	F2	This is a "3/1" type of problem S2 based on glovebox breach
4.6.a-2.is	4.6.1 Loss of cooling to furnaces results I glovebox damage and loss of confinement	Loss of supply Loss of power	Loose contamination in glovebox	Exceed glovebox operating temperature limit Glovebox integrity compromised Potential loss of confinement due to seal failures and heat load which pressurizes box Personnel hazard due to high temperature Extremely hot shell could cause a fire	Temperature measurement within the glovebox Controls on cooling loop Glovebox design Glovebox ventilation system removes part of the excess heat Dump valves	Operator procedures and training	S2	F3	S2 if overheating causes glovebox fire

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-3

S2 Release Accidents Caused by Fire

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - FIRE									
2.2.g-2.op	2.2.7 Fire in glovebox - Receipt area	Electrical equipment ignites packaging materials in glovebox	Loose contamination on packaging material and on other surfaces in the glovebox	Elevated release inside glovebox Degradation of glovebox integrity	Glovebox heat detection Dump valves limit potential pressurization Fire suppression system SPS ventilation system Robust glovebox design Room ventilation system	Housekeeping procedures to limit combustible loading	S2	F2	S2 if fire spreads to other gloveboxes (less likely)
2.3.c-2.op	2.3.3 Fire inside glovebox - Preparation Area - First Section	Plastic bags, cleanup rags, other fuel sources ignited by electrical equipment Pyrophoric metal shavings/turnings ignited Overheated furnace	Loose Pu oxide in glovebox and on packing packaging materials Pu material contained in entire machine (if fire spreads/ consumes other gloveboxes)	Pu released to room and through building vent system Soot and water vapor released challenging building vent system Building damage	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Pyrophoric material controls Visual checks to detect insertion of metal shavings/turnings	S2	F2	S1/F# for fire not spreading to other gloveboxes S2/F2 for fire postulated to spread to other areas of the machine containing more loose Pu material
2.4.c-2.op	2.4.3 Fire inside glovebox - Material Preparation Area Second Section	Plastic bags, cleanup rags, other fuel sources ignited by electrical equipment Pyrophoric metal shavings/turnings ignited Overheated furnace	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Pu released to room and through building vent system Soot and water vapor released challenging building vent system Building damage	Dry fire protection system for glovebox glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Pyrophoric material controls Visual checks to detect insertion of metal shavings/turnings	S2	F2	Loose Pu material available for release in Section 2 greater than in Section 1
2.5.c-2.op	2.5.3 Fire inside glovebox - Transport Area	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Training and procedures	S2	F2	S2/F2 based on fire that involves multiple SPS gloveboxes

Table B-3

S2 Release Accidents Caused by Fire

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.d-2.op	2.6.4 Fire inside glovebox - Furnace Area	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short Overheat of furnaces coupled with combustible materials being present	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system Robust glovebox design Glovebox ventilation system Room ventilation system Room fire suppression system	Fire loading limits Training and procedures	S2	F2	S2/F2 based on fire that involves multiple SPS gloveboxes
2.7.d-2.op	2.7.4 Fire inside glovebox - LOI test area	Combustible materials left from cleanup, insulation on wiring ignited by spontaneous combustion or electrical short Overheat of furnace coupled with combustible materials present	Loose Pu oxide powder in glovebox (material in trays and crucibles)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system Robust glovebox design Glovebox ventilation system Room ventilation system Room fire suppression system	Fire loading limits Training and procedures	S2	F2	S2/F2 based on fire that involves multiple SPS gloveboxes
2.8.c-2.op	2.8.3 Fire inside glovebox - Tipping/Dispense/Fill area	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Training and procedures	S2	F2	S2/F2 based on fire that involves multiple SPS gloveboxes
4.15.a.is	4.15.1 Failure to extinguish fire in Room 641 and 642	Failure of sprinkler system to activate Failure of water supply	Pu oxide in gloveboxes	Damage to gloveboxes Damage to building structure	Design of fire system	Operator training and procedures	S2	F3	Fire presumed in this accident

Table B-3

S2 Release Accidents Caused by Fire

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.3.a.is	4.3.1 Glovebox fire suppression system fails to activate during a glovebox fire	Detectors fail to detect fire Bottle or line failure	Loose contamination in glovebox Combustibles in gloveboxes (source of toxic gases)	Potential damage to glovebox integrity Potential spread of fire to other gloveboxes	heat Sensors in the glovebox Gloveboxes design minimizes potential for significant fires Soot from small fires mitigated by glovebox and room ventilation system filters	Visual detection by operators Operators can extinguish fire with MgO_2 Fire protection program for testing and maintenance of fire suppression system Combustible loading administratively controlled	S2	F2	S2 ranking based on assumption fire could involve the entire line of gloveboxes. Pu release through building ventilation system assumed to be unfiltered. F3 for small fires Large fire will plug ventilation system filters with water and soot
4.3.b.is	4.3.2 Glovebox fire suppression system activates and overpressurizes gloveboxes during fire	Vent system flow capacity insufficient to maintain confinement on activation of fire suppression system	Loose contamination in glovebox Combustibles in gloveboxes (source of toxic gases)	Spread of contamination from glovebox	Heat sensors in the glovebox Gloveboxes design minimizes potential for significant fires Soot from small fires mitigated by glovebox and room ventilation system filters	Visual detection by operators Operators can extinguish fire with MgO_2 Fire protection program for testing and maintenance of fire suppression system Combustible loading administratively controlled	S2	F3	
EXTERNAL EVENTS CAUSING FIRE									
6.1.c-2.ex	6.1.3 Fire spreading to SPS room from other portions of the facility		Loose contamination on packaging material and on other surfaces in the glovebox	Elevated release inside glovebox Degradation of glovebox integrity	Glovebox heat detection Dump valves limit potential pressurization Fire suppression system SPS ventilation system Robust glovebox design Room ventilation system	Housekeeping Procedures to limit combustible loading	S2	F2	S2 if fire spreads to other gloveboxes (less likely)

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-4

S2 Accidents Resulting from Canister Ruptures

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - LOSS OF CANISTER CONFINEMENT									
2.7.j.op	2.7.9 Inadequate stabilization of Pu oxide results in failure of canister and release of Pu oxide during storage	LOI test fails to detect inadequate stabilization See 2.5.9 for furnace faults leading to inadequate stabilization	Quantity of Pu represented by LOI sample	Unstabilized Pu oxide sent on for packaging (eventually resulting in can swelling during long term storage) Process upset if discovered	Stabilization furnace temperature controls and indication, timers, etc. LOI furnace instrumentation (thermocouple readings, amp gauges) allows operator to discover furnace faults CAMs monitor vault atmosphere for canister failures (subsequent consequence control)	Operator training and operating procedures	S2	F2	S2 based on unfiltered release through vault vent system
2.8.g.op	2.8.7 Potential 3013 canister failure in storage vault releasing Pu oxide	Too much Pu (mass) tipped from furnace tray into convenience can caused by failure at weighing station in material prep area Double batch on furnace tray	Pu material in convenience can	3013 canister violating mass limit 3013 canister violating storage wattage limit Pressurization of 3013 package in storage vault; potential rupture of 3013 package in vault	Powder dispensing station scale (initiating failure) Can fill station scale Convenience can weigh station (in can weigh and cap insertion area) Vault ventilation system heat removal capacity may prevent over pressurization 3013 package designed to withstand high pressures	Operator training	S2	F3	
2.8.h.op	2.8.8 Potential 3013 canister failure in storage vault releasing Pu oxide	Furnace tray sent back to material prep area with Pu material still in it caused by failures in weighing at tray fill station or the convenience can fill station	Preexisting Pu material added to new load in convenience can on next cycle	Too much material in furnace tray on next cycle; exceed mass limit in convenience can on next cycle with possible overheating due to excess material. Or process upset, if detected Large worker exposure to ionizing radiation	Powder dispensing station scale (initiating failure) Can fill station scale Convenience can weigh station (in can weigh and cap insertion area) Vault ventilation system heat removal capacity may prevent over pressurization 3013 package designed to withstand high pressures	Operator training	S2	F3	

Table B-4

S2 Accidents Resulting from Canister Ruptures

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
3.4.g.op	3.4.7 Radioactive contamination in vault due to leaky canister	Leaky 3013 package(s)	Portion of material in 3013 package vault	Worker exposure Small release to environment through ventilation system Potential spread of contamination to other areas of facility	3013 package design	Two leak tests provide confidence in integrity of packages Stabilization process limits potential for canister rupture	S2	F3	
3.5.a.op	3.5.1 Contamination in Vault from leaking 3013 packages	Canister rupture due to inadequate pu oxide stabilization in sps Canister rupture due to overloading canisters (too much pu in container results in overpressure due to helium production by decay) Inner and outer overpacks on some canisters not sealed properly and not detected	Portion of material in leaking packages	Small airborne release through ventilation system Worker exposures during entries into vault Potential spread of contamination to other areas of the facility Additional personnel exposures due to cleanup	Vault air monitored with CAMs Vault ventilation system Robust 3013 package design	Leak tests Stabilization process in SPS Mass of Pu added to convenience cans measured in SPS system	S2	F3	
3.5.c.op	3.5.3 Failure of canisters due to overheating from high wattage from overfilling	Several packages stored in vault that exceed wattage limit	Material in 3013 storage packages	Failure of 3013 packages due to overpressure or overtemperature	Ventilation system Design of tube racks or cubicles	SPS system monitors quantity of material added to convenience cans to limit wattage	S2	F2	localized overheating in vault High wattage canisters unlikely to be loaded in a cluster are thermocouples located throughout the vault?
4.7.b.is	4.7.2 High moisture content in air causes storage canister failure due to pressure buildup from inadequately stabilized Pu oxide	Failure of dryer	Pu oxide stabilized inside the furnaces over the time period of the malfunction Pu oxide LOI tested during time period of malfunction Pu oxide run through desiccator during the time period of the malfunction	Understabilized Pu oxide sent on to final packaging without detection (potentially) Subsequent pressure buildup in 3013 canisters in storage; potential rupture of canister and release of contamination from the vault ventilation system	Moisture detection in instrument/plant air supply 3013 cans designed to withstand high pressures CAMs monitor vault atmosphere	Operator training and procedures	S2	F2	common cause failure may make it difficult to detect unstabilized Pu oxide

