

History and Stabilization of the Plutonium Finishing Plant (PFP) Complex, Hanford Site

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Assistant Secretary for Environmental Management

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M. S. Gerber

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TERMS

ADP	automatic data processing
AEC	U.S. Atomic Energy Commission
AEC/RL	AEC Richland Office
ANL	Argonne National Laboratory
ANN	aluminum nitrate nonahydrate
ARHCO	Atlantic Richfield Hanford Co.
ATP	acceptance test procedures
BMI	Battelle Memorial Institute in Ohio
BNL	Brookhaven National Laboratory
BNW	Battelle Northwest
CAM	constant air monitor
CAS	Central Alarm Station
CMSO	Central Scrap Management Office
CMU	canister monitoring units
CWS	Chemical Warfare Service
CWW	CW column waste
D&D	decontaminate and decommission
D.O.	Design Order
DBBP	Dibutyl butyl phosphonate
DDU	destructive distillation unit
DMA	Division of Military Application
DOE	U.S. Department of Energy
DP	Defense Production
Ecology	Washington State Department of Ecology
EDL	engineering development laboratory
EIS	environmental impact statement
ERDA	Energy Research and Development Administration
EURATOM	European Atomic Energy Community
FFTF	Fast Flux Test Facility
FY	fiscal year
H.I.	Health Instruments
HAMTC	Hanford Atomic Metal Trades Council
HDBP	di-n-butyl phosphoric acid
HEC	Hanford Environmental Compliance
HEDL	Hanford Engineering Development Laboratory
HEPA	high-efficiency particulate air
HEU	highly enriched uranium
HEW	Hanford Engineer Works
HF	Hydrofluorination
HI	hydriodic acid
HN	hydroxylamine nitrate
IAEA	International Atomic Energy Agency
IBM	International Business Machines
ITS	in-tank solidification
LASL	Los Alamos Scientific Laboratory
MEV	million-volt
MINATOM	Ministry of Atomic Energy
MORT	management oversight and risk tree
MOX	mixed plutonium-uranium
mph	miles per hour
MPL	maximum permissible limit

TERMS (cont)

MT	miscellaneous treatment
MUF	material unaccounted for
MWI	minor work implementation
n/g/s	neutron counts per gram per second
NDA	non-destructive assay
NDL	Nuclear Defense Laboratory
NFS	Nuclear Fuels Services
NMMSS	National Nuclear Materials Management and Safeguards System
NPR	New Production Reactor
NUMEC	Nuclear Materials and Equipment Corporation
ORNL	Oak Ridge National Laboratory
PFP	Plutonium Finishing Plant
PNL	Pacific Northwest Laboratory
PRCF	Plutonium Recycle Critical Facility
PRE	Plutonium Retrieval
PRF	Plutonium Reclamation Facility
PUREX	Plutonium-Uranium Extraction (Plant)
PVC	polyvinyl chloride
QA	quality assurance
R&B	Receiving and Blending
RECUPLEX	facility for recovery of uranium and plutonium by extraction
REDOX	reduction oxidation
RHO	Rockwell Hanford Operations
RM	remote mechanical
ROD	record of decision
S&C	slag and crucible
SAC	U.S. Strategic Air Command
SAMS	soil assay monitor system
SAS	Safeguards and Security
SE	solvent extraction
SEFOR	Southeast Experimental Fast Oxide Reactor
SEPHIS	Solvent Extraction Process Having Interacting Solutes
SGSAS	segmented gamma scan assay system
SNM	special nuclear material
SRP	Savannah River Plant
START II	Strategic Arms Reduction Treaty
SWP	Special Work Permit (clothing)
SX	solvent extraction
TBE	tetrabromoethane
TCB	1,2,4-trichlorobenzene
TCE	tetrachloroethylene
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>
TRUEX	transuranic extraction
TTA	thenoyl trifluoro acetone
UNC	United Nuclear Corporation, Inc.
UO ₃	uranium trioxide
USGS	United State Geological Survey
USSR	Union of Soviet Socialist Republics
VSIS	Vault Safety and Inventory System
ZPPR	Zero Power Plutonium Research Reactor

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1.0 231-Z ISOLATION BUILDING (PLUTONIUM METALLURGY FACILITY)

1.1 CONSTRUCTION AND ORIGINAL MISSION

The 231-Z Isolation Building or Plutonium Metallurgy Building is located in the Hanford Site's 200 West Area, approximately 300 yards north of the Plutonium Finishing Plant (PFP) (234-5 Building). When the Hanford Engineer Works (HEW) built it in 1944 to contain the final step for processing plutonium, it was called the Isolation Building.

At that time, HEW used a bismuth phosphate radiochemical separations process to make "AT solution," which was then dried and shipped to Los Alamos, New Mexico. (AT solution is a code name used during World War II for the final HEW product.) The process was carried out first in T Plant and the 224-T Bulk Reduction Building and B Plant and the 224-B Bulk Reduction Building. The 224-T and -B processes produced a concentrated plutonium nitrate stream, which then was sent in 8-gallon batches to the 231-Z Building for final purification. In the 231-Z Building, the plutonium nitrate solution underwent peroxide "strikes" (additions of hydrogen peroxide to further separate the plutonium from its carrier solutions), to form the AT solution. The AT solution was dried and shipped to the Los Alamos Site, where it was made into metallic plutonium and then into weapons hemispheres.¹

The 231-Z Building began "hot" operations (operations using radioactive materials) with regular runs of plutonium nitrate on January 16, 1945. During the rest of January, five more runs were processed and accumulated for shipment to Los Alamos. According to DuPont Corporation operators, the "closure on the sample can [shipping container] had been shown to have a high probability of leakage, [so] it was decided to evaporate the product solution nearly to dryness...This was done on...all...shipments."² (See Figures 1-1 and 1-2.)

1.2 EARLY PROCESS CHANGES IN 231-Z BUILDING

The 231-Z Building continued to function in its original capacity for 12 years, with minor changes. When the PFP began operating in July 1949, it started receiving most of the AT solution from the 231-Z Building. At PFP, the dried AT solution was received at the 234-5 Building where it was rediluted as the first step in making metallic plutonium.³

Small amounts of AT solution continued to be sent to the Los Alamos Site. This solution was used in research. During 1950, laboratory studies began at the Hanford Site aimed at the elimination of some of the peroxide precipitation steps in the 231-Z Building. In addition, much testing sought to eliminate the final concentration step for plutonium nitrate in the 231-Z Building, for those shipments destined for the 234-5 Building. In the original process, shipments from the 231-Z Building to PFP were rediluted as a first step in the 234-5 Building process. However, as of February 1, 1951, the final drying step in the 231-Z Building was dropped for shipments bound for PFP, as the travel distance was only a few hundred yards and the solutions had to be rediluted at the start of the PFP process.⁴

Figure 1-1. Cell 1 in the 231-Z Building, World War II.

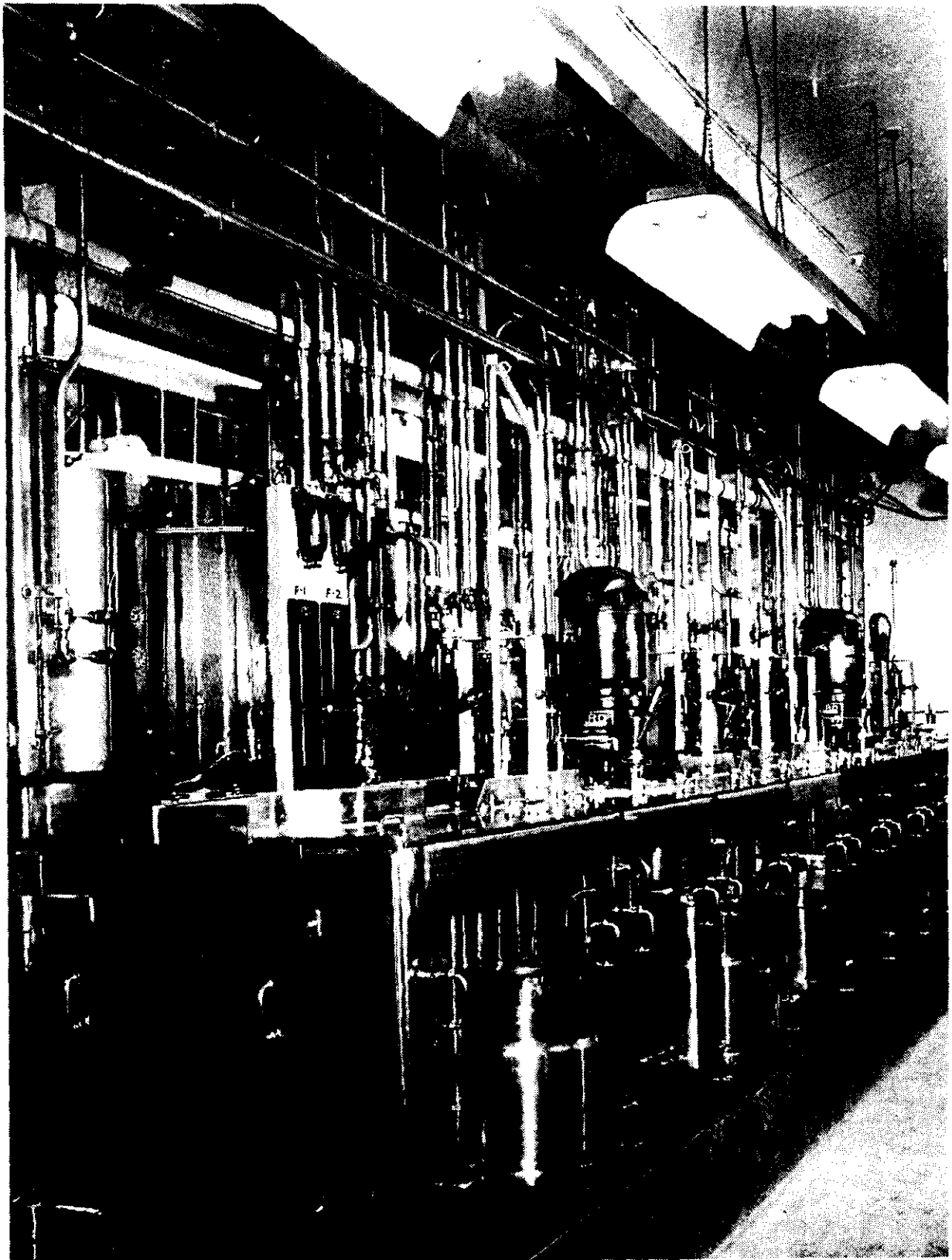
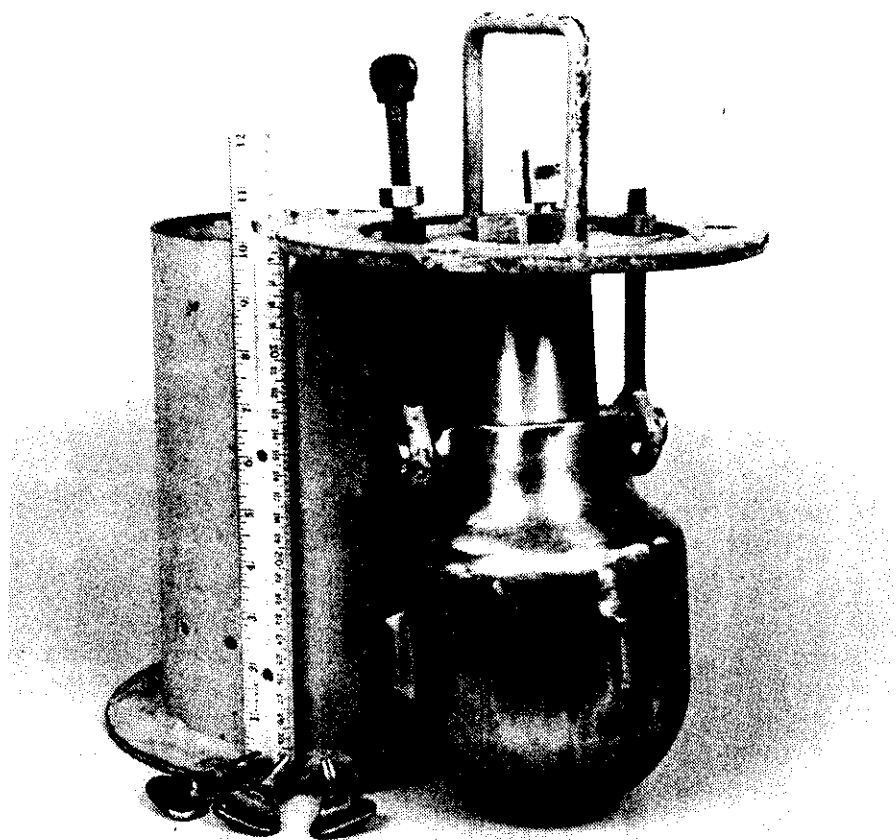


Figure 1-2. Plutonium Nitrate Shipping Can for 231-Z Building Product, World War II.



Americium 241 Recovery. Very early experiments to recover americium 241 (Am-241) were carried out in the 231-Z Building in the 1950's. In July 1950, an order to separate Am-241 was received from the California Radiation Laboratory. The separation was accomplished late in the year using peroxide to precipitate the Am-241 from aged plutonium nitrate in the 231-Z Building, then concentrating it in a recovery unit in the PFP. To the surprise of PFP engineers and chemists, the "quantity of americium obtained far exceeded the amount anticipated" from the plutonium nitrate that had been set aside for the project.⁵ In December 1951, a special batch of dissolved "button" (plutonium metal) material was sent from the 234-5 Building to the 231-Z Building and

processed to recover A-241. Approximately 25 milligrams of Am-241 in solution were shipped to an offsite customer. In December 1952, craftsmen in the 272-Z Shop fabricated a special shipping container for the Am-241.⁶ In early 1954, a complete process was standardized for recovering small amounts of Am-241.⁷

Reduction-Oxidation Process. In 1947, HEW was changed to the Hanford Works (HW), which was the name for the Hanford Site until 1973.

Beginning in April 1951, in Project C-413, four cells in the 231-Z Building were modified so that slurry from plutonium peroxide cake (P-2) could then be transported to the 234-5 Building for processing.⁸

Meanwhile, throughout the early and mid-1950's, research was under way to develop at the HW separations processes that would eliminate the need for the 231-Z Building's concentration or isolation function. The REDOX (reduction oxidation) Plant started up at HW in January 1952 and produced a plutonium product solution that required fewer peroxide strikes in the 231-Z Building. Throughout 1952, studies of how to couple the REDOX 2BP and 3BP (from the second and third plutonium concentration steps) products directly to the 234-5 process intensified. However, for the time being, these products still needed purification and manipulation in the 231-Z Building before proceeding to PFP.⁹ As a result of the success of REDOX operations, B Plant and the 224-B Building ceased bismuth phosphate operations in October 1952.¹⁰

At the same time that REDOX started up, the Atomic Energy Commission (AEC) commissioned a study at the HW to develop and build additional facilities to make a plutonium product "of such concentration and acidity that it can be delivered directly to 234-5, thus bypassing 231 Building." This research design activity (RDA-DC-7) soon became project CA-513 and eventually built the PUREX (plutonium-uranium extraction) Plant and the UO₃ (uranium trioxide) Plant, and expanded and converted the 201-C Hot SemiWorks Building for PUREX/UO₃ developmental work.¹¹

Throughout the mid-1950's, chemical process changes continued in the 231-Z Building. From 1950 to 1956, the 231-Z Building provided a link in various processes that recycled plutonium-bearing scraps from PFP operations to recover plutonium (see Section 8.0). In March 1952, the process development laboratory was consolidated with the PFP process development laboratory.¹² One year later, the 231-Z Building process control laboratory also closed. Facility samples then went to the 234-5 Building analytical laboratory for analysis.¹³

Beginning in July 1952, after the existing oxalate precipitation hoods^a in the PFP were retired, all product from the 231-Z Building, whether derived from the bismuth phosphate or the REDOX process, was sent to the PFP as Pu(IV) oxalate cakes in filter boats.¹⁴ A successful 231-Z Building process test

^a Note: At the early Hanford Site, enclosed glove boxes were known as "hoods," even though later a clear distinction was made between enclosed glove boxes and open-faced hoods. The term hoods is used in this text to preserve the vernacular of that early period.

conducted in June 1953 made streamlining the preparation of the REDOX 3BP solution as PFP process feed possible. In April 1955, the 233-S Plutonium Concentration Facility, built adjacent to the REDOX Plant, began operations. The new 233-Building could give a product solution concentrated to approximately 100 grams per liter (plutonium), with the required acidity levels, thus conforming to the specification needs of new equipment installed in the PFP in Project CG-549 that spring (see Sections 3.8 and 2.10). Thereafter, all REDOX product plutonium material could pass directly from the 233-S facility to the 234-5 Building, completely bypassing the 231-Z Building. Shortly thereafter, the successful completion of a production test allowed 224-T Building product material to be processed into AT material in the 231-Z Building on a standard basis using a streamlined process.¹⁵

At that time, plans were begun to outfit G-Cell in the 224-T Building to accomplish complete preparation of the bismuth phosphate product material from T Plant into AT solution ready for the 234-5 Building. Use of the 224-T Building to incorporate final peroxide processing would allow the final closure of plutonium processing functions in the 231-Z Building, and ready that facility for complete outfitting with specialized laboratories and/or with other functions.¹⁶

1.3 PUREX STARTUP ENDS 231-Z ISOLATION MISSION

In January 1956, the PUREX Plant began operating. Its success caused the closure of T Plant and the 224-T Building in March 1956, which eliminated the need for bismuth phosphate product processing in the 231-Z Building. In a June experiment in the 231-Z Building, PUREX product solution was successfully converted into AT by direct evaporation.

The PUREX product solution started up at HW and produced a plutonium product solution that was supposed to be suitable for direct delivery to the PFP, thus bypassing the 231-Z Building. However, radiation levels in the early PUREX product solutions were unacceptably high, and these solutions had to be transferred to the 231-Z Building for fission product decontamination throughout much of 1956. In the 231-Z Building, PUREX solutions were taken through a peroxide strike process and then concentrated to become AT solution. The isolation process achieved an average decontamination factor of 10.

On April 23, 1956, the PUREX Plant began a major outage to replace its 1A column and plutonium concentrator package, partly to achieve better in-plant decontamination factors. Twenty-four days later, PUREX resumed operations. At that time, according to G.E. Hanford Company, "for the first time since hot start-up, uranium fission products gamma ratios were within specifications...[and] excellent decontamination of both final products" was achieved. In a June experiment in the 231-Z Building, PUREX product solution was successfully converted into AT by direct evaporation. Throughout the summer however, some PUREX product solutions required "special handling" in the Isolation Building because they contained "higher than normal amounts of uranium and fission products."¹⁷

As PUREX operations improved in mid-1956 to provide for further fission product decontamination as a normal part of operations, the PUREX product could be delivered directly to the PFP. Meanwhile, the success of PUREX

operations had brought about the closure of T Plant and the 224-T Building in March 1956, thus eliminating the need for bismuth phosphate product processing in the 231-Z Building.¹⁸

1.4 PHYSICAL DESCRIPTION OF 231-Z BUILDING

Originally, the 231-Z Building was a two-story, flat roofed, reinforced concrete, frame building with 8-inch concrete block panels and 4-inch and 8-inch concrete block partitions. It measured 147 feet by 189 feet, 10 inches by 24 feet, 6 inches tall, with a total square footage of 27,964. A one-story ventilation and equipment room ran along the west end. The west side of the ventilation and equipment room contained fixed louvers protected by an 8-inch concrete barricade wall located approximately 4 feet from the face of the louvers and extending 4 feet above the roof. The 231-Z Building had no windows.

During World War II, the 231-Z Facility contained 57 rooms including 20 laboratories, several process and chemical receiving and storage rooms, offices, change room facilities designed to accommodate 190 employees, air conditioning equipment, a distilled water system, ventilation and exhaust systems, and a compressed air system. Six of the laboratories, known as cell laboratories, served as the major centers where processing occurred. All the rooms except one rest room were located on the first floor. The second floor served as a pipe and service loft, containing duct work and filters for the ventilation and exhaust systems.

The 231-Z Building foundation consists of reinforced concrete piers and concrete walls, both with spread footings. Floors are reinforced concrete varying from 4 to 12 inches thick. The walls and ceilings of the cell laboratories and Vaults A and B are 1-foot-thick reinforced concrete. Roofs also are reinforced concrete. They are 4 inches thick and are covered with built-up felt, gravel surface roofing containing numerous openings for intake and exhaust ducts. The walls, floors, ceilings, and equipment in Rooms 1 to 6, 8, 27, 31 to 45, Vaults A and B, and corridors A, B, C, D, E, and F were painted with "Amercoat"^b (a thick, chemically resistant coating that contains epoxy and is amenable to decontamination), to obtain nonporous surfaces.

Originally, the interior of the 231-Z Building was configured with two 8-foot-wide north and south corridors (A and B), one on each side of the six cell laboratories, with emergency exits to the outside of the building. Corridors C and D ran east and west connecting with corridor B and had emergency exits on the east end of the building. Corridors E and F ran north and south separating laboratories and intersecting corridors C and D. Below-grade piping led to a waste disposal system. This piping was modified in 1948, at the same time that an additional crib was constructed to improve control of 231-Z Building wastes (see Section 15.1).¹⁹

^b Amercoat is a trademark of Ameron Products Inc.

1.5 MODIFICATIONS TO 231-Z BRING PLUTONIUM METALLURGY LABORATORY

In 1955 and 1956, as part of Project CG-645, interior changes to Rooms 47, 48, 49 and 50 of the 231-Z Building created a "plutonium fabrication laboratory," and replaced a small plutonium metallurgy laboratory that had operated in the PFP since 1952. However, no structural changes occurred. As soon as the 231-Z Building's original functions ended in early 1957, Project CG-733 expanded the plutonium metallurgy facilities to fill virtually the entire building. A general cleanout and decontamination of the six-cell laboratories occurred. The ventilation system was improved, adding high-efficiency particulate air (HEPA) filters in the duct level. Project CG-756, which began in mid-1957 and ended in November 1958, added fire-resistant exhaust filters. Project CG-756 replaced the Chemical Warfare Service (CWS) paper space filters in both the 234-5 and 231-Z Buildings with Cambridge Type G^c fire-resistant filters (see Section 3.1).²⁰ In 1959, a new hydraulic press was installed to accommodate experiments in plutonium fabrication. In 1961, a series of safety improvements modified the 231-Z Building's process ventilation system and installed a fire-detection system.²¹

Plutonium metallurgy work pursued in the 231-Z Building during the 1950's and early 1960's included basic research on plutonium metal and its alloys, tensile and stress testing, property determination, and fabrication development work on plutonium weapons components.²² Classified experimental work for the AEC, which was the federal oversight agency that managed the Hanford Site from 1947 to 1973, was carried on in the 231-Z facility between 1954 and 1964. The AEC's Division of Military Application (DMA) also funded other experimental weapons design work in the building. That design work supported the weapons testing program at the Nevada Test Site. Beginning in the mid-1960's, primary development work in reactor fuels containing plutonium and other alpha-emitting materials also took place in the 231-Z facility. After a fire severely damaged the primary plutonium-handling facility at the AEC's Rocky Flats Site in Colorado in 1969, the 231-Z Building became even more important to national weapons designs programs. A unique coating process was successfully developed and demonstrated in the facility in the early 1970's. At nearly the same time, a state-of-the-art method for sampling plutonium buttons was perfected in the building.²³

1.6 FURTHER MODIFICATIONS TO 231-Z BUILDING

In the 1960's and 1970's, the volume of work at 231-Z caused the AEC to authorize several improvements to the building. From 1966 through 1968, a 1-story, 3,400-square-foot office wing was added on the south side. The addition was constructed of concrete block, with a flat roof of built-up tar and gravel. Windows were located along the exterior office walls. The office wing was isolated from the laboratory area by air locks. This project also converted 2,800 feet of existing laboratory, lunch room, locker room, and rest room space in the existing building to office space.

^c Cambridge Type G is a trademark of the Cambridge Filter Corporation.

At the same time, piping modifications below-grade were undertaken to connect the 231-Z Building to a new process waste disposal crib (216-Z-16). In 1971, an additional crib (216-Z-19) was constructed for facility waste. (The 216-Z-20 crib also was used for 231-Z and PFP laboratory wastes after 1981.) (See Section 15.1).

During 1970 to 1973, process area ventilation modifications added refrigeration and air-drying capacities essential to plutonium fabrication work. At the same time, a fire-suppression sprinkler system was installed in the laboratory area and a heat-detecting and alarm system was installed in the glove boxes and hoods. In 1973 and 1974, a 3,700-square foot, 1-story concrete block addition was placed on the north side of the 231-Z Building. This served as a consolidated storage and maintenance facility. In 1979, a second, 3,200-square foot, 1-story addition was completed on the south side. This extended the addition built during 1966 through 1968 to the east.²⁴

In 1975, the DMA began phasing out the weapons design work in the 231-Z facility. Major cleanout of glove boxes and other plutonium-contaminated equipment was undertaken 1978 to 1982. During that time, part of the building was converted to laboratory space for non-plutonium work (materials research), large areas were converted to office space, and the maintenance shop continued to operate.

A safeguards and security (SAS) upgrade at the PFP complex during 1977 and 1978 (see Section 3.5) provided fencing that cut off direct access between the 231-Z Building and the PFP area. As part of this project, a new vehicle access road for constructed for the 231-Z Building.

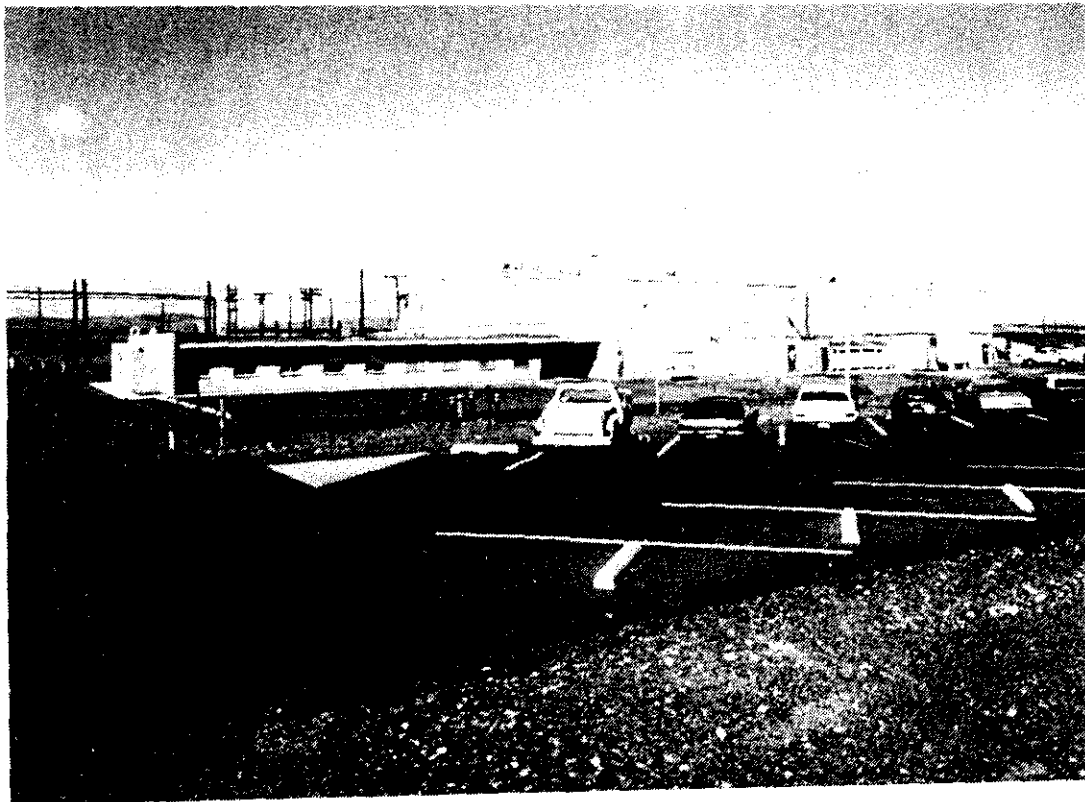
In 1982, the 231-Z facility was considered by the U.S. Department of Energy (DOE), a successor agency to the AEC, as a site for a planned laser isotope separations project. However, funding was not available to retrofit the old facility to meet modern codes and standards. Instead, a 9,000-square-foot Soils and Sedimentation Characterization laboratory was located in the building. The laboratory housed experiments to characterize contaminated crib soils for much of the remainder of the 1980's.

In 1994, DOE conducted a national study to determine places and facilities where plutonium residues might be vulnerable to environmental release, theft, or other disturbance. The study identified the 231-Z Building as needing cleanout, then decontamination and decommissioning (D&D). Work in support of these final recommendations is now in the planning and characterization phase for the 231-Z facility.²⁵ (See Figures 1.3 and 1.4.)

Figure 1-3. Removal of Plutonium Metallurgy Glove Box from the 231-Z Building During World War II.



Figure 1-4. 231-Z Building in 1983.



1.7 SIGNIFICANCE OF THE 231-Z BUILDING

The activities and missions undertaken in the 231-Z Building have directly and significantly affected American history and national policy. In its initial work in processing plutonium nitrate, the 231-Z facility contributed directly to making the test atomic weapon that was detonated at the Trinity Site, New Mexico, in July 1945. This was the world's first atomic explosion and ushered in the Nuclear Age. Work at the 231-Z Building also contributed directly to making the weapon that was dropped over Nagasaki, Japan, in August 1945. This ended World War II and continues to irreversibly influence international events.

In 1947, the long stand-off between the United States and the Union of Soviet Socialist Republics (USSR), known as the Cold War, was beginning. Subsequent plutonium processing work contributed to weapons production for the nation's Cold War arsenal until 1957, and therefore the building is directly associated with the Cold War itself. Much of the specialized plutonium metallurgy work done in connection with weapons development is still classified and cannot be discussed, but it can be said that this work contributed directly to the development of more and more sophisticated and reliable nuclear weapons. The 231-Z Building is directly associated with plutonium fuels development for the commercial nuclear industry and for the Liquid Metal Fuel Breeder Reactor research program--yet another link with a significant branch of modern American history.

2.0 GENESIS, CONSTRUCTION, AND EARLY OPERATIONS OF THE PFP

2.1 NEED AND PURPOSE OF PFP

The original plutonium production process at the WWII HEW carried the product (plutonium 239 [Pu-239]) only to the plutonium nitrate stage (see Section 1.0). When the war ended and the rush for immediate production slowed, the Manhattan District, U.S. Army Corps of Engineers, managers of both HEW and Los Alamos, began to investigate process improvements and production efficiencies. In 1946, they requested that the new operating contractor at HEW, the General Electric (G.E.) Hanford Company, initiate design of an onsite facility for the conversion of plutonium nitrate into oxalate, oxide, and finally metallic form, creating a safer and more stable form of plutonium to be shipped the long distances to weapons assembly facilities. The new plant also was to incorporate the capability to fabricate metallic plutonium into the actual shapes ("pits") ready to be fitted into atomic weapons.²⁶

On January 1, 1947, HEW, along with the other federal atomic defense production sites, passed to the control of the newly created AEC. After surveying the status of the existing facilities, the AEC embarked on a large expansion program in response to projected military needs and new tensions in the world. As a key part of the expansion program at the Hanford Site, the plutonium conversion and fabrication facility, planned since 1946, was accelerated. Project C-198 became a reality, and the 234-5 Building was designed beginning in 1947, and constructed beginning in 1948.²⁷

As early as December 1946, a G.E. Hanford Company representative visited the Defense Production (DP) West Building, the Los Alamos plutonium conversion and fabrication facility, to study its operations for applicability to the Hanford Site. To meet the health and safety standards of the Hanford Site, as well as to process the increased amounts of plutonium that were forecast, the committee soon decided that a remote, mechanized operation would be necessary. In the spring of 1947, committee representatives visited DP West again; in July they issued a design feasibility report. This report concluded that Part I of the operations (plutonium purification, dry chemistry, and reduction to metallic form) would be feasible in a mechanized manner without "extended" process development. It further recommended that actual design work be instituted, both for experimental facilities and for one production line or cell.²⁸

Throughout this initial period the plutonium conversion and fabrication facility project had proceeded on the assumption that the facility would be located in a part of the HW that would be called the 400 Area. Hence, the feasibility examination often was referred to as the "400 Area Study."^d However, in August 1947, to be efficient and economical with the use of existing utility and support facilities, the committee recommended that the new structure be located within the 231-Z Isolation Building fence. Existing boiler, water filtration, electric, telephone, warehouse, road, and guard facilities would have to be expanded, but this course was deemed to be cheaper

^dThe 400 Area proposed in 1947 is not the same as the current 400 Area of the Hanford Site.

than building an entirely new infrastructure. Because the facility would be located inside the 231-Z inclusion area, and because it would house the very last steps in plutonium metal production, it became known as "Z Plant" (the plant at the end of the line).²⁹

2.2 PFP DESIGN MODIFICATIONS

During September, several design decisions were revised. In October 1947, plans to include a large storage vault were deleted from the project and postponed to a separate, later project. Parameters and procedures were established for the analytical and developmental laboratories, waste disposal practices, ventilation needs, temperature cycles for the plutonium finishing processes, and various other operating boundaries. In November, Parts I and II of the operation, which had been scheduled for separate portions of the building, were combined into one line to "eliminate air transfers" and keep the plutonium confined within glove boxes (then known as dry boxes) at all times. Part II involved the fabrication of weapons pits from the metallic plutonium buttons produced in Part I. Part I originally had been planned for the 234 portion of the building, while Part II had been planned for the 235 portion. When the lines were combined, the structure was designated the 234-5 Building. In Hanford Site slang it became known as "Dash 5."³⁰

In February 1948, the AEC communicated its need for an accelerated schedule. While the 234-5 processes were not scheduled to be operational until late 1949, the AEC stated a need to have a plutonium conversion process operating at HW by January 1, 1949. As a result, it was decided to install a manually operated process similar to the one in use at DP West, on a rush basis, while continuing with design of the mechanized, remote process. Because, in the manual process, operators handled plutonium through ports in the glove boxes outfitted with rubber gloves, it became known at Hanford as the "RG" (rubber glove) Line (see Section 4.0). Henceforth, the RG Line, along with its basic support service structures and facilities that were deemed essential to operate it, became known as Phase I of the 234-5 Project.³¹

2.3 CONSTRUCTION OF THE 234-5 BUILDING AND ANCILLARY STRUCTURES

In June 1948, the actual foundations and footings for the 234-5 Building were poured. During the spring and summer, construction progressed on a new railroad spur, telephone cable, 284-W Boiler House extension, and other support facilities. For security reasons, instruments for the 234-5 project were accumulated in the White Bluffs warehouse, where instrument panels for the glove boxes also were fabricated. Concurrently, tests were conducted in glove boxes in Rooms 38, 41, and 42 of the 231-Z Building to establish analytical procedures to be used in the 234-5 laboratory. The 234-5 Building ventilation specifications were established, and tests of process agitators were carried out using Karo[®] syrup as a stand-in for the product solution expected to enter the facility as AT solution. By January 1949, the projected

[®] Karo syrup is a trademark of CPC International, Inc.

start-up date, the 234-5 Building was only 55 percent complete, and acceptance test procedures were just being issued for the electrical facilities, underground water lines, outside steam lines, and other ancillary structures. Ten process hoods were installed in the building that month (about one-third of the total), and the first group of operations personnel was sent to DP West for training. At that point, the operational date was moved to March 1, 1949.³² (See Figure 2.1.)

Throughout the spring and early summer of 1949, operational readiness testing and other preparations for the start-up of the 234-5 RG Line went forward. A 16-day strike by electrical workers in March and April further delayed completion. Operations forces received the bulk of the building from Construction forces on April 29 and May 6, and the full complement of 27 operators was on staff by mid-May. Several stand-in (simulated) runs were made to test process and laboratory equipment. The "plastic bag technique for handling material in and out" of glove boxes was practiced and, according to G.E. Hanford Co., "demonstrated extremely satisfactory contamination control." The main problems in completing the building concerned the ventilation system, where "concerted activity" was directed to balancing the air flow and managing vacuum pressures.³³

According to a technical contractor report, the 234-5 Building was designed to be a "self-contained and independent plutonium fabrication plant with all necessary supporting services and facilities." A key specification was that "the chemical and metallurgical processes in use at Los Alamos be used." However, a main difference between Los Alamos and Hanford was that at Hanford the "entire manufacturing process [was]...carried out within enclosed...hoods which are interconnected by tunnels."^f At Los Alamos, at that time, some steps of the process were not executed in completely enclosed hoods, and not all of the hoods in the process line were interconnected. The initial 234-5 RG Line was completely enclosed and interconnected, with three separate air zones for contamination control (see Section 4.1). Air from all of the contaminated zones was drawn to a common air exhaust manifold, passed through CWS paper filters, and discharged out the 200-foot high, 291-Z Stack at a velocity of up to 30 miles per hour (mph).³⁴ (See Figure 2.2.)

Phase I of the 234-5 project consisted of constructing the 234-5 Building, and many support and ancillary structures and facilities. The 234-5Z Building itself was 180 ft wide by 500 ft long. It extended from 9.5 ft below grade to 46.8 ft above grade. It contained three stories: a first floor, a duct level (actually the second floor), and the designated "second floor" (actually the third floor). The frame was of structural steel with an outer sheathing of aluminum panels over rock wool insulation and 16-gauge sheet steel. The first floor was a concrete slab; the duct level was sheet metal roof decking, and the second floor was a concrete slab. The roof was insulated metal decking. Some interior walls were reinforced concrete;

^f Note: From the earliest 234-5 Building operations, Hanford personnel consistently referred to glove boxes as "hoods." The historical vernacular use of the term "hoods" is thus maintained in this text. However, the equipment being described as hoods actually are fully enclosed glove boxes (except in a few cases where laboratory "hoods" actually are open-faced hoods).

Figure 2-1. PFP Building Construction, October 1948.