Table B-4

S2 Accidents Resulting from Canister Ruptures

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
				EXTERNAL EVENT CAUSED LOSS OF CANISTER CONFINEMENT					
9.5.ch	9.5.1 Construction activities effect ventilation supply to storage vaults in 2736-Z (e.g. damage or crush existing supply ductwork) If crane used, crane could drop load onto or fall into vault or other portion of the facility	Human error Crane failure or human error	Vault contents	Overheat storage vault if supply affected Crane damage may result in radiological release to environment	Vault ventilation system instrumentation to indicate loss of supply flow	Crane rigging manual Construction plan	S2	F3	
9.6.ch	9.6.1 Increase heat load in other vaults because contents of vault being modified will need to be moved creates overheating that causes rupture of storage canisters	Inadequately analyzed storage conditions Human error	Portion of Pu oxide in current storage canisters	Possible canister rupture and Pu oxide release	Vault ventilation system Vault storage rack configuration prevents storage of too many canisters Criticality alarms	Criticality control program prevents criticality in vault where extra canisters are being held	S2	F1	This accident is outside the scope of the project. It is assumed that current storage configuration is appropriate for storage of the required number of canisters

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-5

S2 Release Accidents Resulting from Storage Vault Overheating

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - VAULT OVERHEAT CAUSES LOSS OF CANISTER CONFINEMENT									
3.5.b.op	3.5.2 Canister/Vault Overheating results in release of Pu oxide from canister failure	Long term loss of ventilation flow due to equipment failures Long term loss of power	Material in 3013 storage packages	Degradation of concrete structure (concrete dehydration) Concrete structure compromised due to thermal stress induced cracking Failure of 3013 packages due to overpressure or overtemperature	Temperature monitoring Backup power? Ventilation system design (redundant fans?) Ventilation system instrumentation	Recovery procedures for loss of ventilation or loss of power (avoidance of long term loss of ventilation)	S2	F3	S2 for canister ruptures Catastrophic failure of structure beyond design basis and thus not postulated
5.1.a.is	5.1.1 Loss of sufficient ventilation results in overheating of canisters in storage and subsequent canister failures and release of Pu oxide	Ventilation upsets Loss of power Equipment failures	Material made available for release from canister ruptures	Overheating and pressurization of canisters; potential rupture of canisters Dehydration of concrete; decreased margin of safety in vault structural capacity	Ventilation system controls and alarms Redundant supply and exhaust fans Backup power diesel generator 3013 cans may be sufficiently robust to withstand heat up without breach Local power loss causing loss of vault supply or exhaust will set off alarms Instrumentation in vault ventilation system will indicate loss of ventilation flow	Operator action to restore power	S2	F2	Vault steady state temperature may or may not exceed structural limits at steady state Represents a threat to vault capability to withstand DBE Thermal analysis being performed to determine if vault structural damage is possible 3013 canisters may exceed design limits for temperature

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-6

S3 Accident, Aircraft Impact with Building Causes Release from SPS

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
6.3.a.ex	6.3.1 Aircraft Crashes into 2736-Z or ZB collapsing roof or walls causing release of Pu oxide	Aircraft mechanical failure during overflight Human error during overflight	Pu in storage vault or SPS	Destruction of building structure and release of Pu oxide	--	--	S3	F0	See PFP FSAR

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-7

S2 Accidents, Vehicle Impact with Building Causes Release from SPS

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
6.3.b.ex	6.3.2 Vehicle Impact into 2736-Z or ZB results in structural damage to building and SPS gloveboxes	Vehicle strikes facility, goes through wall opening and impacts SPS	Pu in storage vault or SPS	Release of Pu oxide from glovebox damaged by impact Possible fuel fire	Robust building structure Limited area to build up velocity	Operator training and procedures	S2	F3	See PFP FSAR

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-8

S2 Accident, Seismic Event Causes Release from SPS

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
7.1.a.np	7.1.1.b Seismic Event causes glovebox damage, loss of confinement, building damage, and Pu oxide release	NA	Pu oxide powder in glovebox Stabilized Pu oxide in canisters in SPS room and storage vaults	Loss of power leading to loss of ventilation for gloveboxes and vaults Damage to facility Damage to gloveboxes Spilling of Pu oxide within glovebox Possible criticality initiator due to material geometry rearrangement Shaking of contamination of equipment/glovebox surfaces Various equipment failures Fires Fire/other water line breaks Spread of Pu oxide powder from facility through compromised ventilation systems or damaged structure	Seismically qualified buildings and vaults SPS machine anchoring seismically qualified Seismic displacement absorber on SPS machine	Emergency response procedures	S2	F2	Adds source term to PFP FSAR seismic accident analysis 3/1 interactions should be looked at in detail in definitive design
9.2.ch	Compromise seismic integrity of structure due to openings in load bearing walls	Change the response of load bearing walls to seismic forces	Very little contamination in building or ductwork expected during construction activities After startup, material at risk is Pu oxide in process at the time of a seismic or high wind event	Partial structural collapse in DBE after startup; release of Pu from facility No effect on vault ventilation system expected due to reconfiguration of building rooms	New door and frame will be designed to maintain seismic qualification of structure	Analysis of modification before performed USQ process ECN reviews	S2	F3	

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table B-9

Accident, Extreme Wind Causes Release from SPS

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
7.1.b.np	7.1.2 High Wind results in creation of high velocity objects that impact building	High velocity projectile caused by wind strikes the building structure and penetrates wall damaging glovebox	Pu oxide in gloveboxes Pu oxide in canisters in room and vaults	Damage to building and glovebox Loss of power	2736-Z and 2136-ZB buildings designed to withstand DBW and credible wind driven missiles		S2	F3	S2 category based on damage to glovebox and release to environment S1 for loss of power causing contamination spread from glovebox exposing operators see also PFP FSAR high wind accident analysis

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

APPENDIX C

S1 AND S0 ACCIDENT TABLES

Table C-1. S1 and S0 Accidents Resulting in Unfiltered Release Via Room C-2
Table C-2. S1 Release Accidents Caused by Fire C-12
Table C-3. S1 Criticality Accidents C-15
Table C-4. S1 and S0 Accidents, Loss of Canister Confinement C-23
Table C-5. S1 Worker Protection Related Accidents C-26
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Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - UNFILTERED RELEASE FROM BUILDING									
5.1.c.is	5.1.2.b Loss of confinement results in unfiltered release from building	Loss of filtration	Contamination present in vault	Unfiltered release to environment	Stack CAM HEPA filters in series	--	S1	F3	very limited contamination expected in vault
4.13.a-0.is	4.13.1 Loss of filtration causes unfiltered release to environment	HEPA seal failures Human error during maintenance or installation Long term plugging of HEPA filter Impact by objects entrained in air flow Wrong train placed in service during maintenance Smoke/water vapor plugs HEPA filter from fire-filter blowout	Contamination in room Pu oxide contamination in glovebox atmosphere	Unfiltered release of contamination in room to environment Significant release to environment if glovebox confinement concurrently fails	dP Alarms across filter Exhaust CAMs	Periodic filter testing Operator training and procedures	S0	F3	
INTERNAL INITIATOR - LOSS OF CONFINEMENT BY GLOVEBOX MECHANICAL DAMAGE									
2.3.i.op	2.3.7 Excess vacuum in glovebox causes damage to glovebox and loss of confinement - SPS Material Preparation Area - First Section	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose contamination in glovebox	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.4.i.op	2.4.7 Excess vacuum in the glovebox causes damage to glovebox and loss of confinement - Material Preparation Area Second Section	Imbalance between exhaust and dry air supply loss of dry air supply	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.5.g.op	2.5.6 Excess vacuum in the glovebox causes damage to glovebox and loss of confinement - Transport Area	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.6.j.op	2.6.7 Excess vacuum in the glovebox causes damage to glovebox and loss of confinement - Furnace Area	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.7.h.op	2.7.7 Excess vacuum in the glovebox results in damage to glovebox and loss of confinement - LOI test area	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
2.7.i.op	2.7.8 Loss of glovebox integrity due to overheating - LOI test area	Overheated LOI furnace, temperature control failure Furnace damaged or knocked over	Loose Pu oxide powder in glovebox (material in trays, crucibles)	Release of contamination into room	Furnace temperature controls and indicators Furnace insulation Glovebox heat detection Room CAMs Room ventilation system Glovebox ventilation system Dump valves Furnace secured to bottom of glovebox	Operator training and procedures	S1	F2	S1 rating based on unfiltered release is there a possibility of fire system actuation from furnace overheating box? compounds the confinement issue due to postulated loss of glovebox integrity.

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.8.f.op	2.8.6 Excess vacuum in the glovebox causes damage and loss of confinement-Tipping/Dispense? fill area	Imbalance between exhaust and dry air supply Loss of dry air supply	Loose Pu oxide powder in glovebox (material in trays, etc)	Degraded glovebox seal integrity, potential glovebox collapse possible release of Pu to room	Robust construction of the glovebox Exhaust fans limited in vacuum they can produce Ventilation instrumentation and controls Room CAMs detect and alarm on spread of contamination from glovebox	Operator training and procedures	S1	F3	
4.2.e.is	4.2.5 Insufficient airflow results in glovebox overheating and loss of confinement	Exhaust fan failure Closed damper Plugged filter Imbalance between supply and exhaust	Loose contamination in glovebox	Potential damage to glovebox integrity (seal failures)	Temperature in gloveboxes are monitored Flow indicators on exhaust Backup fan	Operator training and procedures	S1	F3	
4.6.a-1.is	4.6.1 Loss of cooling to furnaces results in glovebox damage and loss of confinement	Loss of supply Loss of power	Loose contamination in glovebox	Exceed glovebox operating temperature limit Glovebox integrity compromised Potential loss of confinement due to seal failures and heat load which pressurizes box Personnel hazard due to high temperature Extremely hot shell could cause a fire	Temperature measurement within the glovebox Controls on cooling loop Glovebox design Glovebox ventilation system removes part of the excess heat Dump valves	Operator procedures and training	S1	F3	S1 based on overheating causing seal failures