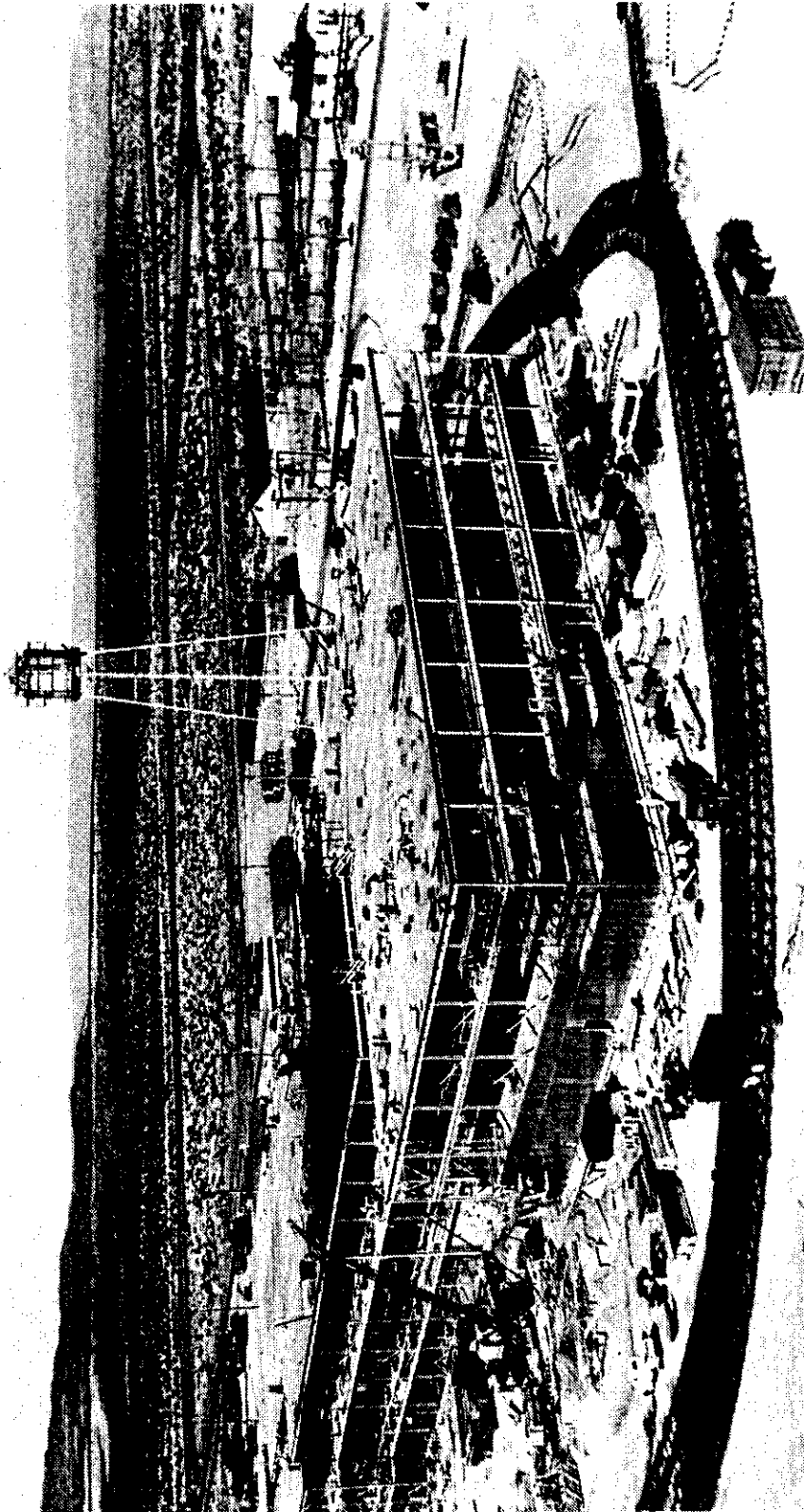
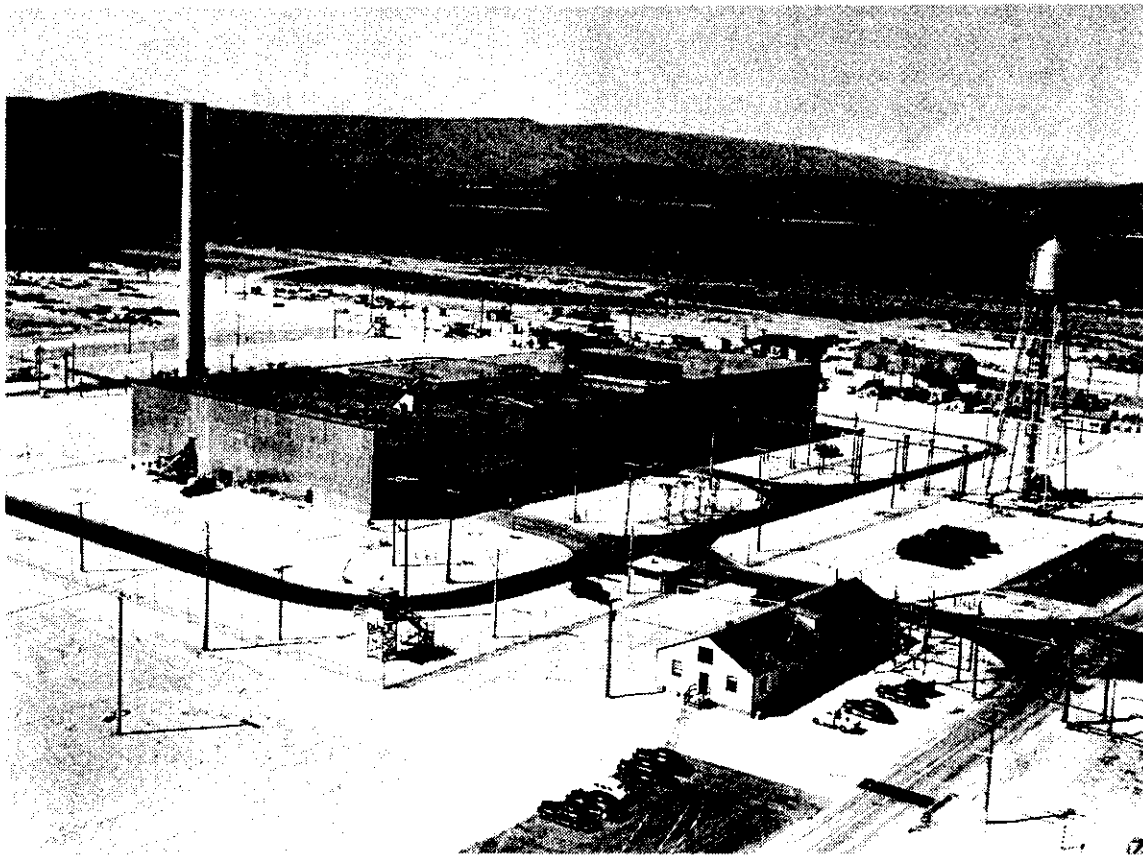


Figure 2-2. Finished PFP Building, June 1949.



The 234-5Z basement consisted of pipe tunnels carrying drain piping to sumps. The first floor contained the RG processing line, an analytical laboratory, a chemical preparation room, a calcium room, plutonium storage rooms, and many other components. Rooms 166, 173, 174, and 175 were designated as vault rooms for plutonium storage, and were equipped with automatic electrical protective and annunciation devices. The duct level contained most of the service piping, ventilation ducts, and some filter boxes. The lunchroom, conference room, materials storage room, chemical feed preparation and aqueous make-up rooms, locker rooms with change facilities and rest rooms, and office spaces were on the second floor. The second floor also housed exhaust air duct work, including filter boxes and filter rooms and the fan room. The fan room, located on the northwestern corner of the second floor, housed the ventilation supply fans, the steam inlet and distribution system, air dryers, the distilled water still, air chilling units, and the Vent and Balance Control Room. The PFP was not equipped with automatic fire detection and suppression systems, but relied on fire hoses and fire extinguishers placed in the facility. Like all early Cold War facilities on the Hanford Site, the 234-5 Building's electrical system was fitted with "blackout controls" so that the facility could be darkened in case of attack.³⁵

extinguishers placed in the facility. Like all early Cold War facilities on the Hanford Site, the 234-5 Building's electrical system was fitted with "blackout controls" so that the facility could be darkened in case of attack.³⁵

During Phase I of the project the 2704-Z Office Building; the 2705-Z Temporary Technical Office Building; the 2719-Z First Aid Building; the 291-Z Exhaust Building and Stack; the 2901-Z Elevated Water Storage Tank; waste cribs 216-Z-1 and 216-Z-2 also were constructed (see Section 15.1). Phase I construction also included the 241-Z Reservoir Pits (also known as the Waste Storage Facility), consisting of tanks, cribs, two basins, pumps and piping; an exclusion area badge house; a gas bottle storage building; and the 272-Z shop and warehouse. Also, the 284-W Boiler House was extended to the east, with the addition of a boiler, combustion control equipment, coal conveyor extension and stack interface. The 283-W Filtered Water Plant was likewise extended to the east, with the addition of another settling basin, pumps, and piping. Utilities that were constructed specifically for the 234-5 Building included 4,670 linear feet of electrical lines (with accompanying switchgear), approximately 6,500 feet of overhead steam lines, 1,211 linear feet of underground process water lines, 140 linear feet of service water lines, 26,000 linear feet of air supply duct work with accompanying blowers, fans and other equipment). Sewer lines, a sanitary tile field, a 20,000-gallon sanitary septic tank, and 380 square yards of gravel roadway were constructed as well.³⁶

2.4 STARTUP AND EARLIEST OPERATIONS OF THE PFP

"Hot" processing (i.e., processing using plutonium nitrate as feed) began in the 234-5 Building on July 5, 1949, at 11:00 PM. However, according to a G.E. Hanford Co. report, "operational and mechanical difficulties...did not permit the forecast July production schedules to be met...Innumerable leaks were found in the [vacuum] system," and detection and correction measures took time. Indeed, production schedules were not met for the remainder of 1949, and in December the facility was "relieved of production commitments in order to make certain necessary repairs."³⁷ The 234-5 Building was operated on a three-shift schedule, Mondays through Fridays. Because many of the personnel wore anticontamination clothing (then known at Hanford as Special Work Permit clothing [SWPs]), approximately 20,000 pounds per month of process laundry was generated by 234-5 operations. Positive air samples obtained in some of the processing rooms and in the analytical laboratory during the first month were at high enough levels to require personnel to wear assault masks.³⁸

Contamination spreads and high air readings inside the 234-5 Building remained problems throughout 1949. In October, the Hanford Site's monitoring organization, the Health Instruments (H.I.) Division, emphasized the need for better contamination control in the new facility. In November, 131 of the 732 air samples taken were above the tolerance standards of the time, and 238 items outside of the hoods were found contaminated. Gross contamination events were such that "it was necessary on several occasions to suspend [operations] completely...and devote all efforts to decontamination work." The toll of the many contamination incidents on production and morale was acknowledged at year's end by G.E. Hanford Co. "The lost processing time, the

hours of hard, unpleasant work under uncomfortable conditions, and the ever-present potential health hazard have had serious effect on the progress of this operation and on the morale of employees concerned."³⁹ Initial estimates of the surface dose rate from plutonium metal (placed at 200 millirep⁹ per hour) in 1949 were later found to be erroneous and low, thus adding to the radiation problems in the building.⁴⁰

2.5 PHASES II AND III OF PROJECT C-198

At the same time that the 234-5 RG Line began operations, Hanford personnel travelled frequently to the General Electric Laboratory (GEL) at Schenectady, New York, where Phases II and III of the 234-5 Project were being designed. Phase II consisted of the completion of additional rooms for the analytical laboratory (144 and 151), a crucible shop, a chemical development laboratory, maintenance shop "D" (a "hot shop" for repair of contaminated equipment and tools), instrument shops (rooms 159a, 208 and 209), and two Zone 2 maintenance hoods. Phase II also included preparation work for the emplacement of the remote mechanical (RM) plutonium finishing line.

The RM line itself was the major component of Phase III. In September 1949, it was specified to provide a production capacity "equivalent to the capacity of REDOX." Phase III of the 234-5 Project also included the completion of a mechanical development shop, men's locker room (226), miscellaneous rooms (161, 146, and 147), a future special products shop, and a future recovery area (for the rework of scrap, or out-of-specification metals and oxides). In April 1949, design and fabrication work in Schenectady on Phases II and III of the 234-5 project (known at GEL as the 432 Project—the numbers were reversed for security) was deemed to be only 45 percent complete. By mid-autumn, with progress still slower than the rate desired by the AEC, G.E. Hanford Company officials reported to the government that, "experience in the operation of the Rubber Glove Line since its completion and start-up has revealed a number of design deficiencies which can be directly attributed to the 'crash' program followed in its design and construction. It can be most positively predicted that, if adequate time is not allowed for careful and intelligent consideration of design...similar end-result difficulties will be obtained with the Remote Mechanical Line. It is strongly advised that the schedule for completion of the Remote Mechanical Line be made flexible enough to avoid this."⁴¹

By April 30, 1950, Phase II of the 234-5 construction project was 80 percent designed and Phase III equipment being fabricated at GEL in Schenectady was 75 percent complete. Floor preparation work and laying of electrical lines for the RM Line commenced that summer.⁴²

⁹. Millirep is one one-thousandth of a rep. Rep is an acronym for Roentgen Equivalent Physical. It is an obsolete term that is not longer used, and was replaced by the term Rem (Roentgen Equivalent Man). Rem is a unit of measure for the dose of ionizing radiation that gives the same biological effect as one roentgen of X-rays. One rem is approximately equal to one rad for X, gamma, or beta radiation. The terms rep and rem are roughly equivalent. See Section 6.2.

2.6 1950 BRINGS CHALLENGES, INITIATIVES

The year 1950 brought continuing operational difficulties and challenges at PFP, but also many initiatives in process improvement. By June, overall performance in the facility had improved so much that "all production commitments to date...[were] exceeded." Toward the end of the year, dramatic calls for increased production by the AEC resulted in new building programs. Construction of a second remote mechanical glove box line, known as the RMB Line, was authorized for the PFP as Project C-413 in October.⁴³

By mid-year, nuclear materials accountability discrepancies between Hanford products shipped and Los Alamos products received were great enough to prompt a series of meetings between the two sites. In July, the final inspection process was improved greatly when a new holding gauge was fabricated. This gauge "markedly reduced" the radiation exposure of the inspectors because they no longer had to hold the plutonium pieces. In October, the practice of core sampling every plutonium button was changed so that only every other button was sampled.⁴⁴

Other changes instituted or attempted in the 234-5 processes during 1950 included several studies of methods to determine both impurities and deliberately introduced blend materials in plutonium metal, and the switch from Model 090 to Model 110 pits. Various components of the RG Line experienced recurring difficulties (see Section 4.2).⁴⁵ Throughout the year, the 234-5 ventilation system and the 291-Z exhaust fans continued to have problems, and multiple adjustments and part replacements were made. Contamination also remained an ongoing problem in the 234-5 facility. By March 1950, plutonium concentrations in the urine of building personnel indicated a "two-fold increase over that for all plant personnel for October, November, December, 1949, and a 50-percent increase for January and February." Contamination sometimes spread into offices and hallways, and many positive air samples were obtained.⁴⁶

2.7 INCREASED PRODUCTION NEEDS FOCUS OF 1951

Throughout early 1951, the AEC continued to call for increased production of defense-grade plutonium. At PFP, times remained hectic as effort was directed toward meeting the rising production goals. On February 20, plans for a 234-5 Building addition and a third RM Line were canceled when it "became apparent [at GEL] that certain changes could be made [to the RMA and RMB Lines] which would increase efficiency."^h On April 30, 1951, Project C-198 was closed out administratively, although the RMA Line was not operational, nor were the crucible shop, some of the laboratory rooms, and some other features of Phase III. At that time, it was decided to combine the remaining work on Project C-198 with Project C-413, because of the need to incorporate the design changes for increased capacity recently developed at GEL.⁴⁷

^h In the late 1950's, a third RM Line, known as the RMC Line, was emplaced in the 234-5 Building. However, the third line planned in 1950-1951 was not built.

Additional projects under way in the 234-5 Building at that time included installation of a 100-line intercommunication phone system within the 234-5 Building (ER-E-453), duct-level floor work (ER-2503), and, in June, replacement of the original wooden floor in Chemical Storage Room 234. According to G.E. Hanford Co., this floor had "deteriorated due to chemical action." It was replaced with a concrete floor.⁴⁸ By year's end the Crucible Shop still was not completed. More minor projects had been undertaken in the building, including the installation of duct-level safety showers (ER-2600, renamed Project C-493 in 1952), laboratory alterations to provide facilities for plutonium metallurgy studies in the 234-5 Building (part of ER-2712), additional RG Line modifications (see Section 4.4), and the construction of new waste cribs (see Section 15.1).⁴⁹

Throughout 1951, ventilation and exhaust stack problems continued to plague the 234-5 Building. In a step to improve contamination control at the nearby 241-Z Waste Storage Facility, a fresh air mask station was installed, which eliminated the need to wear chemical masks in the tank pits.⁵⁰

2.8 1952 BRINGS RMA STARTUP AND FURTHER PFP PROJECTS

The most significant event of 1952 at PFP occurred on March 18, when the RMA Line commenced hot processing (see Section 5.5).⁵¹ On May 17, the RMB Line was accepted by the Manufacturing Department from construction forces, and "cold shakedown" tests began. However, the line did not become operational using product materials during that year.⁵²

In January 1952, the crucible shop in the 234-5 Building was finished. It continued to perform well throughout the year, and in May acquired a steel die for fabrication purposes that, according to G.E. Hanford Co., "will give the 234-5 Building independence with respect to all crucibles with one exception if the situation would demand a supply from entirely local manufacture."⁵³ Laboratory facilities for plutonium metallurgy studies, which had been initiated in 1951 as part of ER-2712 became IR-113 in 1952. The facilities proceeded on the authority of MWI (minor work implementation) 38, and were completed and accepted on September 11, 1952 (see Section 7.1).⁵⁴

Other 1952 projects at PFP included replacement of air lock doors, initiated in January as M-852 (IR-96) and completed and accepted in December. Construction of the 711 Waste Storage Hut for Building 234-5 (a quonset hut that was placed on a concrete pad and fitted metal shelving and an alarm system) was initiated in March 1952 as ER-A-711, renamed Project CG-503 in May, and completed and placed in use in October 1952. Installation of fire protection equipment for the Building 234-5 Filter Room was initiated in April 1952 as ER-2720, renamed D.O. (Design Order) 100289 in July 1952, but not designed or completed by year's end. Installation of a duct-level elevator stop in the 234-5 Building was initiated in May 1952 as ER-2722 and completed and accepted in September. Emplacement of a soundproof operator's booth for the control panel, 234-5 Building was initiated July 1952 as D.O. 100287 and completed in the autumn. Installation of vacuum leak detection equipment in the 234-5 Building (M-844), considered crucial to improving contamination control in the facility, was completed in August 1952.⁵⁵

Another 1952 project at PFP proposed process laboratory revisions in an effort to design a 2,000 to 3,000 square foot addition to the 234-5 Building. The addition would provide floor space for office and change house facilities. Initiated in July as ER-2727, the project became D.O. 100350 in September and changed scope to provide for a 3,700 square foot Development Laboratory annex to the PFP structure.⁵⁶ Another project underway and concluded at PFP in 1952 included the Skull Recovery Facility, which commenced hot operations in November (see Sections 8.1 and 8.2).⁵⁷

Also in November 1952, C-Reactor, the fifth defense production reactor, started up at the Hanford Site, and plans were underway for the design and construction of an additional defense production unit that eventually became the K-Reactor complex (KE and KW). Concurrently, the 200 Area facilities were notified by the AEC that they should make specific plans to handle a large increase in reactor output.⁵⁸ At that time, a study of the "modernization and rehabilitation" of the RG Line was wrapped into a larger research design study to recommend ways to increase 234-5 Building capacity to meet the needs of the overall Hanford Site expansion. At the same time both the RG and RMA Lines went to a three-shift operation to accommodate the production increases.⁵⁹ The RMB Line never became operational (see Section 5.6).

2.9 PROGRAM EXPANSIONS CONTINUE DURING HECTIC 1953 AND 1954

Throughout 1953, major, overall expansion directives from the AEC drove the Hanford Site to begin construction of the PUREX Plant (Project CA-513), the KE and KW "jumbo" reactors (CA-512), five new laboratories and other significant facilities in the 300 Area (CA-514), and Phase I of a multi-year REDOX capacity increase project (CA-187). Plutonium production at the Hanford Site increased that year by a substantial percentage over 1952, and stood at several times the output of 1947.⁶⁰

Beginning in early 1953, as RG Line modernization was abandoned in favor of RMA modifications (see Section 4.6), PFP's non-production activities were focused on Projects CG-549 and CG-551 (see Section 5.5). Throughout the year, the 234-5 Building fulfilled and often exceeded its production commitment to the AEC, with the RMA Line doing the vast majority of the processing.⁶¹ In September 1953, HW production quotas rose sharply, as the Hanford Site began to ship plutonium buttons, as well as plutonium nitrate, to the new Rocky Flats Site in Colorado. Defense production facilities at Rocky Flats consisted of hands-on, rubber glove lines that functioned solely to purify and fabricate metallic plutonium weapons shapes, so they depended on a steady supply of feed material from the 234-5 Building. In October 1953, the PFP began fabricating the new Model 130 pits, along with the older Model 110s.⁶²

Throughout 1954, further facility expansions and increases in plutonium production again dominated and drove events at the Hanford Site. Total plutonium output exceeded that of 1953 by another large percentage. In the spring, assessments were undertaken of the "maximum obtainable capacities of the REDOX, PUREX, and Metal Conversion [UO₃] Plants, and means for obtaining additional capacity." Projects CA-512 (construction of the KE and KW reactors), CA-513 (PUREX construction), and CA-514 (300 Area expansion) went forward. Project CG-535 (REDOX Expansion, Phase II, including construction of the 233-S Plutonium Concentration Facility) got underway, as

did the Project CG-603 (the "4X" Program). The 4X Program was a plan to operate all four of the Hanford Site's radiochemical separations facilities (B Plant, T Plant, REDOX and PUREX) at once, to meet the demands of production increases. B Plant had been closed since mid-1952, but underwent significant revisions throughout 1954 to modernize and upgrade its capacity. Similar improvements were designed during 1954 for future emplacement in T Plant. In South Carolina, the Hanford Site's new "sister" plant, the Savannah River Plant (SRP), began reactor operations, plutonium separations, and plutonium finishing. (Finishing operations there were confined to making plutonium buttons.) SRP began shipping buttons to the Rocky Flats Site in the autumn of 1954, thus relieving some pressure on PFP. However, AEC calls for production increases soon rendered this reprieve temporary. The hectic pace of PFP's early years continued.⁶³

In the 234-5 Building, commitments to the AEC for the production of both buttons and finished weapons components were either met or exceeded throughout most of 1954. In May, June, July, and December, the AEC commitments were exceeded, with both Model 110 and Model 130 shapes fabricated throughout the year. One exception to the high production performance occurred during early August, when the fabrication of shapes was curtailed for nearly 3 weeks following a serious plutonium-turnings fire that occurred in the RMA Line on July 27 (see Section 5.7).⁶⁴

Project work at PFP again was dominated by design and preparations associated with Projects CG-549 and CG-551 in the RMA Line (see Section 5.7). In April 1954, machinery from the 234-5 Building machine shop was removed to the 272-W Building to make room for the new Final Inspection Area in Room 192 of PFP. At year's end, ventilation duct work and electrical power connections for installation within the 234-5 Building was under way.⁶⁵

Among other key needs identified and addressed in 1954 improvement projects at PFP were additional air drying facilities, with design studies begun as D.O. 100850 in April when a contractor report stated that calculations of the refrigerated, dehumidified air required for "good operation of mechanical lines in the 234-5 Building indicate that the need may exceed the capacity of present equipment by a factor of six." Additional air drying facilities were emplaced in PFP as Project CG-617 in early 1955. Extra helium storage facilities were designed for the 234-5 Building, as was an improved carbon dioxide system for Task V, in the autumn of 1954. However, these projects were not undertaken until 1955 and 1956. Likewise in 1954, the fire protection needs of PFP were assessed. Cambridgeⁱ "fire-proof" filters were emplaced in the filter boxes of the RG Line, RMA Line, and analytical and technical laboratories of the 234-5 Building. However, the bonding material around them soon failed, causing increased emissions from the 291-Z Stack. A new fire detection system was proposed for the building, but a decision on emplacement of a system was deferred for further study. Other projects during 1954 included complete rebalancing of the 234-5 Building ventilation system and renovation of the 2705-Z Temporary Technical Office facility. This small administration building became the home for mail and duplicating services for the PFP complex. When those services moved out of the 2704-Z Building, the space there became a repository for classified documents generated at or

ⁱ Cambridge Filter is a trademark of the Cambridge Filter Corporation.

relating to plutonium finishing operations. Also during 1954, the 234-5 Building's crucible shop tested several new crucible alloy and fabrication methods, for both Task III and Task IV crucibles.⁶⁶

2.10 HANFORD SITE EXPANSION CONTINUES AT RAPID RATE IN 1955

During 1955, overall Hanford Site expansion to achieve increased plutonium production continued at a rapid pace. Indeed, the total plutonium output of 1955 at HW exceeded that of 1954 by another large margin. Major projects completed or nearly completed included CA-512 (construction of the KE and KW reactors), CA-513 (construction of the PUREX Plant), CA-514 (300 Area expansion), and CG-535 (REDOX Capacity Increase, Phase II). Large new projects begun included CG-558 (reactor plant modifications for increased production), CA-546 (construction of the Fuel Element Pilot Plant [306 Building] to pilot new fuel fabrication methods and alloys), CG-599 and CG-603 (the 4X Project in the 100 Areas and the bismuth phosphate plants, respectively), CA-613 (expansion of the UO₃ Plant), and construction of the 1706 KER Recirculation Laboratory (an extension of Project CG-674) to pilot reactor improvements that could lead to further production. CG-643 (REDOX Capacity Increase, Phase III) construction began and advanced to 54 percent complete by year's end. In April the 233-S Plutonium Concentration Facility adjacent to the REDOX Plant began operations (see Section 1.2). That month, AEC representatives visited the 234-5 Building to discuss optimal methods to achieve production increases. Their discussions led to the decision, later that year, to build the RMC Line (see Section 6.1).⁶⁷

In the summer of 1955, plans were under consideration to install continuous Task I-Task II equipment that could accomplish continuous plutonium oxalate precipitation, filtration, and calcination in the 233-S Building and in the new PUREX Plant, which was undergoing cold test runs. However, alternative plans being considered addressed developing a continuous Task I-Task II process, which would be kept within PFP. The latter alternative eventually was adopted.⁶⁸

Plutonium production in the 234-5 Building set new records for high output throughout most of 1955, with the exception of the early months when RMA Line operations were closed for the installation of new equipment in Projects CG-549 and CG-551 (see Section 5.8). In January, the monthly production schedule was met in the first 11 days. The A-Line then shut down and did not resume production until late April. In May, the production of plutonium buttons exceeded the previous all-time record by a substantial percentage, and the production of finished plutonium shapes surpassed the previous record by another very large amount. PFP production in June surpassed the May record by another huge jump, and July set still another all-time record. During August and September, product specification issues impeded full production (see Section 5.8). However, in October, the A-Line set a new all-time production record for PFP; that record was surpassed in December.⁶⁹

While new Task I, II and III equipment was being installed in the PFP, the 234-5 Building's new final inspection area was readied and occupied "with no difficulties encountered" in April. Later that year, studies were underway to improve and mechanize the Final Inspection area, with emphasis on "faster

and more accurate gauging methods and improved cleaning and polishing equipment."⁷⁰ At the same time, improved radiation monitoring instruments and techniques revealed that the surface gamma dose rates of the plutonium metal were 40 percent higher than previously thought.⁷¹

Other projects carried out at PFP during 1955 included Project CG-617, Additional Air Drying Facilities, 234-5 Building, which was authorized by the AEC in January, and completed in November. All of the as-built drawings for the PFP itself were completed, and the RECUPLEX facility (see Section 12.0), a reclamation facility for plutonium-bearing scraps and wastes, started up in Room 221 of the 234-5 Building. The PFP's Crucible Shop worked on fabrication orders for special molds for the PFP metallurgy laboratory, the Hanford Site Pile (Reactor) Technology group, and the A-Line (see Section 5.8).⁷²

2.11 DEFENSE EXPANSION SURGES FORWARD IN 1956

Across the nation, expansion of plutonium production capacities continued throughout 1956. That year, total plutonium output at the Hanford Site increased vastly over 1955. Early in 1956, engineers and designers examined the possibility of installing Task I (oxalate precipitation) facilities in both the PUREX and REDOX Plants. (This work never occurred at the REDOX facility, but oxide conversion facilities were installed many years later, between 1978-1983, at the PUREX facility.) Project CG-643, for REDOX Phase III Capacity Increase went forward throughout 1956 and many additional expansion projects began. These included Project CA-513-E, PUREX Phase I Expansion; Project CG-613, UO₃ Plant Expansion; Project CA-558, Reactor Plant Modifications for Increased Production (affecting B, D, DR, F, and H Reactors); Project CG-600, 100-C Reactor Alterations (for increased production); and Project CA-546, the Fuel Element Pilot Plant. Project CA-546 was construction of the 306 Building to pilot new ways to fabricate uranium fuel for increased production. Study plans were developed in late summer for a possible Phase IV capacity increase at REDOX, but these plans later changed in response to the development of different types of fuel and fuel reprocessing needs.⁷³

At the 234-5 Building, the most significant expansion effort concerned planning for a second production line. By year end, the program was being called the RMC Button Line (see Section 6.1).⁷⁴ The other most important project of 1956 at PFP was the design of major new equipment to combine Task I and Task II in the RMA Line (see Section 5.9).⁷⁵ Studies began on the conversion of RECUPLEX to a manufacturing facility (see Section 9.6), design of an office annex to the 234-5 Developmental Laboratory, the construction of a gas cylinder storage pad and shed at the rear of the PFP, waste routing changes (see Section 15.1), and many other RMA improvement projects (see Section 5.9). Designs were completed and an order placed for fabrication of a new "mechanized piece cleaner and polisher" for the final finishing operations, and equipment was developed for mechanizing radiography operations in the final inspection facility.⁷⁶

Other 1956 projects and issues in the 234-5 Building included steam-reducing valves in the fan room being reported as "a major problem which has not yet been solved," and exhaust dampers in the filter rooms and drying towers for instrument air being listed as problems. By March, the preventive

maintenance program was in place in the PFP, but, because of the rush of production, most repairs still occurred on an as-needed, near-emergency basis. Changes also were made in milling of crucibles in the Crucible Shop, and tests continued in the use various agents for removing nickel plating from plutonium metal needing rework.⁷⁷

Throughout 1956, all production commitments and forecasts were either met or exceeded in the 234-5 Building, with most operations described by the contractor as "satisfactory," "routine," or "normal." In February, production of Model 250s was initiated, with some ongoing production of Model 200s and other, older models. In July, fabrication began on the first shipment of plutonium product from the Savannah River Plant.⁷⁸ Processing of PUREX product material began at PFP in February. In the meanwhile, the last processing of T Plant products in the 234-5 Building took place in April.⁷⁹

3.0 PFP OPERATIONS 1957 THROUGH 1989

3.1 HANFORD SITE AND PFP PRODUCTION SET NEW RECORDS 1957 THROUGH 1961; MANY UPGRADE PROJECTS NECESSARY

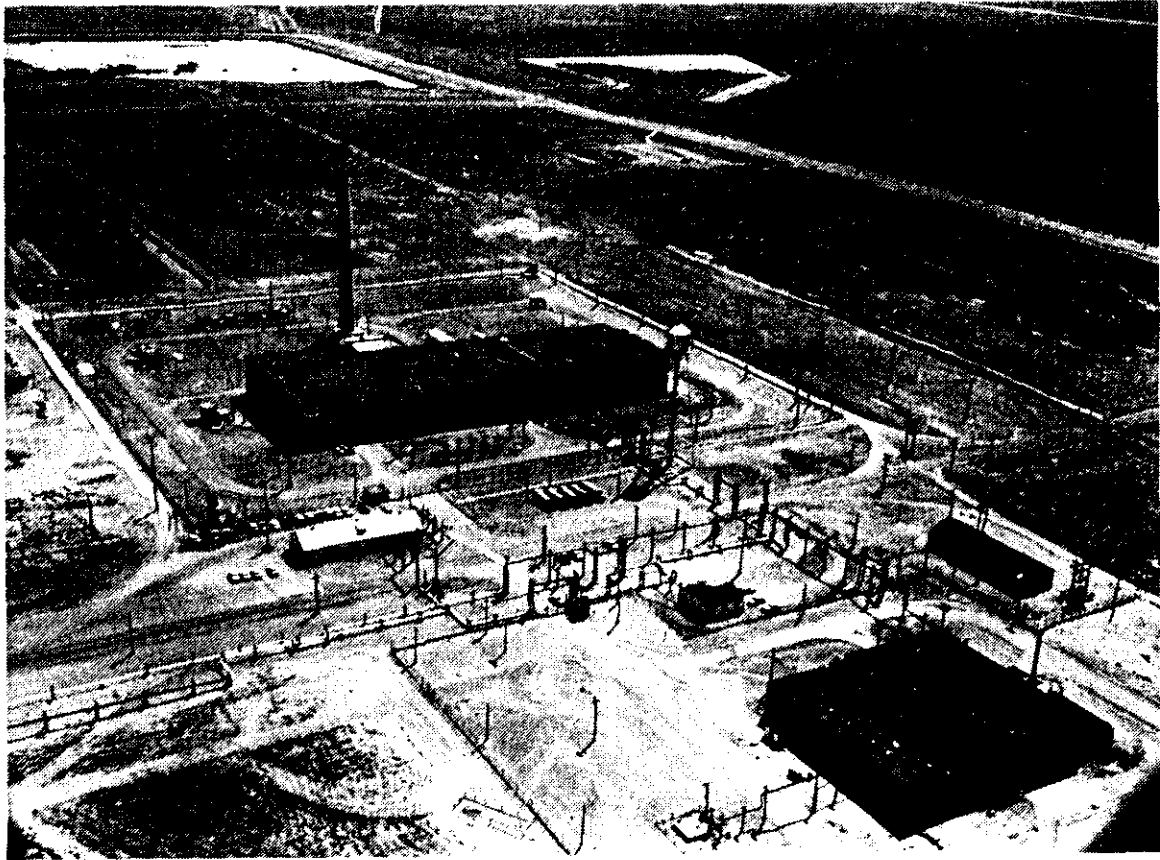
From 1957 through 1961, plutonium production continued to soar at the Hanford Site, mostly because of several operations improvement projects at the PUREX Plant and the completion of Project CG-643, Phase III Capacity Increase at the REDOX Plant. The total 1957 plutonium output stood at just above that of 1956; the 1958 total increased slightly over 1957. Production rose another incremental amount in 1959, while the new, continuous Task I-Task II of the RMA Line was credited with increasing production at PFP "by a factor of two" (see Section 5.10). In 1960, total plutonium output climbed to a sizeable percentage over that of 1959, with another increase in 1961. During 1962, production dropped slightly, because an operating accident at the facility for recovery of uranium and plutonium by extraction (RECUPLEX) closed plutonium finishing operations for several weeks in the spring (see Section 9.8).⁷⁹

Overall, the 234-5 Building finished 1957 just under its production commitment for both fabricated metal and buttons. The production of Model 200 shapes was discontinued at the end of December. However, throughout 1958 to 1960, production of metallic plutonium reached record amounts. Because the RMC Line did not begin full routine operations until October 1960, most of the metal production was accomplished in the RMA Line. Throughout 1961, the A Line remained the only operating fabrication facility in the PFP because RMC operations were confined to Tasks I-III (see Section 6.2).⁸⁰ February 1958 witnessed the largest single leap in production. Output of plutonium metal was many times higher than during any previous month in the history of the 234-5 Building. In January 1960, the previous monthly record for the production of buttons was exceeded, and in April 1960 the January record was exceeded. The year 1960 ended with an annual record total output at PFP. During 1958-1961, Models 201, 251, 65, 66 (very briefly), 85, 81, 81C, and 1251 were manufactured in the 234-5 Building.⁸¹ (See Figure 3-1.)

In the 234-5 Building, many projects were undertaken during the hectic 1957-1961 period in an effort to accommodate the vast production increases generated by the PUREX Plant and the increased reactor throughput. The most significant projects were CG-734, RMC Button Line; and CG-745, RMC Fabrication Line (see Section 6.1); begun in 1957.⁸² The other important event in the PFP during 1957 was the completion and startup of the continuous Task I-Task II process in the A-Line, emplaced in Project CG-691 (see Section 5.10).⁸³

Despite good performance in the new Task I-Task II equipment, the processing of high-activity feed from the PUREX and REDOX Plants caused rapid saturation of the primary filters on the RMA Line glove boxes. In mid-1957, large increases in particulate emissions from the 291-Z stack were noted, indicating ancillary saturation and breakthrough of the secondary HEPA filters. An average of 18 microcuries (μCi) of plutonium were measured per day in stack releases during July, and that average had grown to 117 μCi per day in December. An "accelerated program of inspection and filter replacements" was instituted. However, the problem persisted, with stack emissions averaging 182.1 μCi per day in late 1958, and remaining high into late 1959.⁸⁴

Figure 3-1. PFP Complex in 1957.



Additional projects undertaken at PFP to support the production requirements of the late 1950's and early 1960's included CG-756, Fire Resistant Exhaust Filters, begun in mid-1957 and completed in November 1958. This project replaced the CWS paper space filters in the 234-5 and 231-Z Buildings with Cambridge Type G^j fire-resistant filters (see Section 1.5). It also replaced some corroded filter boxes and added a sprinkler system for the storeroom that held cardboard, paper, and other combustible supplies. At the same time, a program of close housekeeping control of flammable solvents such as bulk oil, TBP/CCl₄, alcohol, and others was instituted in the buildings.⁸⁶ Still more fire protection improvements were installed in Project CG-789, Additional Fire Protection, including fire detectors throughout the 234-5 Building, carbon dioxide fire suppression systems in the hydraulic lines, and a series of automatic wet-pipe sprinkler systems in some of the corridors and vestibules on both the first and second floors of the PFP and under the roof (except under the exhaust filter rooms and the calcium storage rooms). This work overlapped Project CG-756, beginning in early 1958 and concluding in the autumn of 1960.⁸⁷

^j Cambridge Type G filter is a trademark of the Cambridge Filter Corporation.

In late 1958, Project CGC-826, Vacuum System Improvements, was begun in the 234-5 Building, with completion in the autumn of 1959. Undertaken on an urgent basis to keep pace with the expanded production requirements, the project consisted of modifications to the 26-inch vacuum source located in the 291-Z Building and to the loop through the duct levels and the connection and service points in the analytical laboratory, development laboratory, the RECUPLEX, and Tasks I, II, and III of the RMA Line. Flushing and cleanout facilities were installed in the existing vacuum header. Two additional connector lines were provided between the main filters and the pumps in the 291-Z structure, and miscellaneous filter and piping modifications (including the addition of auxiliary demisters and trap assemblies) also were performed. Many feet of the old vacuum lines were replaced. During removal of some of the old vacuum lines in the RMC Line area (formerly the RG Line area) in December 1958, a plastic bag used to transport a portion of the line was dropped and leaked contamination. The leak was not detected until the bag reached a burial box staged 500 feet from the rear (west) of the building, resulting in a serious spread of contamination both inside the building and from the east stairwell to the burial box. The year 1958 also witnessed the start and completion of Project CGC-800, Reduction of Radiation Exposure, RMA Line (see Section 5.10).⁸⁷

Beginning in 1959, a series of modifications to both the RMA and RMC Lines (see Sections 5.10, 5.11 and 6.1), and to add a specialized, vault-type cell inside a 3,600-square-foot addition on the northwest corner of the 234-5 Building, was undertaken as Project CGC-811, Additional Fabrication Facilities. These modifications provided equipment flexibility capable of processing fuels "with exposures from 1,000 to 10,000 MWD/T," and of fabricating many new weapons designs, shapes, and weights. The reinforced, poured concrete and metal addition contained a heavily shielded cell with 4-foot-thick walls, that measured 20 feet wide by 30 feet long by 30 feet high on the inside. It housed a new, consolidated final inspection facility with a million-volt (MEV) X-ray unit. The facility also contained an 8-foot by 5-foot by 5-foot deep, covered pit for servicing the X-ray unit, a lead-shielded dark room, a personnel air-lock entrance, and modifications to the building pipe tunnel. According to the contractor's report, a labyrinth design was adopted to provide "double scattering of radiation rays." The project was completed in 1962.⁸⁸ (See Figures 3-2 and 3-3.)

3.2 PRODUCTIVITY INTERRUPTED BUT PROJECTS ABOUND AT 1962-63 PFP

Reactor output and plutonium production continued to climb at the Hanford Site throughout the early 1960's. During 1962 and 1963, production schedules for both buttons and fabricated plutonium parts at PFP were interrupted often by minor but persistent equipment difficulties, by lack of adequate feed caused by outages at REDOX and PUREX, and, of course, by the criticality accident at RECUPLEX (see Section 9.8) and the consequent loss of much of the 234-5 Building's plutonium scrap recovery capabilities. The accident also suspended all operations in the 234-5 Building until "limited fabrication activities" resumed on April 23. Button line operations resumed on May 18.⁸⁹

Figure 3-2. PFP Building Addition for Project CG-811, March 1960.

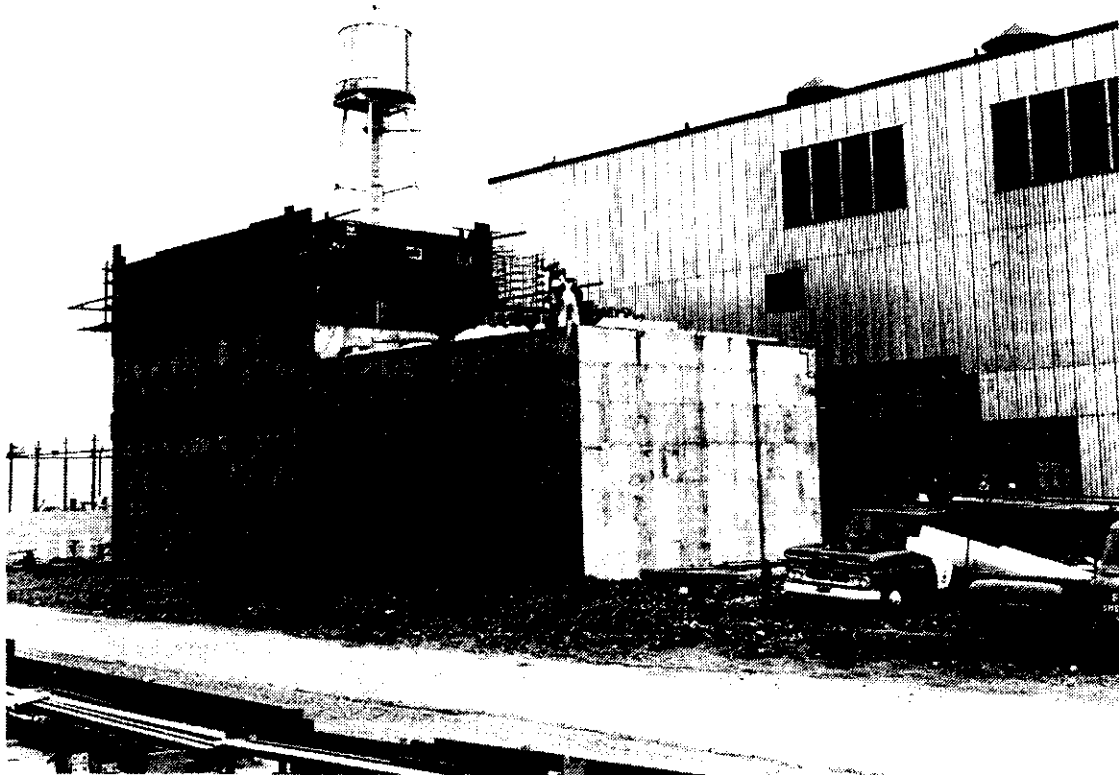


Figure 3-3. Installation of Conveyor in PFP Building Addition for Project CG-811, April 1960.