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.2.f.op	2.2.6 Load in wrong container/material (Pu nitrate, scrap metal, metal button, Pu fluorides) in receipt area could result in damage to glovebox and loss of confinement	Human error	see remarks	see remarks	Assay unit	Controls on material originally put in vault Metals inventory will be oxidized or packaged before SPS operates Packages containing Pu metals will be different size than Pu oxide containing packages Labelling of containers Other Pu materials in PFP will be stabilized or disposed before SPS operates Containers ID'd (bar code checked) after loading in Container assayed in mat prep glovebox	--	--	Item for further development. Expectation is that only Pu oxides will be received. To be developed further in definitive design
2.10.d.op and 2.11.j.op	2.10.4/2.11.10 Laser beam impinges on SPS wall or equipment instead of canister	Fiberoptic cable not installed properly Laser not aimed properly Can not in place when laser is on	Loose Pu in glovebox	Laser may burn hole through glovebox resulting in the release of small quantities of Pu to room	Glovebox ventilation system	Operator training and procedures	S1	F3	Potential also for operator injury due to viewing of laser light or reflections
INTERNAL INITIATOR - LOSS OF CONFINEMENT BY GLOVEBOX PRESSURIZATION									
2.10.a.op	2.10.1 Loss of confinement in fume hood due to pressurization - Inner Can Handling Area	Loss of exhaust flow due to equipment failures, loss of power, closed dampers, etc.	Fumes normally exhausted through fume hood Radiological contamination in fume hood	Welder fumes and helium leak into room Minor contamination spread to room if contaminated canisters have been handled	Room ventilation system Room CAMs	Operator training and procedures	S1	F3	no protection for facility worker for toxic fumes emitted
2.10.b.op	2.10.2 Leak of air into can weigh and cap insertion station (see above) resulting in glovebox pressurization - Inner Can Handling Area	Rotating sphincter seal failure Can not in rotating sphincter	Fumes normally exhausted through fume hood Radiological contamination in fume hood	Welder fumes and helium leak into room Minor contamination spread to room if contaminated canisters have been handled	Room ventilation system Room CAMs	Operator training and procedures	S1	F3	no protection for facility worker for toxic fumes emitted
2.2.h.op	2.2.8 Pressurized glovebox results in loss of confinement - Receipt area	Ventilation upsets Fire: electrical equipment ignites packaging materials in glovebox	Loose contamination on packaging material and on other surfaces in the glovebox	Spread of contamination to room atmosphere	Room CAMs ventilation system instrumentation Dump valves	training and procedures	S1	F3	

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.7.f.op	2.7.5.b Pressurized glovebox results in loss of confinement - LOI test area	Furnace dry air high flow (failure of control valve) Desiccator dry air high flow (failure of control valve	Loose Pu oxide powder in furnace Loose Pu oxide powder in desiccator	Minor spread of contamination into glovebox(s)	Glovebox design limits potential out-leakage Dump valves limit potential pressurization Glovebox ventilation system instrumentation Interlocks prevent operations inside the machine upon detection of ventilation system out of parameter PRV/regulator on dry air supply CAMs in room alarm upon contamination spread from glovebox Flow/pressure gauges on pneumatic and instrument air systems will detect major gas leak Room ventilation system prevents spread of contamination to other rooms and filters release before release out the stack	Worker training and procedures Emergency response procedures Housekeeping controls limit Pu accumulation in glovebox	S1	F3	LOI furnace filter may become plugged? blow up the furnace???
2.9.d.op	2.9.4 Pressurized Glovebox results in loss of confinement - Can Weigh and Cap Insertion Area	Loss of ventilation exhaust Excessive helium flow rate	Airborne contamination present in glovebox	Release of contamination to room	Robust glovebox construction and low leak rate Room CAMs Room ventilation system Glovebox ventilation system controls and alarms	Operator training and operating procedures	S1	F3	S1 based on low contamination level expected in glovebox
4.12.a.is	4.12.1 Insufficient room supply flow causes apparent glovebox pressurization and loss of confinement	Failure of supply fan Ventilation supply damper fails closed	Pu oxide contamination in glovebox atmosphere	Excessive negative dP relative to glovebox Possible movement of Pu oxide contamination it nor room from glovebox (air flow reversal)	Ventilation system has backup supply fan Ventilation system controls shutdown system on low flow indication Room CAMs Supply fan loss of pressure alarm	Operator training and procedures	S1	F3	S1 based on intact glovebox

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.13.c.is	4.13.3 Excessive exhaust flow rate causes apparent glovebox pressurization and loss of confinement	Fully open damper (failure of damper controls)	Pu oxide contamination in glovebox atmosphere	High negative pressure in room Release of Pu oxide from glovebox	Control system for ventilation Room CMAs Pressure alarms for ventilation system	Operator training and procedures	S1	F3	May or may not result in glovebox being positive to room - see 4.12.1
INTERNAL INITIATOR - LOSS OF GLOVEBOX CONFINEMENT BY VENTILATION STAGNATION									
2.3.h.op	2.3.6 Stagnant glovebox - Can Weigh and Cap Insertion Area	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose contamination in glovebox	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S1	F3	
2.4.h.op	2.4.6 Stagnant glovebox - Material Preparation Area Second Section	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S1	F3	
2.5.f.op	2.5.5 Stagnant glovebox - Transport Area	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S1	F3	

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.i.op	2.6.6 Stagnant glovebox - Furnace Area	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S1	F3	
2.7.g.op	2.7.6 Stagnant glovebox - LOI test area	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S1	F3	
2.8.e.op	2.8.5 Stagnant glovebox - Tipping/Dispense/Fill area	Loss of both dry air supply and building exhaust (could be caused by loss of power) Isolation valves or dampers closed on both supply and exhaust	Loose Pu oxide powder in glovebox (material in trays, etc)	Release of Pu to room atmosphere	Glovebox ventilation system instrumentation indicates loss of flow, loss of vacuum. Room CAMs detect spread of contamination from glovebox. Room ventilation system confines release to room and filters release to environment through stack	Housekeeping controls limit Pu accumulation in glovebox	S1	F3	
2.9.e.op	2.9.5 Stagnant glovebox - Can Weigh and Cap Insertion Area	Concurrent failure of ventilation exhaust and helium supply	Airborne contamination present in glovebox	Release of contamination to room	Room CAMs Room ventilation system Glovebox ventilation system controls and alarms	Operator training and operating procedures	S1	F3	S1 based on low contamination level expected in glovebox

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.1.c.is	4.1.3 Loss of dry air supply results in glovebox stagnation and loss of confinement	Loss of power Compressor failure Supply inadvertently valved out Failure of pressure regulation system Plugged line Failure of dryer	Pu material in vault canisters	Swelled/potentially ruptured canisters in storage vault	LOI test Moisture detection in plant air supply system	--	S1	F3	
4.14.a.is	4.14.1 Building ventilation system fails resulting in room and glovebox stagnation and loss of confinement	Loss of power Control system shutdown of supply and exhaust fans	Pu oxide contamination in glovebox atmosphere	Loss of room negative pressure (confinement) Loss of glovebox exhaust and negative pressure (confinement) Migration of Pu oxide into room	Kicker fan High ventilation pressure alarms Backup supply and exhaust fans Packup power supply CAMS in room Glovebox filters Building structure (and airlocks)	Operator training and procedures	S1	F3	Expected state of ventilation system if kicker fan required to be on S1 based on glovebox intact but some leakage
4.2.b.is	4.2.2 Loss of SPS exhaust and supply results in stagnant gloveboxes and loss of confinement	Loss of power Control failures	Loose contamination in glovebox	Migration of Pu material from the gloveboxes to room atmosphere (subsequent release through stack)	Room ventilation system and filters Building structure CAMs in room SPS alarms on lack of negative pressure Backup fan	Operator training and response Routine maintenance on vent system	S1	F3	S2 based on unfiltered release through stack

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.2.c.is	4.2.3 Recirculation loop caused by kicker fan with failure of isolation dampers results in glovebox stagnation and loss of confinement	Loss of primary loss and failure of isolation damper to close when backup (new) exhaust fan turns on	Loose contamination in glovebox	Migration of Pu material to room atmosphere Release of Pu through penetrations in building (function of room/building ventilation system has been defeated) Gloveboxes are probably under positive pressure because of dry air supply flow	HVAC instrumentation (flow indication, pressure indication, damper positions indication, etc) Glovebox pressure indication Room CAMs	Operator training and procedures	S1	F3	Fix potential for recirculation loop
4.4.a.is	4.4.1 Global or local loss of power results in stagnate gloveboxes and room and loss of confinement	Site supply failures outside facility (natural phenomena, etc.) In-facility failures, (e.g., shorts, overloads, switchgear failures, etc.) Facility fires not associated with SPS operations	Loose contamination in glovebox	Faults that cause erroneous equipment operations make ventilation behavior difficult to predict Loss of ventilation flow in SPS or vault (see dry air supply and exhaust, vault ventilation system) Loss of instrumentation Potential spread of contamination from gloveboxes to room; operator exposures Canister handling failures resulting in Pu spills inside gloveboxes adding to loose contamination available for release Operating problems leading to increased worker exposure upon recovery Failure to adequately stabilize some oxide material; subsequent swelling/rupture of canisters in vault	Gloveboxes designed to minimize leakage Ductwork to filters is seismically qualified Room CAMs connected to backup power Glovebox pressure indication warns operator of potential loss of confinement UPS Backup power	Operator detection and response	S1	F3	S1 ranking based on assumed complete loss of power. Pu assumed to be released from stagnant building through cracks, penetrations, and seals. Is vent system connected to backup power? What is UPS connected to? What is backup diesel generator connected to?
4.4.b.is	4.4.2 Various failures can result in glovebox stagnation or pressurization and subsequent loss of confinement			Combinations of faults that are undesired (loss of power to select systems/components)	--	--	--	--	Beyond scope of this evaluation. Various combinations of faults with the electrical system should be addressed during the definitive design phase.