Changes in AEC model requirements imposed added work and delays in Task V during these years. A complete planning and retooling process was undertaken in late 1961 and continued through much of 1962 for Model 1251, but the manufacture of this pit was canceled before production began. Models 45, 1807, and 74C were manufactured during 1962 and 1963. Equipment problems in the aging A-Line became more frequent (see Section 5.11). As a result of these factors, the high production levels of 1961 were not even attained.⁹⁰

Inspection facilities also experienced problems with new, MEV X-ray equipment in 1962 and 1963, and the button lines experienced a "blending problem of significant proportions" early in the period, when "a sharp rise [occurred] in the Pu-240 isotopic content of the feed" received at the 234-5 Building from REDOX and PUREX.⁹¹

As a result of the increases in reactor throughput and AEC directives to augment production, additional modifications for increased safety and production were undertaken at the PFP. Project CGC-953, Personnel Protection, Storage Hood Shielding - 234-5 Building, was started and completed in the RMC Line in 1962 (see Section 6.1).⁹² In October 1962, three additional projects were authorized for the 234-5 Building. Project CGC-968, Additional Plutonium Storage Facilities (see Section 14.0), provided storage facilities for scraps needing reclamation, materials needing rework, and finished products.⁹³ Project CGC-983, Plutonium Ingotting and Auxiliaries Facility, RMA Line, provided specific additional facilities in the A-Line (see Section 5.11), along with milling, grinding, drilling, and boring facilities and gauging devices, to be added to the 272-W Shop. This project was undertaken to support experimental weapon component fabrication facilities for special AEC tests and projects.⁹⁴ Project CGC-984, Electrical and Hydraulic Equipment Mezzanine - RMA Line, installed mezzanine space in the A-Line area to house prototype equipment for research and development in special weapons fabrication (see Section 5.11).⁹⁵

In 1963, Project CAC-987, Metal Stabilization Facility, was authorized as part of the research and development work for special weapons fabrication that was to take place in the 234-5 Building. This project provided for the procurement of a special press and associated equipment and design of a cell for housing the press.⁹⁶ At the same time, scoping studies were conducted that considered enlarging the 272-W Shop and building a special tool grinding shop addition to the 234-5 Building to support specialized fabrication activities and increased weapons production. However, these additions were not constructed.⁹⁷ A number of critical mass control studies and safe conditions studies also were undertaken in various aspects of the Hanford Site's plutonium finishing and transport, aimed at increasing the safety of operations.⁹⁸ In August 1963, a major change in the warning systems occurred in the 234-5 Building, when the siren alarm signaling a nuclear excursion was changed to the "ah-oo-gah" sound. That December, a new air sample counter was placed in service in the facility, making possible faster detection of airborne contamination. The new device "permit[ted] the immediate determination of alpha activity from natural sources in air samples and thus eliminate[d] the former 24-hour delay period which was necessary to allow the decay of natural radiation."⁹⁹

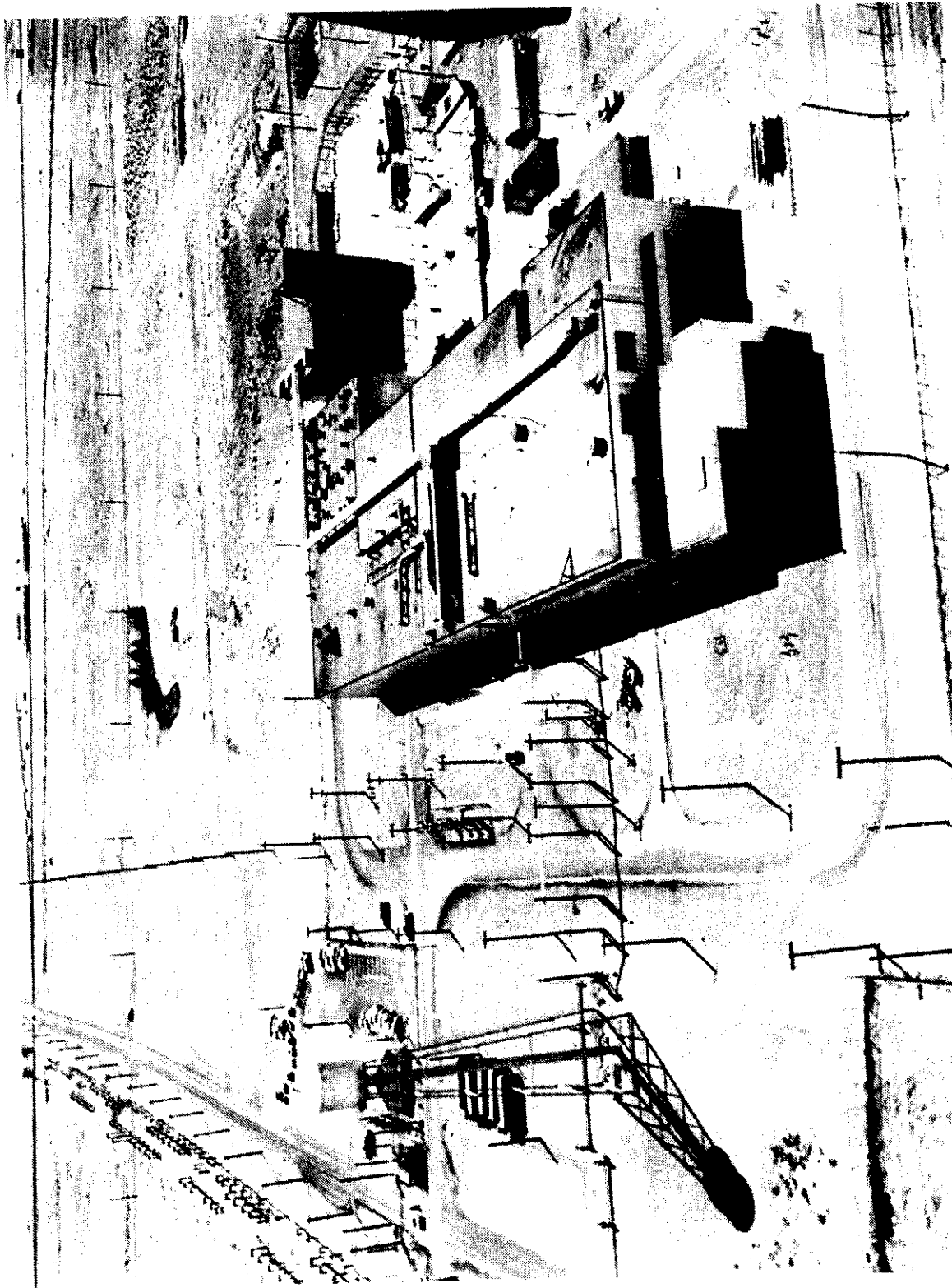
3.3 MAJOR CHANGES AFFECT HANFORD SITE AND PFP IN BEGINNING IN 1964

On January 8, 1964, President Lyndon Johnson announced a decreased national need for special nuclear materials, because of the sufficiency of the existing stockpile and the recent treaty banning atmospheric nuclear weapons testing.¹⁰⁰ Soon afterward, plans to shut down the Hanford Site production reactors in a phased fashion also were announced. The reactor closures began in December 1964, at DR Reactor, and in 1965 both F and H Reactors were deactivated. Ironically, the month in which the record high number of buttons was produced in the PFP was December 1964.¹⁰¹ (See Figure 3-4.)

During the second half of 1965, a decision also was announced to remove the weapons fabrication work from the 234-5 Building and to concentrate that work at the Rocky Flats Site. (Plutonium fabrication activities at the Rocky Flats Site underwent a major expansion beginning in 1966-1967.) The Los Alamos Site also would continue with its small-scale, experimental fabrication projects that were not part of the mass production efforts. In the Hanford Site's 234-5 Building, defense production remained high throughout 1964 and 1965, with Models 88-C and 104-C being produced. The weapons fabrication program concluded in mid-December of 1965. Layaway (but not yet removal) of the fabrication portion of the RMA and RMC Lines (Tasks V onward) was undertaken immediately and essentially completed in March 1966. The metal conversion portions of the RMC Line (Tasks I-III) continued to operate, while Task IV was converted to bag-out and sealing for shipment operations (see Section 6.3). As a result of decreased production needs and equipment problems, the RMA Line was taken out of service completely after the end of 1964 (see Section 5.12). At midnight on December 31, 1965, G.E. Hanford Co. turned over the operation of all of its Hanford Site chemical processing facilities, including the 234-5 Building, to a new operating contractor, Isochem, Inc.¹⁰²

As a result of the AEC decision to move plutonium fabrication work out of the 234-5 Building, a diversification study was undertaken late in 1965 to plan alternative future uses for the facility. An expanded role for the PFP in non-defense work was envisioned (see Section 13.1).¹⁰³ Also during 1965, plans went forward in the 234-5 Building to modify facilities and equipment to convert uranium 233 (U-233) from nitrate form to oxide and metallic forms. U-233, a defense material produced from irradiated thorium, would become a PUREX Plant product for a few months beginning in April 1966, as the result of a special production request from the AEC. The 1966 run at PUREX was an experimental effort, associated with much uncertainty about whether U-233 processing would become an ongoing, production-scale activity. At PFP, the developmental laboratory worked toward developing an oxide conversion technique in 1965 (see Section 7.8). At the same time, plans were made to install oxide conversion equipment in Room 179-B and a metal reduction glove box in Room 221. However, the AEC decided to ship the PUREX U-233 in nitrate form to the Oak Ridge Site (an AEC location in Tennessee) and another offsite destination. The U-233 conversion facilities were not constructed in the 234-5 Building.¹⁰⁴

Figure 3-4. PFP Complex, circa 1964.



From 1966 to 1972, PFP operations were split between defense and non-defense work (see Sections 13.2 and 13.3). In 1966, independent inspection of the 291-Z Stack revealed that "most construction joints are open approximately 1/16 [in.]...There are a few places where seepage is coming through the wall." A crack existed in the top section, south side, and some of the lighting clips had broken loose. The cap and ladder were found to be in good condition, but repairs to the construction joints were authorized.¹⁰⁶ Production in the 234-5 Building was interrupted between August 18 and September 5, 1967, as the result of procedures associated with a changeover in the chemical process operating contractor from Isochem, Inc. to Atlantic Richfield Hanford Co. (ARHCO).¹⁰⁷

Late in 1967, two potential, interrelated new missions were explored for PFP. One concerned a national role in plutonium and uranium scrap processing (see Section 12.3), and one focused on the PFP complex as a national storage center for plutonium, including scrap and finished materials (see Section 14.2).¹⁰⁸

As the commercial nuclear industry continued to expand, non-defense work went forward as part of PFP activities in 1968, occupying about 30 percent of the facility's time and effort (see Section 13.2). In support of the expanded work scope, the oxalate precipitation and oxide portions of the RMA Line were cleaned out and reactivated (see Section 5.13). From that time until the A-Line's final closure in 1980, the RMA Line was known as "the oxide line," while the RMC Line was known as "the metal line."¹⁰⁹

During 1968, the PFP also began participation in an "International Safeguards Experiment" in which some of the plutonium nitrate in the 234-5 Building (and some stored in the 224-T Building) was accessed and inspected by the International Atomic Energy Agency (IAEA), a multi-national, non-proliferation group headquartered in Vienna, Austria (see Section 14.2). The PFP's role in scrap recovery for the AEC complex grew larger throughout the year (see Section 12.3). At year's end, the AEC appraisal for the PFP complex, while it praised the contribution in non-defense work (see Section 13.2), noted problems in waste discard (see Section 15.3) and the need for "detailed unit costs for services and processing of plutonium."¹¹⁰

Throughout 1969, both defense and non-defense work was carried out at PFP, with the proportion of non-defense work in support of commercial nuclear fuel development becoming greater. The RMA and RMC Lines, as well as the Plutonium Reclamation Facility (PRF), functioned throughout the year, except for intermittent repairs. A fire protection sprinkler system was installed in the 234-5 Building Analytical Laboratory, along with an associated laboratory electrical fire alarm system (see Section 7.7). IAEA cooperation expanded, as did attention to waste effluents discard, and to scrap receiving, identification, sorting, and repackaging activities (see Sections 14.2, 12.3 and 15.3). That year, the AEC commissioned a private industrial safety company to conduct a study of the safety and fire resistance of glove box windows at the Hanford Site. Heat resistance tests indicated a need to replace existing plastic panels (usually a methyl methacrylate known as plexiglas^k) with glass windows. Eventually, during 1974 and 1975 and in the

^k Plexiglas is a trademark of Rohm and Haas.

1980's, several such replacements with Lexan¹ polycarbonate plastic were made on A-Line, C-Line, and PFP Laboratories glove boxes.¹¹¹

3.4 NON-DEFENSE WORK, SCRAP MANAGEMENT, WASTE DISCARD UPGRADES AND SECURITY IMPROVEMENTS DOMINATE 1970'S AT PFP

Very little defense-grade plutonium metal was manufactured in the 234-5 Building during 1970, but non-defense work expanded (see Section 13.3). The RMA Line and the PRF operated throughout the year, but the RMC Line was shut down late in the year because of a decrease in defense grade needs. Planning went forward in many effluents control initiatives (see Section 15.3), and Project HCP-640 emplaced improved fire alarm and suppression equipment in the PFP analytical laboratory, peripheral areas, some offices, maintenance shops, and inside the 242-Z facility (see Sections 7.7 and 11.2). Also in 1970, planning for fire protection, fire alarm and electrical improvements (Project HAP-653) was initiated in many areas of the PFP complex.¹¹²

During 1971, non-defense work remained important in the 234-5 Building, as did planning for waste effluents upgrades (see Section 15.3). The RMA Line and the PRF operated throughout the year. In April, in response to increased production at the PUREX Plant, the RMC Line was reactivated to produce weapons-grade metal (see Section 6.3). Defense metal then was produced in substantial quantities for the remainder of the year. Planning for the fire and electrical improvements went forward. Improvements included providing an automatic wet-pipe sprinkler system for the entire first floor of the 234-5 Building (except Rooms 106, 172, 173, 174, 175, 190, 192-B, 192-C, 194 and 225, many of which were used for storage), all stairwells, and the space above the second floor filter rooms (with attendant drainage modifications to prevent water from entering the filter rooms). They also included modernizing the alarm and detection system and extending the sprinkler system to electrical substation 252-ZL outside the north wall of the PFP. The 291-Z Building (and the related electrical substation 252-Z2), which had never had automatic fire suppression equipment, would be provided with detection and suppression equipment. The 232-Z Building and the 236-Z Building also would receive fire protection upgrades in this project (see Sections 10.7 and 12.3), the roof extending between the 234-5 Building and the 2736-Z Building (see Section 14.3) would receive a fire protection system, and sprinklers would be emplaced in some additional, open-faced laboratory hoods inside the PFP (see Section 7.7).¹¹³

A major innovation at the PFP in 1971 was the development of the Plutonium Retrieval (PRE) System, an inventory data system for nuclear materials accountability. The computerized system fed into the National Nuclear Materials Management and Safeguards System (NMMSS) maintained for the AEC at the Oak Ridge Site. The PRE system recorded the attributes of inventory items and reflected their current status and location. However, the PRE system was plagued with inaccuracies and discrepancies for many years.¹¹⁴

¹ Lexan is a trademark product of the General Electric Company.

Throughout 1972, non-defense work continued as a salient function in the 234-5 Building. The production of plutonium oxides for Fast Flux Test Facility (FFTF) development was the most important activity of the RMA Line (see Section 5.13). Planning documents for FY 1972 identified this activity as among the top priorities for the facility, along with processing of defense-grade PUREX Plant output and the reduction of plutonium scrap inventories (see Section 12.3). Weapons-grade metal was produced by the RMC Line in substantial quantities, with residual inventories processed even after the PUREX Plant was placed in a wet standby mode in May (see Section 6.3). In January 1972, a temperature excursion occurred in a stand-alone glove box in Room 227 of the 234-5 Building, when a propane cylinder leaked. Extensive hood damage and a room-wide spread of contamination occurred. The PFP fire suppression and detection projects planned in 1970 and 1971 were emplaced during 1972, and planning for waste effluents control improvements intensified (see Section 15.3).¹¹⁴ Also during 1972, planning began for another fire protection upgrade that eventually was completed in the PFP during 1976-1977. At that time, Project HCP-684 emplaced prefilters covered by sprinkler systems, stainless steel screens, smoke and heat detectors, and automatic shut-off dampers in the E-3 (operating area) and E-4 (glove box) HEPA filters of the 234-5 Building.¹¹⁵ In 1973, a new gamma-indicating radiation monitoring system was installed in the PFP, and criticality overflow drains were emplaced in some glove boxes after installation of the wet sprinkler systems in Projects HCP-640 and HCP-653.¹¹⁶

3.5 PFP DECONTAMINATION AND DECOMMISSIONING ORDER GUIDES LATE 1970'S, EARLY 1980'S WORK

Beginning in May 1973, all of the ARHCO 200 Areas facilities stood down for a review of interfaces with the environment. This assessment was followed by several projects that upgraded waste effluents disposal systems and practices (see Sections 15.2, 15.3, and 15.4). On July 4, the PFP complex and the 242-T Evaporator received permission to restart. They resumed operations the following week. Other ARHCO facilities remained closed for several more weeks (see Section 15.3).¹¹⁷ In August 1973, the RMC Line shut down because of a lack of feed after the closure of the PUREX Plant (see Section 6.3). The RMA Line operated from mid-1968 through early 1975, producing plutonium dioxide mixtures for Cores 1 and 2 for the FFTF and other commercial customers (see Section 5.13). The PRF operated through mid-1976 until a serious accident in the 242-Z facility shut down all PFP complex operations (see Sections 12.4 and 11.3). A centralized non-destructive assay (NDA) facility was proposed in 1973, to upgrade nuclear materials management practices to newer AEC standards. An area of 1,200 square feet in Room 221 of the 234-5 Building was outfitted for this facility, which would consist of specialized counting equipment and sufficient shielding to guard test results against false readings imposed by other nearby radiation sources.¹¹⁸ During this period of rapid mission changes, uncertainty prevailed in the PFP complex and plans shifted repeatedly. A mid-1974 planning document forecast that "the Plutonium Finishing Plant (Z Plant) will continue to provide plutonium processing services through the second quarter of FY 1986 and then be shut down and maintained in standby indefinitely...[services will include] plutonium processing, scrap management, warehousing, and safeguard services."¹¹⁹

From May 1974 through May 1976, some of the weapons fabrication glove boxes and most of the fabrication equipment was removed from the RMA and RMC Lines in the 234-5 Building, as part of a cleanout of facilities that had served the AEC's DMA needs. The removal process began with gamma assay of the materials to be removed, and ended with the placement of 61 containers of these materials in retrievable, transuranic waste burial grounds in the Hanford Site's 200 West Area.¹²⁰

In 1975, the AEC was replaced by the Energy Research and Development Administration (ERDA), and reviews of many practices, policies, and conditions in the PFP complex were undertaken. A complete, new plutonium processing manual was written for the PFP facilities. The need for an overall upgrading of instrumentation throughout PFP facilities was identified early. Reviews of SAS policies, plutonium storage practices, and plutonium storage and shipping containers were performed as a high priority. A new ERDA manual was written, revising mandates for the safety of non-reactor nuclear facilities. A series of comparisons was made between ERDA's plutonium storage criteria and the physical conditions and accoutrements of rooms storing plutonium in the 234-5 Building (see Section 14.4). When it was learned that several of the storage rooms did not comply with ERDA criteria, and virtually could never comply in the old structure, a series of SAS upgrades and special nuclear material (SNM) accountability improvements were emplaced to make the facility as secure as possible. Meanwhile, in July 1976, according to ARHCO, "a small explosion and pressure release caused a contamination spread" during efforts to remove the lid from a 10-liter shipping container storing plutonium nitrate in the 234-5 Building.¹²¹

During 1976-1980, Projects B-157, B-158, B-169, and B-195 were constructed and installed in the PFP complex. Project B-157, Safeguards and Security Upgrading, included construction of the 2701-ZA Central Alarm Station (CAS), located just inside the PFP protected area fence. The 1,500-square-foot CAS facility had 8-inch-thick, reinforced concrete walls. It housed 20 television monitors and a host computer-key facilities in an upgraded electronic surveillance system for the complex and its SNM. Intrusion detectors were installed at various locations in the complex, actuated by penetration of walls, floors, ceilings, openings, or by motion inside rooms. Additional alarming systems were installed in the existing door surveillance system, and a secondary perimeter fence, located approximately 100 feet from the existing Z Plant complex fence, also was emplaced with an alarming system.¹²² Project B-158, Z Plant Calorimeters, was conceived as a extension of Project B-157, and installed a multicalorimeter system capable of analyzing 12 high-level SNM packages in an 8-hour shift. Associated hardware and software also was installed. Project B-195, Materials Management Information System, provided an online nuclear materials tracking system that served as the first phase toward the goal of a real-time inventory. Project B-169, Criticality Alarm Systems emplaced new criticality alarms in the 234-5, 236-Z, and 224-T Buildings.¹²³

During the same years, in Project B-184, improved fire protection equipment and systems were added to PFP facilities and the 224-T Building that still stored plutonium. The fire improvements included water-based suppression capability for glove boxes HC-227-S, HC-227-T, HC-21-A, HC-60, and hoods 4, 5, 6, 9, 10, and 12 in laboratory room 179, and dry powder suppression capability for glove box HC-21A. The improvements also included

an additional water main and hydrant for the PFP complex, and a lunch room fire escape. Alarming equipment, and additions to the perimeter fence that denied direct access to PFP from the 231-Z Building also were emplaced.¹²⁴ Also, safety and emergency power needs at the PFP were evaluated and, in 1977, in response to ERDA audits, a series of preventive maintenance program upgrades was undertaken in the A-Line, the PRF, the PFP laboratories, and the 234-5 process systems in general. An inventory of failed equipment was made in the PFP complex in late 1976, with steps taken to obtain replacement items.¹²⁵

In July 1977, ARHCO was replaced by a new chemical processing contractor at the Hanford Site, Rockwell Hanford Operations (RHO). Among its first acts, RHO initiated reviews of all procedures for the PFP, and NDA measurements in all hoods "throughout Z Plant operating areas."¹²⁶

During 1976, all of the E-4 filters were replaced in the 234-5 Building, and a pipe leak from contaminated duct work in the building was repaired with nearly all flooring also replaced.¹²⁷ In early 1977, a study of the PFP's ventilation system, including the 291-Z Stack, duct work, fans, and filters, indicated that approximately 26 grams of plutonium had built up in the ventilation system over its 30-year life. Given this estimate, according to the contractor, it was judged that "stack discharges from credible accidents would be hazardous." Additionally, corrosion holes were observed in some duct work. A replacement ventilation facility that would meet "all criteria for a plutonium production facility" was scoped and designed, to eliminate potential discharge from the existing system. In August of that year, design estimates for Project B-178, Z Plant Ventilation and Services Upgrade, placed the cost of the extensive remodeling at \$14 million.¹²⁸

Meanwhile, contractor evaluations were conducted at PFP, based on worker safety and health issues. These evaluations revealed multiple "conduct of operations" violations in the areas of chemical storage, flammable and combustible liquids storage, compressed gas cylinder storage, and material storage. Also cited in the evaluations were insufficient means of egress in cases of emergency; electrical and general housekeeping hazards; inadequate availability of fire extinguishers, safety showers, and eye wash stations; the presence of tripping hazards; the absence of stair railings; and other items. In mid-1977, the Hanford Site's chemical processing contractor summarized an overall assessment of PFP conditions and capabilities by stating: "During the early 1970's, it became increasingly obvious that corrosive process solutions were exacting a toll in terms of deterioration of piping and equipment...Considering the obsolescence and general deterioration of equipment, as well as the evolutionary upgrading of regulatory requirements...extensive repairs and revisions are necessary..."¹²⁹

In January 1978, an independent engineering study found that the 234-5 Building and the 291-Z Stack had "insufficient capacity to withstand tornado or SSE [safe shutdown earthquake] loadings...tornado forces could overstress [these facilities]...Lateral restraints of the ventilation ductwork and piping...are lacking. Critical equipment items and components (glove boxes, primary filters, electrical panels, criticality alarms, master fire alarm boxes, fire protection systems controls, continuous air monitors, etc.) do not have good connections and anchorages to the building...the emergency utility systems for the 234-5 Z Building are not separate, self-contained

systems...Hence the loss of normal power may also prohibit the use of emergency power." These design factors, along with the inability of the old facility to meet modern plutonium containment criteria, standards requiring double containment of process systems, new environmental canons, criticality safety norms, and many other tests, were significant. Later that month the U.S. Department of Energy (DOE) issued the directive for the Hanford Site chemical processing contractor to formulate plans to decontaminate and decommission (D&D) the PFP complex. (DOE is the successor agency to the ERDA.) RHO's initial estimate in early 1978 was that the D&D project would require a "380 man-year effort scheduled over a period of 7 to 8 years."¹³⁰

Quickly, D&D planning assumptions were formulated in which the 2736-Z vault building, along with the 2736-ZA and 2736-ZB facilities, would remain in use for decades, the PFP laboratories would remain operational to support the PUREX Plant, and the PRF would continue to function to process scraps from the cleanout of the PFP complex and to support other ongoing Hanford Site activities. Early studies also showed that full D&D and removal of the major PFP production facilities would be extremely expensive. Therefore, two phases of activities were proposed. Cleanout or "stabilization" of much of the residual plutonium would be Phase I, to be completed by 1983. Various criteria were postulated for plutonium removal in the stabilization phase. The most consistent values advocated cleaning glove boxes until they contained no more than an average of 1 g of plutonium per square foot of interior surface, and cleaning systems such as transfer lines, vessels, process cells, and vacuum headers until at least 75 percent of the plutonium present at the start of cleanout was removed. Final D&D (Phase II) then would wait for future evaluation. By July 1978, D&D planning had become Project B-244 at the PFP complex. By January 1979, RHO's mission statement for the PFP complex advocated: "Stabilize all scrap in inventory to the shippable form. Place all Production Processing facilities in a safe layaway status." During 1978 and 1979, a plutonium repackaging facility, with upgraded equipment necessary to repack plutonium metal buttons and oxides into new metal cans was proposed and emplaced in Room 230 of the 234-5 Building, funded as part of the stabilization and D&D mission. (In October 1980, a contamination spread occurred during a scrap repackaging operation in this facility. [See Section 14.4.]) In 1984, the repackaging facility in Room 230 underwent D&D, as its activities had transferred to the PRF.¹³¹ In 1980, the decision was made to begin stabilization activities with the 232-Z and 242-Z facilities first. D&D planning and some preliminary cleanout activities at the initial two facilities continued through 1983 (see Sections 10.7 and 11.3).¹³²

In December 1977, at nearly the same time that the D&D planning directive was given by the DOE, a new sampling of the PFP's ventilation system determined that only approximately three grams of plutonium were held up in the system. Because of this lower estimate, and the modified future vision, Project B-178 was modified to include only replacement of the galvanized metal filter boxes for the E-4 filter system with stainless steel boxes, replacement of the exhaust collection headers associated with filter boxes, replacement of some duct work, and upgrading of selected circuit breakers.¹³³ The downsized Project B-178 was emplaced at the PFP during 1980 and finished in early 1981. In July 1981, an upgrade to the 291-Z Building's 17-inch vacuum system also was completed. During 1979-1980, effluents upgrade Project B-183 relocated the PFP's 26-inch mercury vacuum pumps from the 291-Z stack to Room

308 in the 234-5 Building, placed HEPA filters downstream of the pumps (see Section 15.3), and, for criticality prevention, emplaced traps to drain off the condensate from these HEPA filter housings. In early 1982 however, while operators were changing the vacuum filters in Room 308, a serious loss of contamination control event occurred during which eight individuals received external and/or internal alpha contamination.¹³⁴

Meanwhile, in response to contamination control needs in 1978, the 234-5 Building was depressurized for the first time in its history. Since its construction, the building had been operating at a positive pressure relative to the outside atmosphere, to prevent the inflow of "unconditioned dust and air." According to the contractor, in response to ERDA directives to operate potentially contaminated areas at negative pressure relative to adjacent areas, the 234-5 Building's air flow systems were reconfigured "in such a manner to cause air flow from areas of low contamination potential to areas of high contamination potential." In the actual changeover, ventilation ducts were rearranged within the building so that Zone 1 (corridor and office) air was supplied and exhausted by separate ducting from the remainder of the structure. Air locks were provided between this "clean zone" and potentially contaminated areas, the exterior of the building adjacent to contaminated areas was sealed to prevent "inleakage", new dampers and fans were placed in the 291-Z Building, floor drains were filled with antifreeze to prevent air blow-backs, new air monitoring and warning systems were installed, and new zone pressure control instruments were installed.¹³⁵ During 1984 and 1985, cleanout, removal, and burial of abandoned portions of the old 26-inch vacuum lines in the 234-5 Building was completed.¹³⁶

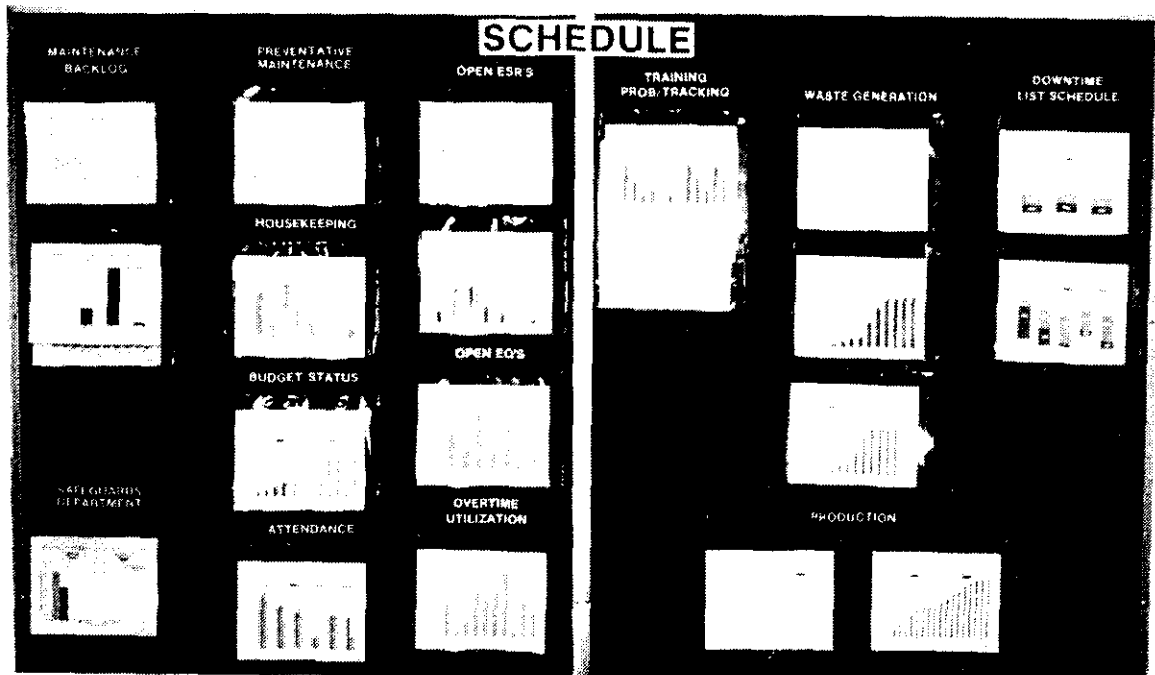
3.6 RESTART OF PFP OPERATIONS ORDERED IN 1984; OPERATIONS THROUGH 1989

In response to a build-up of nuclear arms ordered by President Ronald Reagan in the early 1980's, the Hanford Site's PUREX Plant restarted in November 1983. In February 1984, a contractor environmental assessment of the PFP speculated that the "current national needs for weapons grade plutonium increase the likelihood of full scale production activities being resumed and continued for several years."¹³⁷

Just a few months later, the RMC Line was ordered to restart for defense processing. Both the C-Line and the PRF operated in three separate campaigns, with the final campaign ending at PRF in December 1987, and the final campaign in the RMC Line ending in June 1989 (see Sections 6.4, 6.5, and 12.4). In preparation for each of these campaigns, a series of intensive upgrades was made in each of these facilities, and in the PFP as a whole. In the 234-5 Building a new criticality alarm was installed, the gamma alarm system was upgraded, the building was reroofed in 1983, new hand and foot counters were installed, fire suppression systems were leak-tested, as-built drawings were verified and corrected, waste storage and staging facilities were upgraded, procedures and safety analyses were written for plutonium containers and movement of SNM through the facility, and many other modifications were performed. The aftercooler in the 291-Z facility was replaced. Also, the 270-Z Office Building was constructed just north of the 234-5 Building. Process and operating specifications were rewritten for many PFP processes, and a safety analysis of all PFP operations was conducted.¹³⁸ (See Figure 3-5.)

Beginning in the early 1990's, the PFP complex again changed missions in response to changing world events (see Sections 14.4, 16.1, and 16.2). In July 1987, the Hanford Site's operating contract was consolidated, and the chemical processing work was awarded to a new contractor, Westinghouse Hanford Company (WHC).

Figure 3-5. Restart Schedule at the PFP, 1987.



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4.0 RUBBER GLOVE LINE AT THE PFP

4.1 DESCRIPTION OF RUBBER GLOVE LINE EQUIPMENT AND PROCESS

The initial RG Line that was emplaced in the 234-5 Building during 1948-49 was composed of 28 stainless steel hoods, measuring 180 feet. Plutonium-handling activities took place in Zones 2, 3, and 4, with Zone 4 (inside the hoods) having the most negative pressure for contamination control. Metal plates extending from the floor to the hoods and from the hoods to the ceiling separated Zones 2 and 3 to minimize cross-contamination from high-hazard to low-hazard activities. Air locks and removable panels on the backs of hoods were used for plutonium removal and maintenance. Air from all of the contaminated zones was drawn to a common air exhaust manifold, filtered, and discharged out the 291-Z Stack (see Section 2.3).¹³⁹

The basic plutonium finishing operations carried out in the RG Line consisted of several standard steps known as "tasks". Task I, Purification or Oxalate Precipitation (also known as Wet Chemistry or Feed Preparation), consisted of precipitating the plutonium nitrate feed solution with oxalic acid and other agents. In Task II, Hydrofluorination (HF - also called Dry Chemistry in the very early years), hydrogen fluoride gas was diffused through the precipitate in a furnace at a very high temperature, producing plutonium tetrafluoride. In Task III, Reduction, the plutonium tetrafluoride was combined with calcium and other agents and fired at very high temperature until it fused or "reduced" into plutonium metal. In some furnace charges, gallium was added as a stabilizer. The plutonium metal chunk (about 2 kilograms [kg]) was called a "button." In Task IV, Casting, plutonium buttons were rendered molten and cast into a mold shape roughly approximating the desired "pit" (weapon component). In Task V, Machining, the pit was machined to precise, specified dimensions and configuration. In Task VI, Cleaning, the machined pit was chemically degreased. In Task VII, Coating, the plutonium metal pit was coated with nickel plating. This coating served as a radiation shield during inspection, transport, and storage. In Task VIII, Final Inspection, the pit was measured for uniformity of coating, neutron energy, isotopic content, dimensional precision, cracking, and other conditions.

4.2 STARTUP AND EARLIEST OPERATIONS OF THE RG LINE

"Hot" processing (i.e., processing using plutonium nitrate as feed) began in the RG Line on July 5, 1949, at 11:00 p.m. However, according to a G.E. Hanford Co. report, the equipment was plagued by "operational and mechanical difficulties."¹⁴⁰ In mid-autumn, contractor officials reported candidly to the government that, "experience in the operation of the Rubber Glove Line since its completion and start-up has revealed a number of design deficiencies which can be directly attributed to the 'crash' program followed in its design and construction." They then warned: "It can be most positively predicted that, if adequate time is not allowed for careful and intelligent consideration of design...similar end-result difficulties will be obtained with the Remote Mechanical Line. It is strongly advised that the schedule for completion of the Remote Mechanical Line be made flexible enough to avoid this."¹⁴¹

Throughout the remainder of the year, the attention of engineers, chemists, and operators in the 234-5 Building was consumed with various operational problems in the RG Line. Imbalances in the ventilation system, with associated contamination spreads, remained a key difficulty until November, when balancing was reported complete. Likewise, several leaks occurred in the vacuum systems of various glove boxes, along with other "operating difficulties" in Task I (oxalate precipitation). Vacuum leaks in Task I hoods were so frequent that the contractor soon reported "it became evident that the air locks [in these hoods]...were wholly inadequate." The electric furnace in Hood 14 of the RG Line (one of the Task III, or reduction, glove boxes) failed five times in September and needed major component substitutions. However, according to a contractor report issued in November, the "largest single obstacle remaining in the path of attaining successful and continuous operation in the 234-5 Building has been the coating operation, to which concentrated improvement studies are being applied." Visits of personnel between the Los Alamos and Hanford Sites for "operating problems consultations" continued, and various engineering studies went forward to add deentrainment chambers to various process hoods and make other modifications. In September, a new can was designed to store core components in an inert atmosphere while awaiting further processing in the line.¹⁴²

The daunting operational problems experienced in the RG Line during 1949 were summed up in a contractor report that pointed to the very short period of "cold testing" (tests using water, acids, and other nonradioactive substances) that preceded hot startup: "The majority of the [operational] difficulties...were not known until subsequent to start-up. Repairs necessary, therefore, required very considerable time and were many times more delaying as they would have been during testing due to the serious contamination problems...These difficulties were to the dismay of many, but to the surprise of none in the operating organization." Among the difficulties reported were the fact that "purification time cycles were approximately twice as long as anticipated...continuous maintenance of the hydrogen fluoride rotameters was necessary...the high vacuum equipment required constant attention...and the necessity of wearing assault masks [from the Army's Chemical Warfare Service] in Zone 3...became apparent during the first week of operation." Further, the purification and recovery vacuum transfer systems failed "frequently...due to plugging of the filters." Also, pressing and coating operations produced multiple reject pieces, and multiple glove ruptures were called out as a particular problem.¹⁴³

4.3 RG LINE CHALLENGES CONTINUE IN 1950

The year 1950 witnessed ongoing attempts to improve RG Line performance. Coating operations for the pits received attention early in the year, because many cores experienced rejections or "near-rejections" because of alpha emissions through the coatings. By spring, however, the coating problems were essentially eliminated.¹⁴⁴ Also early in 1950, "corrections of equipment misalignments" between the press and the base on which it rested allowed production commitments to be consistently met for the first time. In March, G.E. Hanford Co., reported "considerable improvement in producing plutonium cores" that would "pass through the 'Go' gage." By June, performance had improved so much that "all production commitments to date...[were] exceeded."¹⁴⁵ In casting operations, the "hold time" at high temperature

was increased, while the outgassing period was reduced. However, late in the year problems still were evident in many of the cast samples.¹⁴⁶

The vacuum systems on various glove boxes, especially coating Hoods 25 and 26, experienced recurring difficulties in 1950, and corrosion failures of parts within hoods took place repeatedly.¹⁴⁷ In July, a G.E. Hanford Co. report stated that the HF system in Hood 8 continued "to be a source of trouble." Liquid HF gathered in the rotameters and mixing chambers, despite raising the temperatures on gas cylinders and other components and "the application of heat lamps on exposed parts." In September, a gasket failed on a reactor vessel in Hood 10 (one of the Task III [reduction] glove boxes), and in October this glove box pressurized to the point that the ports blew out. In December, much of the original RG Line equipment was deemed to be in unsatisfactory condition, with electrical problems and exhaust line perforations the major concern.¹⁴⁸ At the same time, Projects C-366, to construct and emplace auxiliary stainless steel hood enclosures for the RG Line, and M-802 to construct loading facilities to move recycle material were begun.¹⁴⁹

4.4 1951 BRINGS RG LINE IMPROVEMENTS

In January 1951, studies were begun to find ways to potentially triple the production of the RG Line. In March, G.E. Hanford Co. was notified that it might be "required to convert all RM equipment for fabrication of a different size product prior to RMA start up" (see Section 5.1). Since "delays would follow" such a change, the RG Line would be needed for expanded service.¹⁵⁰ Projects authorized at that time included installation of an additional coating unit for Hood 26 of the RG Line (authorized first as Engineering Request [ER] 2547 and then as Project C-444), emplacement of auxiliary stainless steel ventilation duct work for Hoods 4-8 (Project M-739), fabrication of an experimental coating hood (Project C-398), and emplacement of an additional casting unit for Hood 13 (ER-2577).¹⁵¹

Several process changes also were instituted in the RG Line in early 1951 to expand and improve production. Efforts continued throughout the summer and autumn to standardize the chemical addition step in the Task III (Reduction) to simplify operations and save money.¹⁵²

However, the RG Line continued to experience difficulties throughout 1951 with the vacuum systems of several hoods. A continuous gas analyzer detection system for the Zone 3 area was installed as a safety measure in midyear. Two incidents of gross contamination occurred in the facility, one in January when two operators were sprayed with highly acidic contaminated liquid as they attempted to sparge the Hood 29 evaporator by applying air pressure. The other incident occurred in November in reduction Hood 9, when a violent reaction took place involving lathe turnings combined with calcium and iodine in the preparation stage. Because the reaction occurred before the reduction "bomb" (vessel) was sealed, there was "considerable spread of product and considerable damage to Hood 9 equipment." The practice of preparing buttons directly from turnings was discontinued at that time.¹⁵³

4.5 RG LINE CHANGES OCCUR IN 1952

In March 1952, the RMA Line started up in the 234-5 Building. However, by the summer of 1952, operating problems in the reduction step (Task III) of the new line required that the RG Line assume a majority of the reduction work of the PFP. During the closing months of 1952, the RG Line's share of production in the 234-5 Building hovered between 30 and 50 percent. However, together the RG and RMA Lines were able to deliver the full commitment of weapons shape assemblies for 1952 to the AEC.¹⁵⁴