Table C-1

S1 and S0 Accidents Resulting in Unfiltered Release Via Room

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
EXTERNAL EVENT INITIATOR - LOSS OF CONFINEMENT BY GLOVEBOX MECHANICAL DAMAGE									
6.3.c.ex	6.3.3 Tall structures falling into building	see remarks	--	--	--	--	--	--	See PFP FSAR
6.3.d.ex	6.3.4 Effects of Military Activities	see remarks	--	--	--	--	--	--	See PFP FSAR
6.3.e.ex	6.3.5 Range Fire	see remarks	--	--	--	--	--	--	Out of scope SPS and vault modifications do not change baseline compared to original facility
NATURAL PHENOMENA - CAUSING LOSS OF GLOVEBOX CONFINEMENT DUE TO GLOVEBOX DAMAGE									
7.1.c.np	7.1.3 Lightning strikes building resulting in damage	NA	Pu oxide in gloveboxes	Damage to building Loss of power Equipment failures	Lightening protection system Stout building design	--	S1	F3	S1 for equipment failures causing worker injury or exposures contamination spread to environment due to loss of ventilation expected to be minor
7.1.e.np	7.1.5 Ashfall	Natural phenomena	Pu in gloveboxes and vault	Damage to building Loss of power	Stout building design	Operator actions to shutdown activities, change out filters, and potentially shovel off roofs	S1	F2	S1 for migration of Pu oxide to room from SPS due to loss of power/loss of SPS ventilation Long term loss of power and ash buildup in vaults could cause vault overheating
7.1.f.np	7.1.6 Range fire	Natural phenomena	Pu in gloveboxes and vault	Damage to building Loss of power	Stout concrete building design	Groundskeeping Hanford Fire Department	S1	F3	S1 for migration of Pu oxide to room from SPS due to loss of power/loss of SPS ventilation Long term loss of power and ash buildup in vaults could cause vault overheating

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table C-2

S1 Release Accidents Caused by Fire

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
				INTERNAL INITIATOR - FIRE					
2.2.g-1.op	2.2.7 Fire in glovebox - Receipt area	Electrical equipment ignites packaging materials in glovebox	Loose contamination on packaging material and on other surfaces in the glovebox	Elevated release inside glovebox Degradation of glovebox integrity	Glovebox heat detection Dump valves limit potential pressurization Fire suppression system SPS ventilation system Robust glovebox design Room ventilation system	Housekeeping procedures to limit combustible loading	S1	F3	S1 for anticipated fire
2.3.c-1.op	2.3.3 Fire inside glovebox - Preparation Area - First Section	Plastic bags, cleanup rags, other fuel sources ignited by electrical equipment Pyrophoric metal shavings/turnings ignited Overheated furnace	Loose Pu oxide in glovebox and on packing packaging materials Pu material contained in entire machine (if fire spreads/ consumes other gloveboxes)	Pu released to room and through building vent system Soot and water vapor released challenging building vent system Building damage	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Pyrophoric material controls Visual checks to detect insertion of metal shavings/turnings	S1	F3	S1/F# for fire not spreading to other gloveboxes
2.4.c-1.op	2.4.3 Fire inside glovebox - Material Preparation Area Second Section	Plastic bags, cleanup rags, other fuel sources ignited by electrical equipment Pyrophoric metal shavings/turnings ignited Overheated furnace	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Pu released to room and through building vent system Soot and water vapor released challenging building vent system Building damage	Dry fire protection system for glovebox glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Pyrophoric material controls Visual checks to detect insertion of metal shavings/turnings	S1	F3	Loose Pu material available for release in section 2 greater than in section 1
2.4.k.op	2.4.9 Fire inside glovebox - Material Preparation Area Second Section	Human error causes canister to be Inadvertently opened and processed (material contained in canister intended to be overpacked) and passed through the system	Potentially metallic Pu in canister Other	Contamination from burning Pu Fire in glovebox (particularly if metal put in furnace)	Screened funnel prevents metal from being added to furnace tray (metal in larger pieces than powder)	Operator training and procedures controls on handling metal	S1	F2	

Table C-2

S1 Release Accidents Caused by Fire

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.5.c-1.op	2.5.3 Fire inside glovebox - Transport Area	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Training and procedures	S1	F3	S1/F3 based on small fire
2.6.d-1.op	2.6.4 Fire inside glovebox - Furnace Area	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short Overheat of furnaces coupled with combustible materials being present	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system Robust glovebox design Glovebox ventilation system Room ventilation system Room fire suppression system	Fire loading limits Training and procedures	S1	F3	S1/F3 based on small fire
2.7.d-1.op	2.7.4 Fire inside glovebox - LOI test area	Combustible materials left from cleanup, insulation on wiring ignited by spontaneous combustion or electrical short Overheat of furnace coupled with combustible materials present	Loose Pu oxide powder in glovebox (material in trays and crucibles)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system Robust glovebox design Glovebox ventilation system Room ventilation system Room fire suppression system	Fire loading limits Training and procedures	S1	F3	S1/F3 based on small fire
2.8.c-1.op	2.8.3 Fire inside glovebox - Tipping/Dispense/Fill area	Combustible materials left from cleanup, insulation on wiring, ignited by spontaneous combustion or short	Loose Pu oxide powder in glovebox (material in trays, etc)	Pu oxide particulate released to glovebox atmosphere Possible toxic gas release Glovebox structural integrity compromised Soot and water vapor release challenging SPS ventilation system	Dry fire protection system for glovebox Glovebox heat detection system SPS ventilation system Room ventilation system Glovebox design	Fire loading limits Training and procedures	S1	F3	S1/F3 based on small fire

Table C-2

S1 Release Accidents Caused by Fire

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
				EXTERNAL EVENTS CAUSING FIRE					
6.1.c-1.ex	6.1.3 Fire spreading to SPS room from other portions of the facility		Loose contamination on packaging material and on other surfaces in the glovebox	Elevated release inside glovebox Degradation of glovebox integrity	Glovebox heat detection Dump valves limit potential pressurization Fire suppression system SPS ventilation system Robust glovebox design Room ventilation system	Housekeeping Procedures to limit combustible loading	S1	F3	S1 for anticipated fire
6.2.b.ex	6.2.2 Fire spreading to vault corridor from other portions of the facility	Combustible materials ignited elsewhere in the facility; fire spreads to vault corridor		Loss of power to vault ventilation system Compromise structural integrity of a portion of the building or vault due to thermal stress or concrete dehydration Limited fire in vault if fire spreads to vault	Facility fire protection system Fire doors Air locks between vault and office areas Vault door prevents spread of fire to the inside of the vault Vault is constructed of noncombustible material Limited combustibles in vault	Emergency response procedures Fire prevention program Fire station	S1	F2	S1/F2 for loss of ventilation flow in vault due to loss of power; 3013 packages not expected to rupture due to loss of ventilation flow or small fire in vault. structural collapse due to facility fire beyond scope of this analysis--See PFP FSAR.
6.3.e.ex	6.3.5 Range Fire affecting 2736-ZB and 2736-Z buildings Out of scope SPS and vault modifications do not change baseline compared to original facility	--	--	--	--	--	--	--	beyond scope of this analysis.
9.4.ch	9.4.1 Fire occurs when fire water to portion of 2736-ZB or -Z inadvertently shut off during construction work on another section of the 2736-ZB or -Z fire protection system	Human error		Loss of fire protection in some areas away from modification work					

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
				INTERNAL INITIATOR - CRITICALITY					
1.1.d.op	1.1.4 Criticality in storage vault to SPS Machine path due to violation of double contingency	Use of unapproved cart Operator puts too many canisters on cart	NA	Violation of double contingency requirement Criticality may occur if two contingencies violated Operators exposed to high doses	Cart design prevents critical geometries	Criticality controls Procedures	S1	F3	
2.1.d.op	2.1.4 Criticality in SPS gloveboxes (general locations)	Too many canisters too close together Moderator (water) present with sufficient number of canisters	NA (primary hazard is ionizing radiation)	Operators exposed to high doses Release of fission product gases Release of Pu oxide powder disturbed in event to glovebox atmosphere	Criticality controls, including: Criticality detection in the gloveboxes, alarms in the rooms Criticality drains in gloveboxes Can handlers designed to only hold 1 can at a time Dry fire protection system for glovebox instead of water System designed in manner that prevents critical mass from coming together in a seismic event Spacing of storage spaces and equipment inside gloveboxes precludes criticality Design precludes ingress of water during seismic events Canister handling equipment interlocks preclude buildup of cans in areas of the machine	Criticality control procedures on spacing and number of containers in given area	S1	F3	check to see if criticality drains have been removed from design
2.11.i.op	2.11.9 Criticality in outer can weld area	Double contingency violation Too many canisters in lag storage placed too close together due to human error or automatic loader error Fire suppression system activation (during fire, or due to spurious failure) with sufficient number of 3013 packages stored in room	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages)	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.2.i.op	2.2.9 Criticality in receipt area	Too many canisters too close together Moderator (water) present with sufficient number of canisters	NA (primary hazard is ionizing radiation)	Operators exposed to high doses Release of fission product gases Release of Pu oxide powder disturbed in event to glovebox atmosphere	Criticality controls, including: Criticality detection in the gloveboxes, alarms in the rooms Criticality drains in gloveboxes Can handlers designed to only hold 1 can at a time Dry fire protection system for glovebox instead of water System designed in manner that prevents critical mass from coming together in a seismic event Spacing of storage spaces and equipment inside gloveboxes precludes criticality Design precludes ingress of water during seismic events Canister handling equipment interlocks preclude buildup of cans in areas of the machine	Criticality control procedures on spacing and number of containers in given area	S1	F3	check to see if criticality drains have been removed from design
2.3.b.op	2.3.2 Criticality inside glovebox - SPS Material Preparation Area - First Section	Too many cans simultaneously too close together Flooding with water in combination with multiple cans Flooding with other moderators (e.g., hydraulic oil)	Number of cans in material prep area	Operator exposed to high doses Release of fission product gases Release of pu oxide powder disturbed in event to glovebox atmosphere	Criticality controls, including: Criticality drains in gloveboxes Can handlers designed to only hold 1 can at a time Dry fire protection system for glovebox minimizes potential for water intrusion System designed such that only two cans can contact each other in a seismic event Design precludes ingress of water during seismic events Interlocks preclude buildup of cans in areas of the machine	Criticality control procedures on spacing and number of containers in given area	S1	F3	

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.4.b.op	2.4.2 Criticality inside glovebox - Material Preparation Area Second Section	Too many cans simultaneously too close together Flooding with water in combination with multiple cans Flooding with other moderators (e.g., hydraulic oil) Overload furnace trays (e.g., control failures in powder dispensing station) Dump pu powder elsewhere besides weighed furnace tray; critical mass accumulation in glovebox Too much material in screw feeder (e.g., plugging, failure in control logic) Stack furnace trays containing pu oxide too close together Water intrusion with overloaded tray(s) Cans containing metal or other pu material, sent through system for repacking, exceeds combined oxide metal limits	NA	Large worker exposure to ionizing radiation	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls
2.5.b.op	2.5.2 Criticality inside glovebox - Transport Area	Furnace trays containing pu oxide too close together Water intrusion with overloaded tray(s) Cans containing metal or other pu material, sent through system for repacking, exceeds combined oxide metal limits Spilling powder from multiple furnace trays exceeds safe mass limits	NA	Large worker exposure to ionizing radiation	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.c.op	2.6.3 Criticality inside glovebox - Furnace Area	Furnace trays containing Pu oxide too close together Water intrusion with overloaded tray(s) Spilling powder from multiple furnace trays exceeds safe mass limits	NA	Large worker exposure to ionizing radiation release of fission Product gasses Release of Pu oxide powder disturbed by criticality to the glovebox atmosphere	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls chemical reactions possible in furnace with compounds contaminating the Pu oxide?? what about wrong material such as Pu nitrate, fluorides, organic solvents???
2.7.c.op	2.7.3 Criticality inside glovebox - LOI test area	Furnace trays containing Pu oxide too close together due to tray handling system error Water intrusion with overloaded tray(s) in sample area Spilling powder from multiple furnace trays exceeds safe mass limits	NA	Large worker exposure to ionizing radiation Release of fission product gasses Release of Pu oxide powder disturbed by criticality to the glovebox atmosphere	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls on throughput, spacing, and mass accumulation	S1	F2	frequency ranking without controls chemical reactions possible in LOI furnace with compounds contaminating the Pu oxide?? what about wrong material such as Pu nitrate, fluorides, organic solvents???
2.8.b.op	2.8.2 Criticality inside glovebox - Tipping/Dispense/Fill area	Furnace trays or convenience cans containing pu oxide too close together due to handler errors Water intrusion with overloaded tray(s) Cans containing metal or other pu material, sent through system for repacking, exceeds combined oxide metal limits Spilling powder from multiple furnace trays or convenience cans exceeds safe mass limits (caused by handler failures)	NA	Large worker exposure to ionizing radiation	Criticality alarms inside glovebox Can handling equipment interlocks and controls Intrinsically safe configurations, by equipment design Dry fire protection system for glovebox minimizes chance for water intrusion Design precludes ingress of water during seismic events	Criticality controls, including: Controls on Throughput Spacing Mass accumulation	S1	F3	frequency ranking without controls