Several process changes were undertaken during 1952 in attempts to improve the performance and expand the production of both the RMA and RG Lines.¹⁵⁵ In September, a production test was begun to evaluate air displacement from the crucible assembly in Task III by admitting argon under pressure. The use of this pressurized argon purge instead of a vacuum purge seemed to work well, and was adopted in December.¹⁵⁶ The experimental coating unit (C-398), begun in 1951, was completed and began testing a variety of new procedures to lower the high coating rejection rate being experienced at PFP.¹⁵⁷

In June 1952, the use of a Pu(IV) oxalate process similar to that used in the 231-Z Building to prepare RMA Line feed material (purification step, Task I) was adopted in the RG Line. This process eliminated the use of the highly corrosive hydriodic acid (HI) as a reducing agent, and allowed the direct recycle of RG Task I supernates to the 224 Building process without initial processing of the wastes through recovery evaporator units. At the same time, filtering equipment was placed in use in the purification hoods (5, 6, and 7) of the RG Line to separate the precipitates of Pu(IV) oxalate. This equipment eliminated time-consuming settling and decantation procedures, and also allowed the drying and HF cycles in Task II to be shortened. The following month, however, the decision was made to retire Hoods 5, 6, and 7 (Task I, oxalate precipitation) of the RG Line from service, necessitating the shipment of all product from the 231-Z Building to the 234-5 Building as Pu(IV) oxalate cakes in filter boats (see Section 1.2). Task II (hydrofluorination) could be carried out directly in these boats. That summer, a new casting furnace was emplaced in the RG Line. Other 1952 projects included fabrication of a final shape machining unit for the RG Line (M-845), completed early in the year.¹⁵⁸ In October, improved drying procedures were investigated for Task II, including the use of heat lamps while pulling air through the oxalate before hydrofluorination.¹⁵⁹

In August 1952, a study of the "modernization and rehabilitation" of the RG Line was begun, and soon was wrapped into a larger research design study to recommend ways to increase 234-5 Building capacity to meet the needs of the overall Hanford Site expansion (see Section 2.8). By autumn, the RG Line study had focused on modernization of the "front end" of the line (Tasks I, II, and III) and enlargement of the inspection facilities. In December, these recommendations coalesced into D.O. 100427, funded at an initial \$1,725,000, and a project proposal was being drafted. In September, both the RG and RMA Lines went to a three-shift operation to accommodate the production increases (see Section 2.8).¹⁶⁰

Serious contamination events in the RG Line during 1952 included a fire in Hood 2 in January. The following month, an employee received an internal

deposition of plutonium "adjudged" (by the G.E. Hanford Co. Radiological Sciences Department) to probably equal the maximum permissible limit [MPL]." The deposition was received through a hand wound when a glove in Hood 8 ruptured along with the employee's inner surgeon's glove during maintenance work. In March, "gross plutonium contamination" of Room 231 occurred when a reactor vessel failed in Task III (reduction) of the RG Line. This event, caused by gasket failure on a reduction bomb, resulted in glove failure and room contamination so severe that the room was evacuated except for decontamination personnel for three weeks. A special study of the service life of reduction bombs, as well as their alloy composition, was undertaken soon afterward. In March, a pressure vessel ruptured, spreading an estimated 0.1 gram of plutonium throughout several rooms of the 234-5 Building.¹⁶¹

4.6 RG LINE MODERNIZATION CANCELED; LINE SHUTS DOWN IN 1953

In January 1953, the final draft of the project proposal for the "mechanization and rehabilitation" of the RG Line was prepared. However, G.E. Hanford Co. reported at the same time that "further developments have indicated that increased capacity [in the 234-5 Building] might best be obtained by modifying and expanding the RMA Line." This state of flux characterized planning efforts at PFP throughout the late winter and early spring.¹⁶² The RG Line conducted only 6 percent of the total 234-5 Building processing in February 1953, and did no fabrication work and only 5 percent of the incoming processing work (Tasks II and III) in March. At the end of March, the line was placed in standby condition with the exception of the coating units (Hoods 25 and 26). Although the coating hoods continued to operate during April, they too were placed in standby in May. The RG Line conducted no further processing, except for two weeks of Task III operations in September, following a serious contamination event that closed parts of the RMA Line for decontamination activities for that period (see Section 5.5).¹⁶³

In April 1955, AEC representatives visited the 234-5 Building to discuss, among other topics, the final disposition of the old RG Line.¹⁶⁴ Task I and II equipment of the line was removed and buried later that year.¹⁶⁵ In July 1956, the decision was made to improve the RMA Line by installing a continuous Task I-Task II process (see Section 5.9). By year's end, it had been decided to first install the new process on a temporary basis in Hood 9B of the old RG Line, to maintain operating continuity on the RMA Line, and to construct a similar process in Hood 9A in preparation for installation in the RMA Line at a later time. "Incidental work in connection with this project was underway in December, including preparations to remove most of the remaining hoods of the RG Line."¹⁶⁶

In 1957, to meet increased production needs, the AEC authorized construction of new RM Line in the 234-5 Building, to incorporate all of the improvements and changes that had been developed over the previous years of RMA operations (see Section 6.0). The new line, designated the "C" Line (or RMC) was emplaced where the former RG and RMB Lines had stood, and the majority of RG Line equipment removal was completed in early 1957.¹⁶⁷ (See Figures 4-1 and 4-2.)

Figure 4-1. RG Line, Hood 19, Just Before Removal, May 1957.

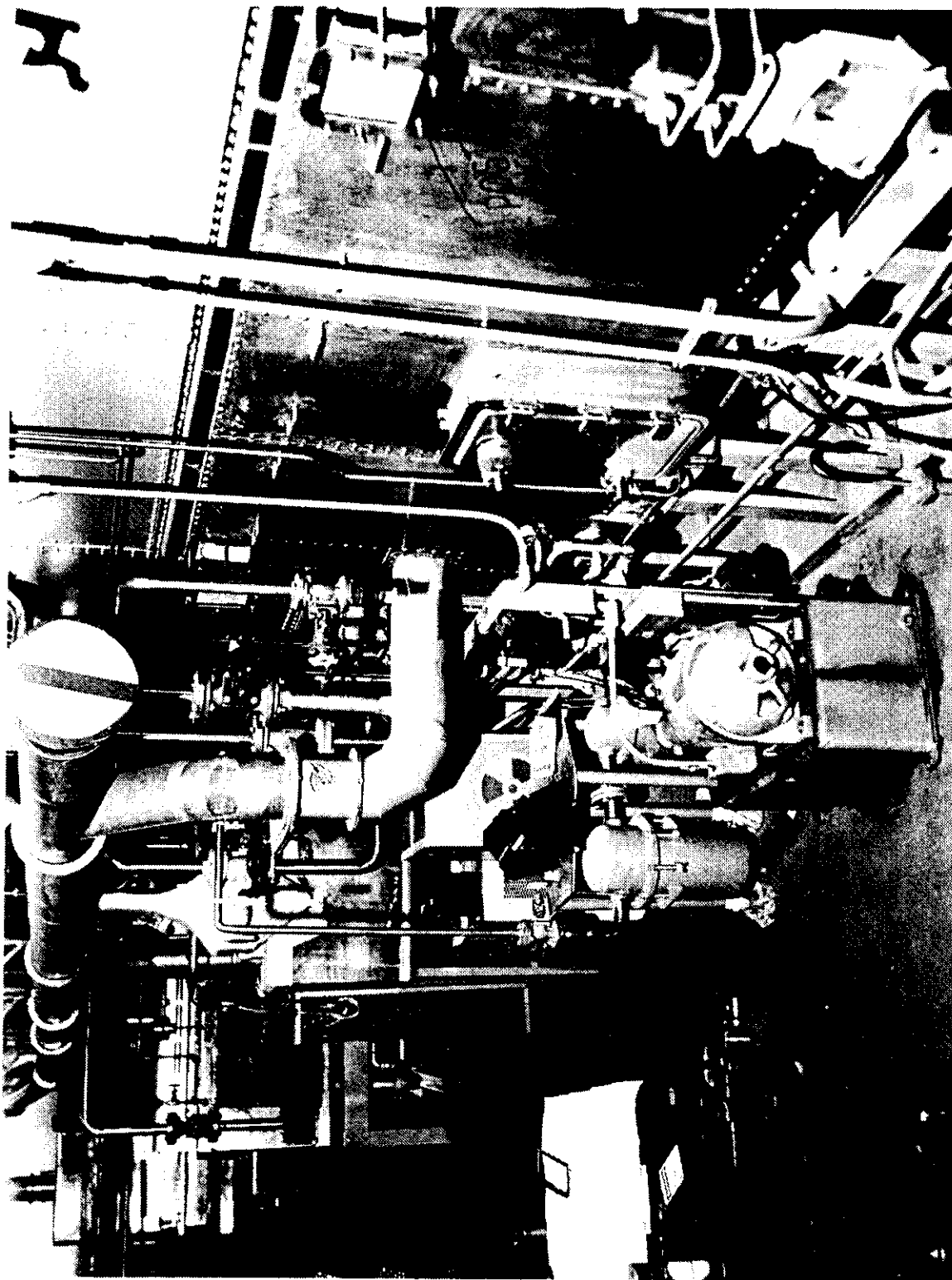
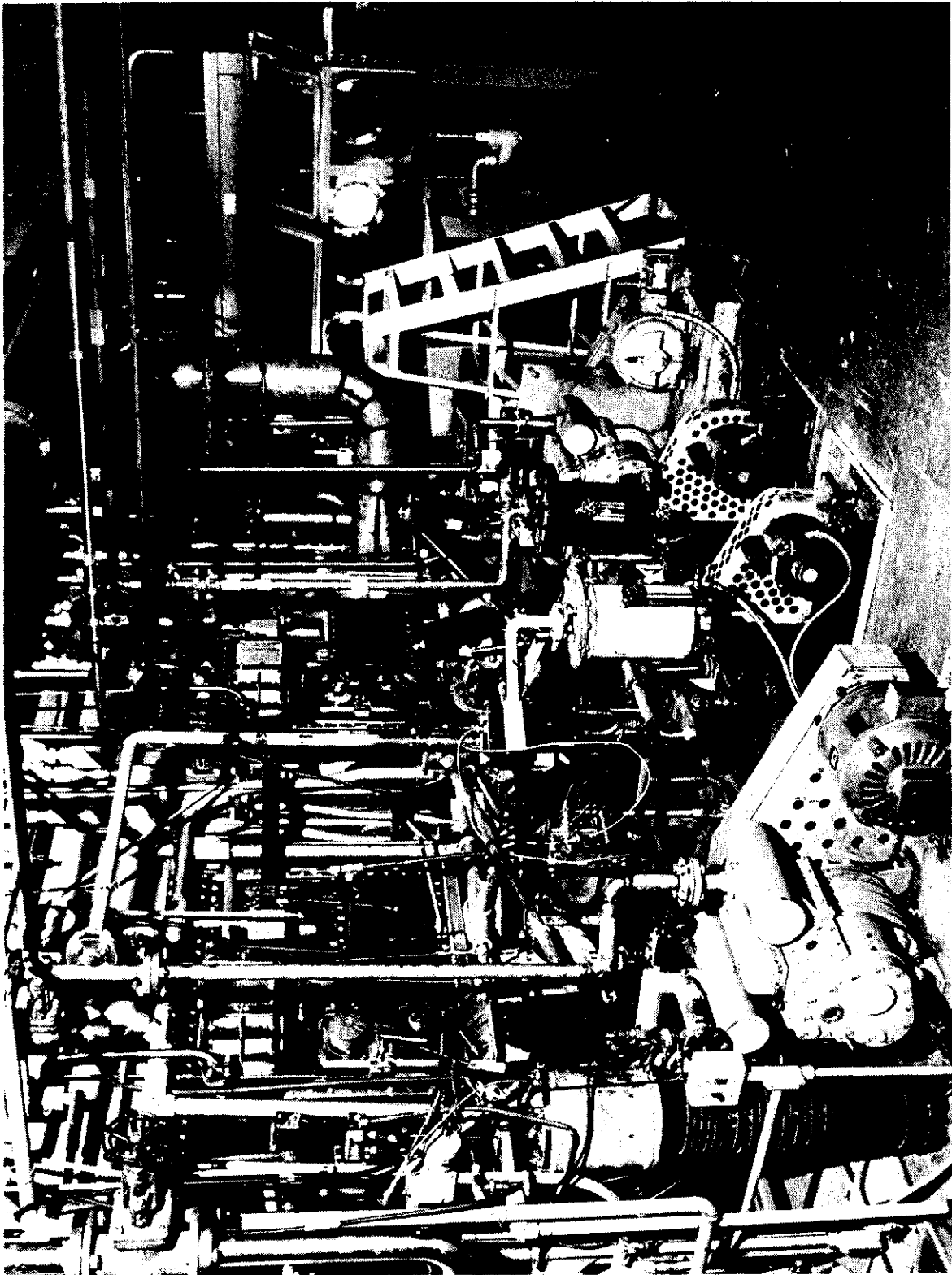


Figure 4-2. RG Line, Task VII Equipment, At Removal, May 1957.



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5.0 RMA LINE AND RMB LINE

5.1 GENESIS AND CONSTRUCTION OF THE RMA AND RMB LINES

When Project C-198 (the project to construct the PFP [see Sections 2.3 and 2.5]) was split into three phases in 1949, preparation work for the emplacement of the remote mechanical (RM) plutonium finishing line was included in Phase II. The RM Line itself became the major component of Phase III.¹⁶⁹ On October 24, 1950, in response to changing world events and the escalation of the Korean Conflict, the AEC ordered an expansion of plutonium conversion and fabrication capacity at PFP. Funds were authorized and design studies conducted for Project C-413, which would build a second RM Line similar to the one already under construction but omitting Tasks I, II and III. The design studies also addressed building an addition to the 234-5 Building to house a third RM Line; this project did not happen. The original RM Line, to be finished under Project C-198, then became known as the RMA Line, while the second line was dubbed the RMB Line. Completion dates were established as July 1, 1951, for the RMA Line and January 1, 1952, for the RMB Line. By year's end, installation of the RMA Line was 35 percent complete, and approximately 85 percent of the finished hoods and other components had been shipped from the GEL, the construction contractor in Schenectady, New York.¹⁷⁰ (See Figures 5-1 and 5-2)

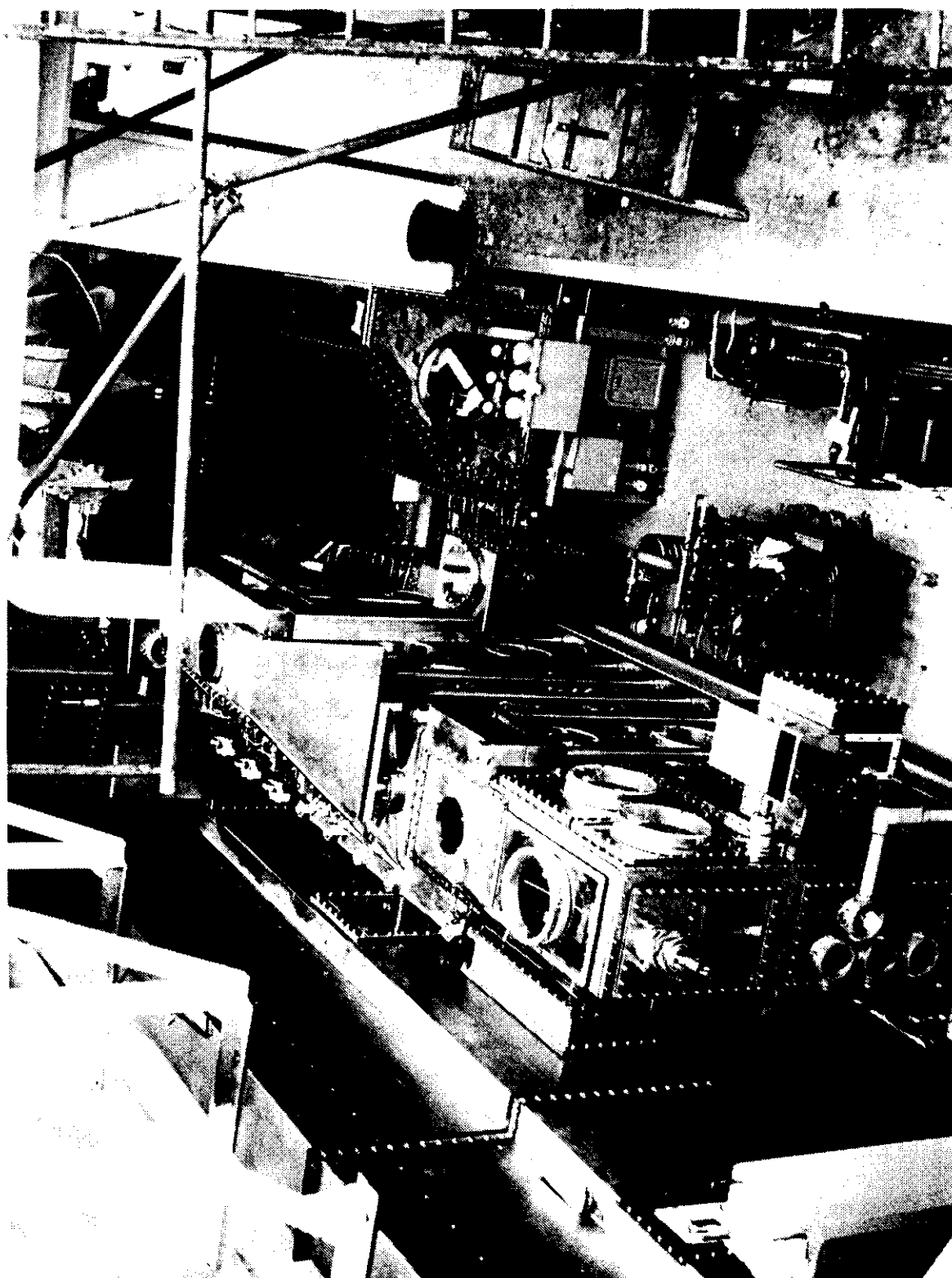
By February 1951, final shipments of RMA Line equipment from GEL were behind schedule because of the urgent work going forward there on fabricating the RMB and on designing modifications to both lines to increase their production capacities. At the 234-5 Building, installation work also was falling behind because of the beginning of floor removal and other work related to RMB Line site preparation. The RMB Line was being emplaced on the first floor, west end, between Column Lines 18 and 23.¹⁷¹

For the balance of 1951, progress on the RMA and RMB Lines remained slow because modifications were required both for the Model 130 pit (see Section 2.9) and for production increases. Of the 46 modifications assigned to the RMA Line, the most important concerned Task II (larger platinum filter boats and furnace changes), Task IV (an additional furnace along with a high-vacuum system, transformer, instrument panel, control crucible and miscellaneous supporting equipment), and Task XII (modifications to the general conveyor system, including a cross conveyor and elevator). The RMA modifications also concerned multiple changes to the fabrication equipment. The AEC directed that both lines acquire the capacity for "reconversion of the plutonium parts in stockpile to the required design for new weapons models." The writing and testing of procedures ("run-books"), as well as final adjustments and calibrations further delayed startup of the RMA Line. In June, the first shake-down runs of Task I equipment in the RMA Line, using stand-in solutions (uranium in this case), found that the procedures needed a "virtually complete revision." That month, Maintenance Shop D was completed and began fabricating tools and adapters for the RMB Line.¹⁷²

Figure 5-1. A-Line Installation, November 1950.



Figure 5-2. A-Line Installation, January 1951.



By August 1951, RMA Line modifications were reported to be 72 percent complete, and on October 15, the line was released to the Manufacturing Department with all acceptance tests completed except final testing of instruments and blowers in the helium recirculating system of Task XI. Dry runs and calibration work then proceeded task by task, but by year's end the RMA Line was not yet operating. The RMB Line was 84 percent designed and 92 percent fabricated in Schenectady, but only approximately 60 percent installed in the 234-5 Building.¹⁷³ (See Figures 5-3 and 5-4.)