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
3.1.c.op	3.1.3 Criticality during transfer - SPS Machine to NDA lab	Double contingency violation Too many cans on cart	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages) Cart designed to maintain critically safe configuration if tipped over	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
3.2.b.op	3.2.2 Criticality in NDA Lab	Too many canisters stored in NDA area in unsafe configuration Fire water break or activation in NDA area with sufficient canisters present	NA	Worker exposure to large amounts ionizing radiation	Criticality alarms Critically safe storage racks?	Criticality control program	S1	F3	check on storage configuration or administrative criticality controls for this area
3.3.c.op	3.3.3 Criticality during transfer - NDA Lab to Storage Vault	Double contingency violation Too many cans on cart	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages) Cart designed to maintain critically safe configuration if tipped over	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
3.4.c.op	3.4.3 Criticality during transfer - SPS Machine to Storage Vault	Double contingency violation Too many cans on cart	NA (ionizing radiation)	Worker exposure to large amounts ionizing radiation	Criticality alarms Lag storage cart designed to be critically safe (only holds two storage packages) Cart designed to maintain critically safe configuration if tipped over	Criticality controls on spacing and quantity	S1	F3	assumes no criticality controls
3.4.f.op	3.4.6 Criticality in Storage Vault	Violation of criticality specifications	NA	Worker exposure to ionizing radiation in large quantities	storage vault configuration	criticality prevention procedures	S1	F3	
4.11.a.is	4.11.1 Criticality in glovebox - Transport glovebox	Degraded or unintelligible picture caused by: Bad cables Failed camera Loss of power Failed electronics permits undetected dumping of cans or trays in the glovebox	Pu oxide powder in trays being transported Pu metal in canisters being transported through	Dump trays of Pu being transported onto glovebox floor (criticality and contamination concern) Dump trays of Pu being transported to furnaces onto furnace floor (criticality and contamination concern) Inability to observe furnace door status (process failure/stoppage) Inability to observe tray entry and exit from furnace (process stoppage)	Criticality alarms CAMs in the room and exhaust stack Filtered glovebox exhaust Handler control system (minimizes chance of spill/criticality due to reliability of system to perform correctly without observation)	Operator training and procedures	S1	F2	S1 rating based on spill consequence from criticality (operator exposure) or spills in glovebox requiring additional exposure for cleanup

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
4.15.b.is	4.15.2 Fire system releases water into rooms 641 and 642 when not required creating conditions for potential criticality	Spurious actuation Piping leak	NA	Possible flooding of room Potential for criticality	Glovebox is well sealed Construction of building not water tight Alarms on fire system when actuation occurs	Operator training and procedures	S1	F3	S1 based on criticality
4.15.c.is	4.15.3.a Sprinkler system falls on SPS glovebox causing breach and flooding area creating conditions for potential criticality	Hanger failure Seismic event causing hanger failure	Pu oxide in gloveboxes	Loss of glovebox confinement Possible water intrusion into glovebox Possible criticality	Design of hangers and building structure Building ventilation system (in case of no seismic event)		S1	F2	This is a "3/1" type of problem
4.5.a.is	4.5.1 Criticality occurs when drains fail to drain when water present	Plugged drain Flowrate of water into box exceeds drain capacity	NA (ionizing radiation exposure)	Significant exposure to operators	Criticality alarms inside gloveboxes No significant supplies of water inside gloveboxes Glovebox design prevents intrusion of water from external sources	Emergency response by operators	S1	F2	
4.5.b.is	4.5.2 Criticality in drain piping/storage location	Powder goes down drain with water; collects in critical configuration inside tank, pipe, etc.	Pu powder that might go down the drain	Possible significant exposure to personnel in the facility	Criticality alarms No significant supplies of water in gloveboxes Glovebox design prevents entry of water from external water sources Screens on drains	Operator emergency response	S1	F2	
4.8.b.is	4.8.2 Leak in chilled water system for Laser Welder allowing flooding of area and creation of conditions for possible criticality	Line leak into the glovebox	NA (ionizing radiation exposure problem)	Potential spread of moderator to other boxes Spread of contamination within the machine; spread of contamination to the room Spread of contamination to the criticality drain system Double contingency violation; potential criticality	Design minimizes likelihood of water leak into the box Criticality alarms Design of gloveboxes minimizes potential water leakage to room Criticality drains	Operator visual detection	S1	F2	F2 for leak into glovebox S1 ranking based on assumed criticality or spread of Pu to room

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
				EXTERNAL EVENT CAUSING CRITICALITY					
6.1.b.ex	6.1.2 Floods initiated in other portions of the facility spreading to SPS room creating conditions for possible criticality in SPS machine area	Actuation of fire system in other portions of the building Fire water main break Other water supply line breaks	Fissile material in machine and lag stored around the machine Loose Pu material that could be spread	Criticality leading to high radiation doses to operators Spread of Pu oxide outside glovebox, perhaps outside the room or building	Gloveboxes and lag storage cart elevated off the floor Building is single story at ground level (SPS machine not in a basement room) Water can't build up to glovebox height. No water supplies to glovebox portion of machine Design of building would likely allow water to flow outside instead of accumulating to significant depths inside the building Criticality drains in gloveboxes Drains in other parts of facility Actuation of fire water systems or breaks in fire water lines are indicated by instrumentation and alarms.	Operator visual detection Operator training and procedures Criticality control program	S1	F1	confirm criticality drains will be used See PFP SAR regarding internal water floods S1 based on criticality without significant spread of Pu oxide outside room or building
6.2.a.ex	6.2.1 Floods initiated in other portions of the facility spreading to vault area creating conditions for possible criticality	Fire water system actuation Fire water line breaks Breaks of other water supplies	Fissile material in vault	Postulated criticality	Canisters stored up off the floor of the vault Racks or storage tubes maintain separation of canisters should the vault flood Storage racks or tubes will be designed to provide critically safe configuration even if the vault is flooded or water mist is present between canister arrays	Criticality control program	S1	F1	

Table C-3

S1 Criticality Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
NATURAL PHENOMENA CAUSING CRITICALITY									
7.1.a.np	7.1.1.a Seismic Event initiates criticality	NA	Pu oxide powder in glovebox Stabilized Pu oxide in canisters in SPS room and storage vaults	Loss of power leading to loss of ventilation for gloveboxes and vaults Damage to facility Damage to gloveboxes Spilling of Pu oxide within glovebox Possible criticality initiator due to material geometry rearrangement Shaking of contamination of equipment/glovebox surfaces Various equipment failures Fires Fire/other water line breaks Spread of Pu oxide powder from facility through compromised ventilation systems or damaged structure	Seismically qualified buildings and vaults SPS machine anchoring seismically qualified Seismic displacement absorber on SPS machine	Emergency response procedures	S1	F2	Adds source term to PFP FSAR seismic accident analysis 3/1 interactions should be looked at in detail in definitive design
7.1.d.np	7.1.4 External Floods	--	--	No consequence. External floods cannot flood building (including severe rain) (see PFP FSAR).	--	--	--	--	See PFP FSAR

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table C-4

S1 and S0 Accidents, Loss of Canister Confinement

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
INTERNAL INITIATOR - LOSS OF CANISTER CONFINEMENT									
2.11.b.op	2.11.2 Spread of Pu to leak testing equipment and to vacuum pump due to leaky inner can	Failed weld on inner can	Pu oxide from convenience can that has migrated or been released into the inner can plenum	Contaminated mass spec head Contaminated vacuum pump Spread of contamination to room Operator exposure on cleanup Contaminated outer can	Inner can helium leak test	Operator training and procedures	S1	F3	intrinsic nature of leak test spreads contamination it's trying to prevent the spread of
4.10.a.is	4.10.1 Loss of helium supply results in inability to detect leaky canisters	Line break Valved out Line plug Bottle empty	Pu oxide powder in inner can	Failure to detect leaky inner and outer canisters; Potential moisture intrusion into inner can and subsequent pressurization of canisters in storage vault	Helium flow and pressure are monitored Inner can leak detection unit Outer can leak detection unit Canister design minimizes chances for canister rupture	Operator training and procedures	S1	F2	S1 ranking based on assumed rupture of canister and unfiltered flow through vault ventilation system. Release limited by multiple canister barriers.
4.10.b.is	4.10.2 Loss of helium supply results in bad welds and leaky canisters that release Pu oxide	Line break Valved out Line plug Bottle empty	Pu oxide powder in inner can	Bad welds; inner and outer canisters may leak	Helium leak detectors (inner and outer can leak detection units)	--	S1	F2	
5.1.b.is	5.1.2.a Loss of confinement due to ventilation system failures allows release of Pu oxide to environment from leaking canisters	Pressurized vault due to imbalance between supply and exhaust Loss of supply and exhaust (stagnant case)	Contamination present in vault	Migration of particles from vault to 2736-ZB building; facility worker exposures	Vent system controls and alarms Zone Ventilation in areas where contamination may spread limits release to environment CAMs in rooms of 2736-ZB	Manual surveillances for contamination	S1	F3	
1.1.a.op	1.1.1 Drop of canister inside vault causes breach of canister	Human error	Pu oxide inside canister	Damaged outer can	Cans are small and relatively easy to handle Inner can is bagged and then overpacked into two other sealed cans Inner cans have been shown to survive 3 m falls without releasing powder (pfp sar)	Procedures and training	S0	F3	S0 based on three barriers precluding release. Inner can has slipfit lid which is taped. Inner can is also bagged and the bag heat sealed. Two overpack cans are mechanically sealed.

Table C-4

S1 and S0 Accidents, Loss of Canister Confinement

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
1.1.b.op	1.1.2 Drop canister off cart causes breach of canister	Human error	Pu oxide inside canister	Damaged outer can	Cart design plus above	Procedures and training	S0	F3	S0 based on three barriers precluding release. Inner can has slipfit lid which is taped. Inner can is also bagged and the bag heat sealed. Two overpack cans are mechanically sealed.
2.11.a.op	2.11.1 Failure to detect leaky inner canister results in release of Pu oxide	Failure of detection equipment Loss of vacuum pump Leaky seal on inner canister during leak test; sweep air dilutes helium readings	NA	Leaky inner canister stored in vault Possible moisture intrusion into 3013 package during storage; violation of 3013 storage requirements	Instrumentation on vacuum pump (e.g., flow, temp., pressure)	Operator training and procedures	S0 S1	F3 F1	S1/F1 ranking for pressurized/ruptures 3013 package in storage vault (two independent leak tests would have to fail)
2.11.c.op	2.11.3 Failure to evacuate outer can before adding helium results in failure to detect leaky canister	Vacuum pump failure not detected Failure to seal before evacuating outer can	NA	Air/helium mixture in outer can when capped making subsequent leak test less reliable	Vacuum pump instrumentation	Operator training and procedures	S0 S1	F3 F1	violation of storage requirements for canister leakage of contamination to vault during storage
2.11.d.op	2.11.4 Failure to backfill with helium results in failure to detect leaky canister	Loss of helium supply Control failure	NA	No helium in outer can to detect potential leaks with	Instrumentation on vacuum pump (e.g., flow, temp., pressure)	Operator training and procedures	S0 S1	F3 F1	
2.11.e.op	2.11.5 Failure to seal outer can results in release of Pu oxide	Various laser welder failures	NA	Leaky outer canister	Helium leak testing equipment (mass spec)	Outer can helium leak test	S0 S1	F3 F1	no spread of contamination to vault unless convenience can, inner can also leak
2.2.a.op	2.2.1 Drop canister on floor of room 641 in transferring from cart to glovebox results in release of Pu oxide into room	Human error	Outer canister surface contamination and Fraction of Pu material inside double overpacked inner canister	Damaged storage package; potential minor release of Pu material from storage package should outer and inner overpacks rupture	Room CAMs will detect unlikely release from canisters Site convenience can is overpacked in two mechanically sealed food pack cans Convenience can (inner can) slip lid is taped on Convenience can is overpacked in bag to limit contamination spread to food pack cans Multiple barriers substantially limit potential release from canister assembly	Operator training/ procedures Results of drop tests on slip lid fit convenience cans provide confidence convenience can will not leak Pu material should the inner and outer overpacks rupture	S0 S1	F3 F1	S0, F3 for drop which results in no significant leak S1, F2 for canister drop resulting in minor contamination spread to the room

Table C-4

S1 and S0 Accidents, Loss of Canister Confinement

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.6.m.op	2.6.9.a Inadequate stabilization of Pu oxide results in failure of canister and release of Pu oxide during storage	Furnace temperature too low (control failure or human error) Furnace dwell time too short (control failure or human error) Failed furnace heating coil	Trays of Pu oxide in furnace	Unstabilized pu oxide sent on for packaging (eventually resulting in can swelling during long term storage) Possible process upset if discovered	LOI furnace Furnace temperature controls and indication CAMs monitor vault atmosphere for canister failures (subsequent consequence control)	LOI test Operator training and operating procedures	S0	F3	this is a process upset condition resulting in reduced throughput as long as the LOI test identifies that a problem exists if problem goes undetected, could result in release to vault (S1 consequence)
2.6.n.op	2.6.9.b Inadequate stabilization of Pu oxide results in failure of canister and release of Pu oxide during storage	Failure of furnace dry air supply (assuming plant instrument air supply) (valve failed closed or inadvertently left closed)	Trays of Pu oxide in furnace	??Pu not fully stabilized (lack of full oxidation) ??Furnace integrity threatened (leak tight furnace designed for air supply)	LOI furnace	LOI test Operator training and operating procedures	S0	F3	
2.9.c.op	2.9.3 Wrong atmosphere in glovebox results in failure to detect leaky canister	Helium supply shut off Wrong gas supplied	NA	Possible failure to detect bad welds due to no helium present Depending on the wrong gas, results could be quite variable	Oxygen monitoring on outlet of glovebox	Procedures governing bottle replacement	S0	F3	S0 based on bad inner weld not detected and later causing problems wrong gasses could result in significant consequences. explosive gasses could create significant damage to glovebox due to laser ignition source or other ignition sources
4.7.c.is	4.7.3 Undersupply of instrument air causes storage canister failure due to pressure buildup from inadequately stabilized Pu oxide	Upstream line break Compressor failure Valved out Power loss	Pu oxide in trays in furnace	Operational upsets Pu oxide insufficiently stabilized Swelling of canisters in vault	LOI furnace	LOI test	S0 S1	F3 F3	S0 based on immediate effect S1 base on release to vault at future date due to ruptured canisters assume furnace is nearly leak tight so that suction from exhaust not adequate to pull sufficient air into furnace from glovebox
4.9.a.is	4.9.1 Possible relation to specific laser gas supplies and quality of welds that could result in canister failures during storage	--	--	--	--	--	--	--	entries TBD in definitive design. No significant hazards anticipated.

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table C-5

S1 Worker Protection Related Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
1.1.c.op	1.1.3 Expose other facility workers to direct ionizing radiation - Vault Storage to SPS Machine	Failure to adhere to radiation control procedures (alara). Facility workers do not maintain safe distance between containers and themselves	Na (ionizing radiation source)	Increased worker exposures		Radiological control program Training Procedures	S1	F3	New shielded cart may be used
2.1.b.op	2.1.2 Loss or degradation of shielding - SPS Gloveboxes (general) Shielding inadequate for radiation source term in the glovebox - SPS Gloveboxes (general)	Human error in maintenance Pu accumulation over time in the box Higher than expected activity in source material	NA (no release, hazard is ionizing radiation)	Increased operator exposures	Design of the glovebox Area radiation monitors	Maintenance procedures Control of feed material Radiation control program (surveys) Housekeeping limits accumulation in glovebox	S1	F3	
2.11.f.op	2.11.6 Failure to detect contamination on outside of 3013 package - Outer Can Weld and Monitoring Area	No swab performed due to control or operator failure Failure of counting equipment	Contamination on outside of can	Operator contamination when canister handled Spread of contamination to room atmosphere	Frisk portals Room ventilation system Room CAMs	Operator training and procedures Personnel exit surveys	S1	F3	
2.11.g.op	2.11.7 Failure to properly decontaminate contaminated outer can - Outer Can Weld and Monitoring Area	Operator error	Contamination on outside of can	Operator contamination when canister handled Spread of contamination to room atmosphere	Frisk portals Room ventilation system Room CAMs	Operator training and procedures Personnel exit surveys	S1	F3	
2.11.h.op	2.11.8 Contamination spread during bagout of inner canisters that fail leak test - Outer Can Weld and Monitoring Area	Improper bagging Dropped canister after bagout	Pu in bag	Contamination spread to room	frisk portals Room ventilation system Room CAMs	Operator training and procedures	S1	F2	
2.2.b.op	2.2.2 Loss of glovebox confinement during load in - Receipt area	Human error Ventilation upset Entry device seal failures	Loose contamination inside receipt glovebox [assumed to be very low]	Small spread of contamination to room	Room CAMs Glovebox exhaust system	Operator training and procedures Inner canisters are frisked for contamination not opened until passed through airlock into material preparation area	S1	F3	Receipt glovebox will have very low levels of contamination because cans that are found to be contaminated are bagged and passed on to the next glovebox before opening. Unknown if cans will be loaded in through airlock, sphincter seal, or if they will be bagged in.

Table C-5

S1 Worker Protection Related Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.2.d.op	2.2.4 Mishandling of contaminated cans/bags loaded out from glovebox - Receipt area	Human error Failure of frisking operation	Surface contamination	Worker exposure Minor release to room	Room CAMs Room ventilation system mitigates release to environment	Operator training and procedures	S1	F3	
2.2.e.op	2.2.5 Air flow reversal from material preparation glovebox - Receipt area	Ventilation imbalance Entry airlock failure	Loose contamination in mat prep glovebox	Contamination spread to "clean" receipt glovebox Increased worker exposure	Glovebox ventilation system controls Interlock controls on airlock doors	Operator training and procedures	S1	F3	
2.3.j.op	2.3.8 Contamination spread to other (cleaner) gloveboxes - SPS Material Preparation Area - First Section	Ventilation upset Open isolation doors Internal pressurization due to pneumatic air leaks	Loose contamination in glovebox	Increased personnel exposure (ionizing radiation)	Isolation doors Ventilation balance	Operator training and procedures Surveys	S1	F3	
2.4.j.op	2.4.8 Contamination spread to other (cleaner) gloveboxes - Material Preparation Area Second Section	Ventilation upset Open isolation doors Internal pressurization due to pneumatic air leaks	Loose Pu oxide power in glovebox (material in trays, screw conveyer, open cans, etc)	Increased personnel exposure (ionizing radiation)	Isolation doors Ventilation balance	Operator training and procedures Surveys	S1	F3	
2.7.b.op	2.7.2 Radioactive material spill inside LOI furnace - LOI test area	Spill from crucible during load in	Material being transferred in crucible (30 g)	Operation of furnace with oxide powder on heating coils may result in coil failure Difficulty in cleaning up spill resulting in increased personnel exposure	Glovebox ventilation system and HEPA filters	Personnel training and procedures	S1	F3	
2.8.i.op	2.8.9 Contamination spread to can weigh and cap insertion area - Tipping/Dispense/Fill area	Gas lock failure Loss of helium supply to gas lock	Contamination in glovebox air	Contaminated 3013 packages Increased worker exposures in cleaning up	Gas lock control system and interlocks Helium supply instrumentation	Operator training and operating procedures	S1	F3	S1 rating based on increased worker exposure from cleanup activities
2.8.j.op	2.8.10 Loss of glovebox confinement - Tipping/Dispense/Fill area	Sphincter seal failure Error during load in of convenience can	Contamination in glovebox atmosphere	Release of small quantities of contamination to room atmosphere	Glovebox ventilation system Room ventilation system Room CAMs Sphincter seal design	Operator training and operating procedures	S1	F3	S1 rating based on small quantity of material released
2.9.a.op	2.9.1 Radioactive material spill inside the glovebox - Can Weigh and Cap Insertion Area	Cap not installed correctly on convenience can	Material that falls out of can as it is oriented horizontally	Contamination spread in glovebox	Can height measurement equipment Glovebox ventilation system Glovebox confinement function	Operating procedures and operator training	S1	F3	S1 based on added exposure for cleanup F3 based on no controls

Table C-5

S1 Worker Protection Related Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
2.9.b.op	2.9.2 Loss of confinement - Can Weigh and Cap Insertion Area	Rotating sphincter seal failure Inner can post in sphincter failure Improper can insertion into sphincter seal Can not inserted into sphincter seal to maintain confinement Filter missing from inner can cap	Airborne contamination present in glovebox	Release of contamination to room	Glovebox ventilation Room CAMs Room ventilation system	Operator training and operating procedures	S1	F3	S1 based on low contamination level expected in glovebox
3.1.a.op	3.1.1 Movement of radioactive materials near workers - SPS Machine to NDA lab	Normal operation requires movement of material from processing area to NDA lab	NA	Direct radiation exposures to facility workers	Shielded lag storage trolley Interlocks prevent trolley from being moved from Outer Can Weld and Monitoring area until shielding door on cart is closed	ALARA controls for workers to maintain safe distance if shielded cart not used Radiation protection program	S1	F3	
3.3.a.op	3.3.1 Movement of radioactive materials near workers - NDA Lab to Storage Vault	Normal operation requires movement of material from processing area to NDA lab	NA	Direct radiation exposures to facility workers	Shielded lag storage trolley Interlocks prevent trolley from being moved from Outer Can Weld and Monitoring area until shielding door on cart is closed	ALARA controls for workers to maintain safe distance if shielded cart not used Radiation protection program	S1	F3	
3.4.a.op	3.4.1 Movement of radioactive materials near workers - SPS Machine to Storage Vault	Normal operation requires movement of material from processing area to NDA lab	NA	Direct radiation exposures to facility workers	Shielded lag storage trolley Interlocks prevent trolley from being moved from Outer Can Weld and Monitoring area until shielding door on cart is closed	ALARA controls for workers to maintain safe distance if shielded cart not used Radiation protection program	S1	F3	
3.4.e.op	3.4.5 Direct radiation from storage canisters - SPS Machine to Storage Vault	Normal operation	NA	Worker exposure	Shielding in vault	ALARA program	S1	F3	
4.7.d.is	4.7.4 Operator exposure caused by cleanup work	Failure of control valve: Oversupply of instrument air to stabilization furnace Incorrect setting of control valve (human error) (oversupply to gloveboxes covered in 4.7.6)	Pu oxide in trays in furnace	Furnace unable to maintain correct temperature (inadequate stabilization - see 4.7.3) Pressurized furnace (potential for destruction) Pu oxide disturbed and dispersed into glovebox atmosphere	Furnace ventilation exhaust Control valve design Glovebox design Glovebox ventilation system	Operator training and operating procedures	S1	F3	S1 based on increased operator exposure due to cleanup

Table C-5

S1 Worker Protection Related Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
8.1.a.os	8.1.1 Exposure to hazardous materials (e.g. solvents, fumes, decontamination chemicals) during cleanup	Operator exposed to decontamination chemicals Operator exposed to cleaning solvents or solvent fumes		Operator injury		Hazardous material training and Procedures Use of MSDS	S1	F3	Occupational hazard
8.1.b.os	8.1.2 Operator injury from moving equipment inside glovebox	Operator caught in moving tray elevators, can handlers, belts, pulleys		Operator injury	Shields and guards	Operator training and procedures	S1	F3	Occupational hazard
8.1.c.os	8.1.3 Operator injuries from moving equipment outside the glovebox	Operator hit by moving cart Operator struck by or pinched in can turntable		Operator injury	Guards? Interlocks?	Operator training and procedures	S1	F3	Occupational hazard
8.1.d.os	8.1.4 Operator burns due to exposure to heat sources (e.g., hot furnace trays, furnaces, etc.) inside gloveboxes	Exposure to hot stabilization trays Exposure to hot furnaces Exposure to hot surfaces created during welding operation		Operator injury	Glovebox heat detection	Operator training and procedures	S1	F3	Occupational hazard
8.1.e.os	8.1.5 Operator injury due flying missile (i.e., failed gas storage bottle)	Pressurized gas bottle knocked over and supply valve broken off		Operator injury	Bottle restraints Special bottle handling carts	High pressure gas safety procedures	S1	F3	Occupational hazard
8.1.f.os	8.1.6 Operator exposure to asphyxiants (from bottled gases)	Excessive concentration of helium or nitrogen gas due to line breaks		Operator injury	Room ventilation system	Operator training and procedures	S1	F3	Occupational hazard
8.1.g.os	8.1.7 Operator exposure to heat and toxic fumes	Fires inside or outside glovebox		Operator injury	Wet fire suppression system outside glovebox Dry fire suppression system inside glovebox Glovebox heat detection	Housekeeping	S1	F3	Occupational hazard
8.1.h.os	8.1.8 Operator injury due to electrical shock	Human error in equipment hookup Electrical shorts Insulation failures due to abrasion, radiation hardening, improper installation		Operator injury	Equipment design	Operator training and procedures Maintenance procedures	S1	F3	Occupational hazard
8.1.i.os	8.1.9 Operator exposure to excessive noise	Operator in room containing rotating equipment such as supply fans, exhaust fans Frequent exposure to loud alarms		Operator injury		Plant health and safety procedures	S1	F3	Occupational hazard

Table C-5

S1 Worker Protection Related Accidents

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
8.1.j.os	8.1.10 Slips, trips, falls, back injuries	Poor housekeeping Human error Poor labeling of hazardous areas Design that requires difficult body positioning		operator Injury	Equipment design	Operator training and procedures Plant health and safety procedures	S1	F3	Occupational hazard
8.1.k.os	8.2.11 Operator injury due to dropped objects	Human error Improper storage of Pu oxide 3013 cans Maintenance activities		Operator injury		Operator training and procedures Criticality prevention specifications	S1	F3	Occupational hazard
8.1.l.os	8.2.12 Operator injury during glovebox work--internal contamination caused by cuts	human error sharp objects in glovebox operator gets caught in moving equipment		Operator injury Internal contamination	Equipment design Guards and shields	Operator training and procedures	S1	F3	Occupational hazard
8.2.a.os	8.2.1 Operator injury operating hoist (dropped load, pinch in moving parts, etc.)	human error equipment failure		Operator injury	Equipment design	Operator training and procedures	S1	F3	Occupational hazard
8.3.a.os (also 2.10.d.op & 2.11.j.op)	8.3.1 Operator exposure to YAG laser light operator burn due to welding equipment	improperly aimed welding head human error failure of fiber-optic cable		operator injury (burns or eye damage)	Equipment design Shields/guards/interlocks	Maintenance and inspection Operator training and procedures	S1	F3	Occupational hazard
4.16.a.is	4.16.1 Failure of container assay nitrogen dewar pressure boundary causes release of nitrogen below SPS	Equipment failure	Nitrogen in dewar system	Cryogenic burns to operator or asphyxiation hazard if operator working in vicinity of dewar at time of leak	Dewar pressure boundary design	Operator training and procedures	S1	F3	
3.2.a.op	3.2.1 Direct radiation from canisters in lag storage - NDA Lab	Normal operation is to have radioactive material in the lab	NA	Direct radiation exposures to facility workers	--	ALARA program radiation protection	-	-	

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

Table C-6

S0 Process Upset Events

ID	Hazardous Event/Failure Mode	Candidate Causes	Material at Risk	Immediate Consequences	Engineered Safety Features	Administrative Safety Features	Cons Cat[1]	Freq Cat[2]	Remarks
3.1.b.op	3.1.2 Canisters dropped from cart or cart dumped over during transfer causes process upset	Human error Seismic event	Material in canister (canister and overpacks not assumed to fail)	Damaged 3013 packages	3013 package design	operation procedures	S0	F3	
3.3.b.op	3.3.2 Canisters dropped from cart or cart dumped over during transfer causes process upset	Human error Seismic event	Material in canister (canister and overpacks not assumed to fail)	Damaged 3013 packages	3013 package design	Operation procedures	S0	F3	
3.4.b.op	3.4.2 Canisters dropped from cart or cart dumped over during transfer causes process upset	Human error Seismic event	Material in canister (canister and overpacks not assumed to fail)	Damaged 3013 packages	3013 package design	Operation procedures	S0	F3	
3.4.d.op	3.4.4 Dropped canister causes process upset	Human error	Pu in can (can not assumed to fail)	Damaged can or storage tube Can stuck in tube Damaged storage rack	Winch for tube storage concept Canister designed to withstand drop	Operator training and procedures	S0	F3	programmatic impact
4.12.b.is	4.12.2 Excessive supply air flow causes process upset	Controller failure on supply fan	NA	Pressurized rooms	Control system on ventilation		S0	F3	
4.7.a.is	4.7.1 Loss of air supply causes process upset	Line break Compressor failure Power loss Valved out	Loose contamination within glovebox	Operational upset, inability to run canisters through the process Contamination spread between gloveboxes	Alarms on low pressure air	Operator procedures and training	S0	F3	Operational concern only for inability to operate equipment Maintenance for repair or clean up will increase personnel exposure
4.8.a.is	4.8.1 Loss of coolant to laser welder causes process upset	Loss of supply Valved out Line leak upstream Loss of temperature control	NA	Damage to the laser; production upset	Unknown	Visual observation	S0	F3	Cooling is performed in room remote from gloveboxes so criticality due to this water source not a concern. Is there an interlock that prevents laser use if chilled water is lost?
2.10.c.op	2.10.3 Drop or damage can assembly during transport to outer can weld and monitoring area causes process upset	Failure of can handling equipment	NA	Programmatic impact May have to send inner can/convenience can assembly back through process	--	--	--	--	

1. Consequence category is based on "no controls".
2. Frequency category is based on "no controls".

APPENDIX D

WORKER SAFETY EVENT IDENTIFICATION GUIDELINES

WORKER SAFETY EVENT IDENTIFICATION GUIDELINES

Worker Safety Events are:

1. Of the type and magnitude that are routinely encountered and/or accepted by the public in everyday life.

2. Hazardous materials or operations encountered in general industry in appropriate applications that are adequately controlled by Occupational Safety and Health Administration regulations or one or more national consensus standards (e.g., American Society of Mechanical Engineers, American National Standards Institute, National Fire Protection Association, Institute for Electrical and Electronic Engineers, National Electrical Code), where these standards are adequate to define special safety requirements, unless in quantities or situations that initiate events with serious impact to the public, workers, or environment.

3. Hazards such as noise, electricity, flammable materials, welding operation, small quantities of chemicals that would likely be found in homes or general retail outlets, and hazardous materials transported on the open road in Department of Transportation specification containers are considered to be worker safety events encountered in everyday life.

   Worker safety events must be considered as initiators for accidents involving other types of hazards. For example, flammable materials may be at first screened out, however, if the flammable materials could potentially cause a fire that releases toxic materials, the flammable materials must be considered as a potential initiator for a toxic material release.

   Examples of worker safety events are those involving:

   - specific materials (e.g., lead and asbestos) that have their own control program
   - thermal energy sources (potential for burns)
   - hazards typically found in machine shops
   - fork lifts
   - cranes
   - gas cylinders transported and stored in Department of Transportation configuration and within design limits unless they are stored in large (hundreds) quantities

- personnel pinches, trips, falls, slips, etc.
- confined space hazards
- hazards typically found in office areas
- mechanical presses.

Additional guidance on worker safety events determination:

X-ray Equipment

The intent is to screen out those facilities with X-ray equipment that are commercially available, conform to appropriate national codes and standards (e.g., ANS N537/NBS123) for X-ray equipment and have not been modified with regard to safety-related design and operating features such as voltage and shielding. If the X-ray system does not conform to the appropriate national code standard, then it must be kept for further hazard analysis.

Lasers

The intent is to screen out Class I and Class II lasers (per ANSI Z136.1) and Class III lasers with enclosed beams because these do not represent a significant health threat. If these Class I, II, and III laser systems do not conform to the appropriate national standard then they must be kept for further hazard analysis. Class III lasers with non-enclosed beams and Class IV lasers are to be kept for further analysis. Gas supplies that are an integral part of an unmodified, sealed purchased system design do not have to be treated separately; however, gas supplies that are not sealed in the purchased system or systems that have been modified must be considered separately as appropriate (i.e., toxic material criteria).

Electrical

The intent is to screen out standard electrical hazards but to retain for further analysis those that represent special safety concerns. Systems to be retained are (1) those with 600V or more and 2.5 mA or more output, and (2) stored energy systems with 50J or more stored energy and terminal-to-terminal voltage of 60OV or more. The National Electric Code (NEC 70-1990) identifies these as systems requiring special consideration.

Kinetic Energy

There are many situations in our facilities in which there exist sufficient amount of kinetic energy to seriously injure personnel (e.g., cars, trucks, cranes, machinery). However, these should be screened out as normal industrial hazards. Only unusual or unique high kinetic energy systems (e.g., large centrifuges, high-speed massive flywheels) should be kept for further analysis.

Pressure

The intent is to screen out normal hydraulic systems, plant air systems, etc., and to retain only those systems, either gas or liquid, whose pressure is greater than 210.92 kgf/cm^2 (3,000 lbf/in^2) or whose stored energy is greater than 0.004 kg (0.1 lb) TNT. Above these levels special high pressure design and operating considerations are required.

Temperature

The intent is to screen out high temperature systems whose only consequence is a contact burn and to keep systems (1) that could result in a strong overpressure if a coolant or other fluid contacted the high temperature mass or (2) that could cause toxic products if materials in the area were exposed to the high temperature or (3) that could cause a fire that would spread radioactive or toxic materials.

Biohazards

The intent is to screen out common sources of biohazards such as cooling towers but to retain for further analysis facilities containing biohazards of such a nature that special industrial hygiene controls (protective clothing, breathing apparatus, special warning placards) are required.

Asphyxiant

Asphyxiants do not have threshold limit values and, therefore, cannot be handled as toxic materials. Consider whether there are ready wells to entrap asphyxiants and unsuspecting personnel or situations that would impact large numbers of people. Cylinders of compressed asphyxiants should be included in these evaluations. Such situations should be kept for further analysis, specifically those situations in which the oxygen level would be less than 18 percent resulting from increased asphyxiant gas concentration.

ENERGY SOURCE CHECKLIST
(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	Small UPS only
	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 construction and maintenance
	Small Equipment	Used during construction and maintenance

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
NUCLEAR		
	Vaults	Pu oxide storage vaults - 4
	Temporary Storage Areas	None
	Receiving Areas	Pu oxide received at SPS
	Shipping Areas	NA
	Casks	NA
	Burial Grounds	NA
	Storage Tanks	NA
	Canals and Basins	NA
	Reactor In-Tank Storage Areas	NA
	Dollies	Small dollies used to transport Pu Oxide canisters
	Trucks	Not permitted
	Hand Carry	Process allows hand carry of Pu oxide canisters
	Cranes	Small cranes may be used in storage vaults, Large cranes may be used during construction
	Lifts	NA
	Shops	NA
	Hot Cells	The SPS is a glovebox system
	Assembly Areas	The SPS has an assembly process
	Inspection Areas	The SPS has an inspection area
	Laboratories	NA
	Pilot Plants	NA
NUCLEAR (IN-REACTOR)		
	Reactors	NONE
	Critical Facilities	NONE
	Subcritical Facilities	NONE

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
KINETIC/LINEAR (IN PLANT)		
	Fork Lifts	Not allowed
	Carts	Used to transport Canisters of Pu Oxide
	Dollies	Not allowed
	Railroad	NA
	Surfaces	The facility is ground level
	Obstructions (Collision With)	The facility has obstructions that can be collided with
	Shears	There are no shears, but the can opening facility may have some type of shearing actions
	Presses	None
	Crane Loads in Motion	Possible during construction and under certain canister placement scenarios
	PV Blowdown	Pressurized air is used in the process in various locations
	Power Assisted Driving Tools	Used during construction and maintenance
KINETIC/LINEAR (VEHICLE)		
	Cars	Outside the facility only
	Trucks	Outside the facility only
	Buses	Outside facility only

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
KINETIC/ ROTATIONAL		
	Centrifuges	NA
	Motors	Undefined number of motors will be present
	Pumps	None
	Cooling Tower Fans	NA
	Cafeteria Equipment	NA
	Laundry Equipment	NA
	Gears	Located in SPS glovebox - many areas
	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 helium to the SPS
	Pressure Vessels	The "3013" canisters could be considered pressure vessels
	Coiled Springs	There may be coiled springs in the SPS machinery
	Stressed Members	NA
	Gas Receivers	There may be air receivers associated with this project

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
MGH (FALLS & DROPS)		
	Human Effort	Always present in some form
	Stairs	Possibly present under some storage concepts
	Bucket and Ladder	Possible during construction
	Trucks	Possible during construction
	Elevators	NA
	Jacks	Possible during construction
	Scaffolds and Ladders	Possible during construction
	Crane Cabs	Possible during construction
	Pits	Possible during construction
	Excavations	There will be excavations performed for this project
	Elevated Doors	None
	Canals	NA
	Vessels	NA
MGH (CRANES AND LIFTS)		
	Lifts	Possible during construction
	Cranes	Possible during construction and may be used for final storage activities
	Slings	Possible during construction
	Hoists	Possible during construction

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
FLAMMABLE MATERIALS		
	Packing Materials	NA
	Rags	May be present during cleanup activities inside and outside the SPS
	Gasoline (Storage and in Vehicles)	Only external to facility
	Oil	Small quantities present to permit lubrication of moving parts
	Coolant Oil	NA
	Paint Solvent	Possible during construction
	Diesel Fuel	NA
	Buildings and Contents	The facility does contain combustible materials
	Trailers and Contents	There will be a trailer facility associated with this project
	Grease	Possibly present
	Hydrogen (Including Battery Banks)	The UPS will have a small set of batteries
	Gases - Other	NA
	Spray Paint	Possible during construction
	Solvent Vats	NA
CORROSIVE		
	Acids	NA
	Caustics	NA
	"Natural" Chemicals (Soil, Air, Water)	The glovebox system is intended to exclude water
	Decon Solutions	Decon solutions could be used to clean up glovebox from time to time

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
RADIATION		
	Canals	NA
	Plug Storage	NA
	Storage Areas	The vaults contain Pu oxide storage canisters
	Storage Buildings	The vaults comprise a storage building
	Radioactive Sources	The Pu oxide canisters and the Pu oxide represent a source of ionizing radiation
	Waste and Scrap	The SPS will generate waste and scrap
	Contamination	Pu oxide contamination will be present inside the SPS gloveboxes
	Irradiated Experimental and Reactor Equipment	NA
	Electric Furnace	Three Electric furnaces will be used in the SPS
	Blacklight (e.g., Magniflux)	NA
	Laser	A YAG laser will be used for canister welding
	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

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
THERMAL RADIATION		
	Furnaces	Three furnaces will be used in the SPS
	Boilers	NA
	Steam Lines	NA
	Lab and Pilot Plant Equipment	NA
	Sun	NA
THERMAL (EXCEPT RADIANT)		
	Convection	The three furnaces represent a convection heating source
	Heavy Metal Weld Preheat	NA
	Exposed Steam Pipes	NA
	Electric Heaters	None outside the furnaces
	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	There are three furnaces in the SPS

ENERGY SOURCE CHECKLIST

Type of Hazard	Form of Hazard	Quantity
EXPLOSIVE PYROPHORIC		
	Caps	NA
	Primer Cord	NA
	Dynamite	NA
	Power Metallurgy	There is some likelihood that Pu metal powder may be present but it is small
	Dusts	NA
	Hydrogen (Including Battery Banks and Water Decomposition)	There is a possibility that hydrogen may be present in the cans of Pu oxide that are to be opened in the SPS
	Gases - Other	NA
	Nitrates	There is a small likelihood that Pu nitrates may be present in very small quantities
	Electric Squibs	NA
	Peroxides - Superoxides	There is a small likelihood that Pu compounds of this sort may be present in very small quantities

ENERGY SOURCE CHECKLIST

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	May be present during construction activities only
	Trichloroethylene	NA
	Dusts and Particulates	Present during construction
	Pesticides-Herbicides-Insecticides	NA
	Bacteria	NA
	Beryllium and Compounds	NA
	Chlorine and Compounds	NA
	Sandblast	It is not envisioned that sand blasting will be used during this project
	Metal Plating	NA
	Asphyxiation-Drowning	NA

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