5.2 LOS ALAMOS REMOTE MECHANICAL LINE BEGINS PRODUCTION

Meanwhile, on August 13, 1951, the Los Alamos Site started up the first RM Line in the world for plutonium purification and fabrication. Although purification operations had been under way there since 1944, and fabrication operations since 1945, they had been conducted in "dry boxes" (early glove boxes), with some steps of the operation carried out in open-faced, unconnected hoods. The Los Alamos RM Line fulfilled many of the goals and objectives in both contamination isolation and production efficiencies that were planned for the PFP RMA Line at the Hanford Site. It consisted of two duplicate production lines in a room 40 feet wide by 50 feet long. Each line was an air-tight box 20 inches wide by 30 inches high by 28 feet long. The two lines were located on opposite sides of a control section that was sealed from the rest of the room by "tight plaster walls containing safety glass windows." The process employed was essentially the same as that used in the RG Lines at both the Los Alamos and Hanford Sites, except that no rubber gloves were used. Each line contained two precipitation-hydrofluorination assemblies at "opposite ends of the box," with the reduction unit occupying the center section. In other words, there were four precipitation units, four hydrofluorination units, and two reduction assemblies.¹⁷⁴

5.3 RMA STARTUP, DESCRIPTION

In January 1952, responding to the mandate for production increases, criticality studies were undertaken at the PFP to determine the safety of making two castings per furnace in the RM Lines. The double castings were approved after certain procedural changes were instituted to prevent the conveyors from carrying additional plutonium to the area while second furnace loadings were taking place. On March 18, 1952, the RMA Line in the 234-5 Building commenced hot processing, with the hydrofluorination of Pu(IV) oxalate prepared in the 231-Z Building. (The initial operations of the RMA Line performed all of the process steps in plutonium metal production and fabrication except Task I.) At the end of the first month, operations were reported by G.E. Hanford Co. as "successful...No serious equipment problems have been evident, although minor maintenance and revision were necessary."¹⁷⁵

The RMA Line consisted of a row of 30 interconnected stainless steel glove boxes (still known as hoods), 30 control desks, 10 control cubicles, 24 instrument panels, 9 resistance furnaces, 5 induction furnaces, a sample can handling assembly, a 110-foot-long general conveyor and manipulator, and other smaller conveyors and furnace loaders and miscellaneous support

Figure 5-3. A-Line Installation, April 1951.

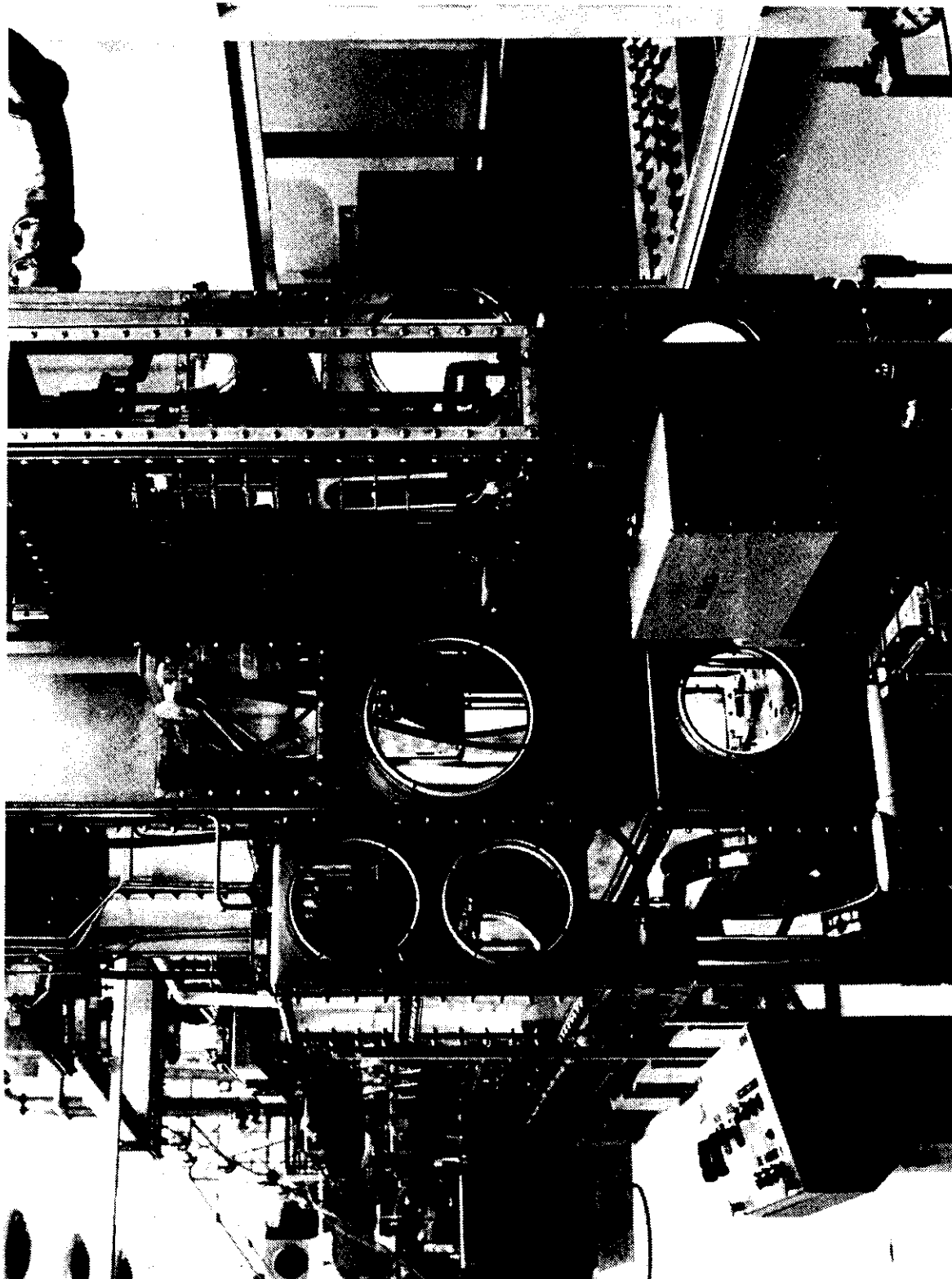
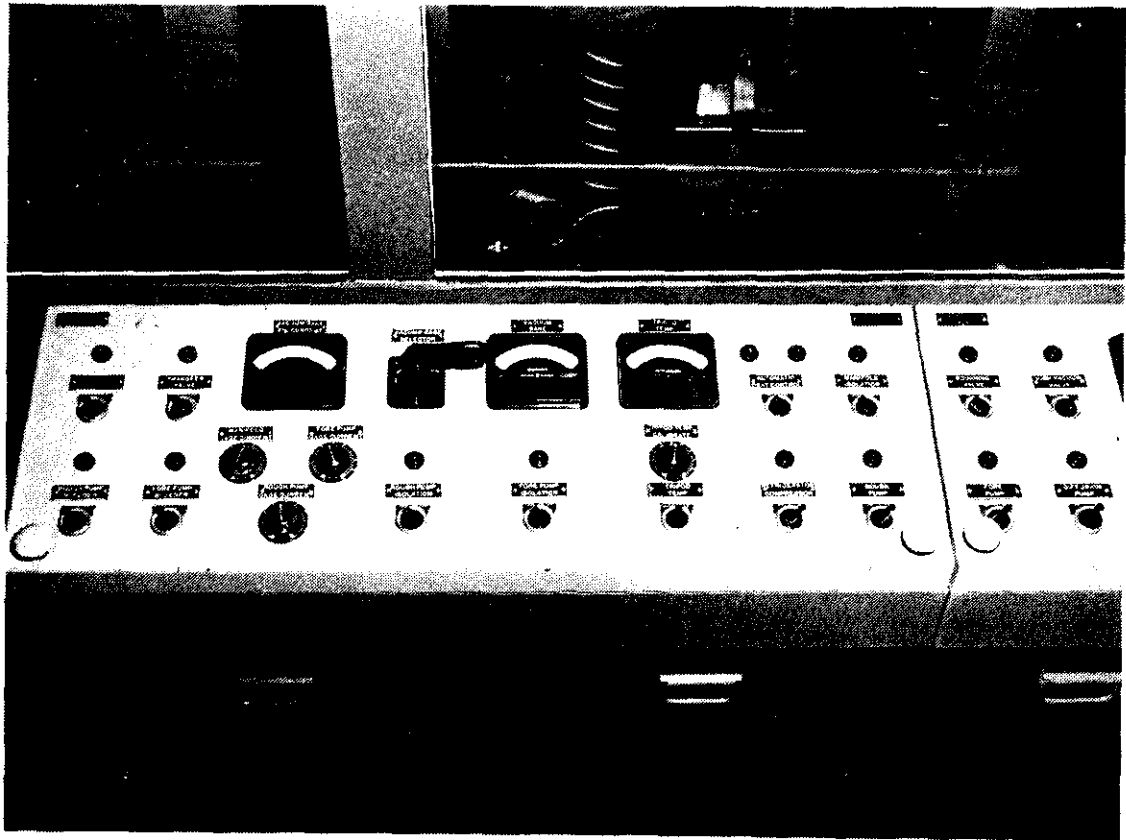


Figure 5-4. Original A-Line Control Panel Before Use, October 1951.



equipment. The RMA Line was located in Rooms 227, 232, 233, 235-A1, 235-A2, and 235-A3 of the PFP. A "mechanically unpierced solid barrier...made of steel" with glass windows for "observing operations in Zone 4 (the space in the hoods where actual handling of product occurs)" was a key feature of the line. The barrier, along with a wall behind the control panel, separated Zone 2 (the operating side) from Zone 3 (the equipment side). Office space and corridors in the 234-5 Building occupied Zone 1, the area with highest positive air pressure for contamination control. Tasks I through VIII of the RMA Line identified process equipment and steps (the same as those in the RG Line), but added instrumentation was topically identified as Task IX, control as Task X, ventilation as Task XI, the conveyor system as Task XII, maintenance equipment as Task XIII, and sampling as Task XIV.¹⁷⁶

5.4 RMA EARLY OPERATING DIFFICULTIES, MODIFICATIONS

Within a few weeks after startup, RMA Line operating problems became apparent. In April 1952, the contractor reported that "equipment difficulties of increasing severity developed during the month, particularly in the vacuum

equipment of the Task II Hydrofluorination." Of 47 batches processed through RMA Task II that month, 37 "required special handling procedures...because of one or more 'off-standard' conditions...[including] cycle interruptions due to loss of vacuum in furnaces...and water-trap alarms and shut-downs." In May, "processing difficulties in all tasks prevented the following of an established production schedule for the month." The most frequent disturbances continued to involve "erratic functioning of the water-trap alarms and automatic shut-down equipment located in the furnace exhaust lines, leaking solenoid valves in the exhaust lines...[and] leaks in the furnace and exhaust systems that prohibited evacuating furnaces." Throughout June, according to G.E. Hanford Co., "the RMA Line was operated on a limited basis because of process and equipment difficulties...Most of the month's production was assumed by the RG Line and this will continue to be the case until an improvement program on RMA can be completed."¹⁷⁷

Beginning in July 1952 and continuing into the autumn, Task II, the hydrofluorination step, presented most of the problems that beset the RMA Line. Twenty-four of the 105 runs processed during July required refluorination, a procedure requiring 6.5 extra hours. In both August and September, approximately 35 percent of the runs required refluorination. However, by October, Task II was improved. That month, only 16.3 percent of the batches required refluorination, with "the factor responsible for most of the process improvement...[being] the ability to maintain a lower pressure differential between the hood in the furnaces which reduced the amount of air leaking...[through] the furnace doors." In November however, the number of RMA runs requiring refluorination again soared to 35 percent.¹⁷⁸

A special research design activity (RDA-DC-9) was authorized in mid-1952 to recommend improvements to the RMA Line. By late summer, internal recommendations focused on both technical and "mental" aspects of operating the new system. The RDA Working Committee approved a report that concluded that "remote operation of all plutonium purification and fabrication equipment is ultimately desirable. However, until reliable, tested, remote-control equipment is available, the remote control requirement may have to be compromised on some steps of the process to allow non-remote or rubber glove operation in order to obtain equipment with sufficient operating reliability." Another, nearly concurrent contractor evaluation focused on the "mental hazards" of an RMA improvement program. Given the high degree of excitement and performance anxiety surrounding the line, the report cautioned that: "there will be the natural desire to execute rapid changes or improvements that may appear to offer an immediate solution but fall short of...[long-range] objectives...Second, variations in performance may result in a feeling of optimism one week and a feeling of pessimism another."¹⁷⁹

By Summer 1952, as the reduction step (Task III) continued to be a problem and to require that the RG Line assume a majority of the reduction work of the 234-5 facility, the design group recommended fabrication of new mixing equipment for Task III. The new mechanism would attempt to prevent powder hold-up in the transfer equipment between the filter boat dumping station and the crucible. At year's end, fabrication of the new mixer (undertaken as ER-2736) had just been completed and testing outside of the RMA Line was beginning. A new general conveyor and a new hood conveyor for Task III had been developed and were nearly fabricated. Also, a process change late in the year authorized a new method of argon purging (introduction

of argon as the air replacement when beginning the reduction step) for Task III, designed to "permit equipment simplification" and save wear and tear on some of the pumps and valves. In autumn 1952, both the RG and RMA Lines went to a three-shift operation to accommodate the production increases (see Sections 2.8 and 3.5). During the closing months of 1952, the RMA Line's share of production in the 234-5 Building hovered between 50 and 70 percent. However, together the RG and RMA Lines were able to deliver the full commitment of weapons components for 1952 to the AEC.¹⁸⁰

Other process changes undertaken during 1952 in attempts to improve the performance and expand the production of the RMA Line were similar to those emplaced in the RG Line (see Section 4.5). In December, as with the RG Line, the coating time cycle was cut and another process change was made in the coating operations.¹⁸¹

Additional 1952 projects aimed at improving RMA Line performance included fabrication of a final-shape machining unit (M-853), emplacement of additional waste gas disposal lines for RMA Task II (initiated in June 1952 as D.O. 100231 and completed in the autumn), and installation of a soundproof operator's booth for the control panel, 234-5 Building (initiated in July 1952 as D.O. 100287 and completed in the autumn [see Section 2.8]). Installation of a chip cutter for the RMA Line was initiated October 1952 as D.O. 100347 and completed in December.¹⁸²

5.5 RMA IMPROVEMENT PROJECTS CONSOLIDATED IN 1953

In early 1953, while considering RG Line modernization (see Section 4.6), G.E. Hanford Co. increasingly turned its attention to RMA Line modifications as the optimal way to increase production. In May, various design strategies for RMA improvements coalesced into Projects CG-549 and CG-551. Project CG-549 focused on building a new Task I process into the 234-5 Building, capable of bypassing the precipitation and purification activities then being carried out in the 231-Z Isolation Building. Project CG-551, entitled "Expansion of Building 234-5," focused on a sweeping series of revisions to Tasks II and III, aimed at increased production and efficiency in the facility, including the addition of a seventh furnace to Task II. This project also provided for the relocation and expansion of final product inspection facilities to the former quarters of the 234-5 maintenance shop, when that shop's equipment and capability were moved to the 272-W Area Shop. The consolidation of these major projects closed out D.O. 100427 and ER-2736 from 1952, and two additional engineering requests from 1953: "high spot" estimates for RMA Line improvements (ER-2738), and final inspection facilities, Building 234-5 (ER-2740).¹⁸³

In September 1953, HW production quotas rose sharply in response to the AEC directive to ship plutonium buttons, as well as plutonium nitrate, to the new Rocky Flats Site (see Section 2.9). Anticipating this need, several measures were undertaken in the RMA Line to increase production. Early in the year, batch sizes were increased in Task III, and "double-batch reductions" were tried in March. By year's end, 40 percent of the reductions were being conducted as double-batches.¹⁸⁴

Despite its accomplishments, the RMA Line continued to experience difficulties in many task areas. The percentage of runs requiring refluorination in Task II was 22.3 overall, with the latter 5 months being slightly lower (better) after a modification in the fluorination time cycle was adopted in August. At that time, a faster, hotter cycle was instituted in Task II and, beginning in December 1953, the "fast" cycle was referred to as the "regular" cycle at PFP.¹⁸⁵

Additional difficulties besetting Task II included general furnace failures caused by corrosion, mechanical failures of the conveyor (causing fluoride spillage), and the buildup of explosive mixtures of hydrogen and air in the HF cylinders. In May, a cylinder sampling and testing program began, with the requirement that cylinders be purged to remove hydrogen before they were placed in service. Six months later a program of routine preventive maintenance for the furnaces commenced.¹⁸⁶

The RMA Line also experienced problems in Task III (reduction) during 1953. "Mechanical difficulties" with the Task III equipment were reported throughout the year. In May, reports of "erratic distribution" of gallium in the metal product led to further changes in the use of gallium as a plutonium alloy material in June. Late in the year, changes were made in the reduction crucibles, with much investigation of crucible composition to address the persistent problem of slag sticking to the crucibles.¹⁸⁷

The year 1953 witnessed four serious contamination events in the RMA Line. In February, the door to furnace #4 was "ejected onto the hood floor, spilling the entire run" as a result of the presence of liquid hydrofluoric acid in the furnace. In March, a pressure surge in a Task II furnace expelled the furnace door and the filter boat containing the fluoride powder. The most significant event occurred in September, with a alcohol vapor explosion in a Task III hood. As a result, reductions could not be performed in the RMA Line for 2 weeks. The following month, a "gross contamination event" occurred when the air pressure balance changed while the panels were being changed on RMA Hood 200 (machining), and contamination spread throughout Room 233. Production was delayed for 24 hours.¹⁸⁸

5.6 RMB LINE BECOMES OBSOLETE; NEVER RUNS

The RMB Line was not activated in 1953; its primary machining glove box (Hood 200-B) was moved into the RMA Line Zone 3 area in September, to allow for "simultaneous fabrication" of two model shapes (Model 110, and the new Model 130).¹⁸⁹ From 1954 through 1956, as more experiments were tried and continual modifications were emplaced in the A-Line, the RMB Line became increasingly obsolete. It was removed, never having processed plutonium, when the RMC Line was emplaced in the PFP during 1957-59.¹⁹⁰ (See Figure 5-5.)

5.7 PROJECTS CG-549 AND CG-551 DOMINATE 1954 UPGRADES IN RMA LINE

Throughout 1954, design and preparations associated with Projects CG-549 and CG-551 in the RMA Line dominated non-production activities at the PFP. By November, testing of the continuous calcination/hydrofluorination (Task II) process proved successful. Cerium was used as a stand-in for plutonium during

testing. The stage was set for installation in the RMA Line. The new Task III equipment consisted of a welded, stainless steel reduction vessel, with redesigned heating coils, packing glands, valve stems, and seals. A key need in the new Task III equipment was to ensure a completely tight seal to prevent water from entering the reduction crucible. Most of the essential elements of this equipment were tested successfully in August. By year's end, fabrication of all components of the new Task II and Task III equipment stood at 78 percent complete, and site preparation (ventilation duct work and electrical power connections) for installation within the 234-5 Building was under way.¹⁹¹

Design work for Project CG-551 was completed in April 1954, and fabrication of the new equipment was begun in the 272-W Shop. By November, testing of new continuous calcination/hydrofluorination (Task II) equipment in the PFP developmental laboratory (see Section 7.5) had proved successful, and the stage was set for installation in the RMA Line. The new Task III equipment consisted of a welded, 309 SCb stainless steel reduction vessel, with redesigned heating coils, packing glands, valve stems, and seals. A key need in the new Task III equipment was to ensure a completely tight seal to prevent water from entering the reduction crucible. Most of the essential elements of this equipment were tested successfully in August. By year's end, fabrication of all components of the new Task II and Task III equipment was 78 percent complete. Also in 1954, another briquetting hood was emplaced in the RMA Line to package plutonium-bearing scraps for recycle (see Section 8.3).¹⁹² (See Figure 5-6.)

At the end of 1954, a new casting storage hood was being designed for the A-Line, to replace the "several individual storage hoods" then being used. Increased radiation safety was one impetus for the new storage hood. Also in 1954, studies were initiated to revise the A-Line conveyor system, but little progress was made until 1955.¹⁹³

Overall production was high in the RMA Line throughout 1954, except for 3 weeks in early August, when the fabrication of shapes was curtailed following a serious plutonium turnings fire that occurred in the line on July 27. Both the casting (Task IV) and machining (Task V) operations were "down" (inoperable) for decontamination work until August 16, but the fabrication of buttons (requiring the operation of just Tasks II and III in the 234-5 Building) continued.¹⁹⁴

In everyday operations during 1954, most of the difficulties the RMA Line experienced were in Tasks II (hydrofluorination) and III (reduction). Early in the year, Task II experiments showed promise in reducing the rehydrofluorination rate. By early March, the rate was down to an average of only 10 percent, but by summer, attempts to increase production by fluorinating double batches of PuO_2 powder again caused the rate to rise. As double batches became standard and the refluorination rate continued to hover between 25 and 40 percent, the difficulties centered around air leaks into the reduction vessels. The buttons from these batches "spalled" (flaked and peeled) and oxidized in their cans and plastic bags during shipment to the Rocky Flats Site. As a result, they "lost weight" during shipment, and nuclear materials accountability discrepancies arose between the Hanford and Rocky Flats Sites. Studies of plutonium isotopic purity and final product quality also were undertaken.¹⁹⁵

Figure 5-5. RMB Line Remote Balance (left) and Task IV (right)
At Removal, May 1957.

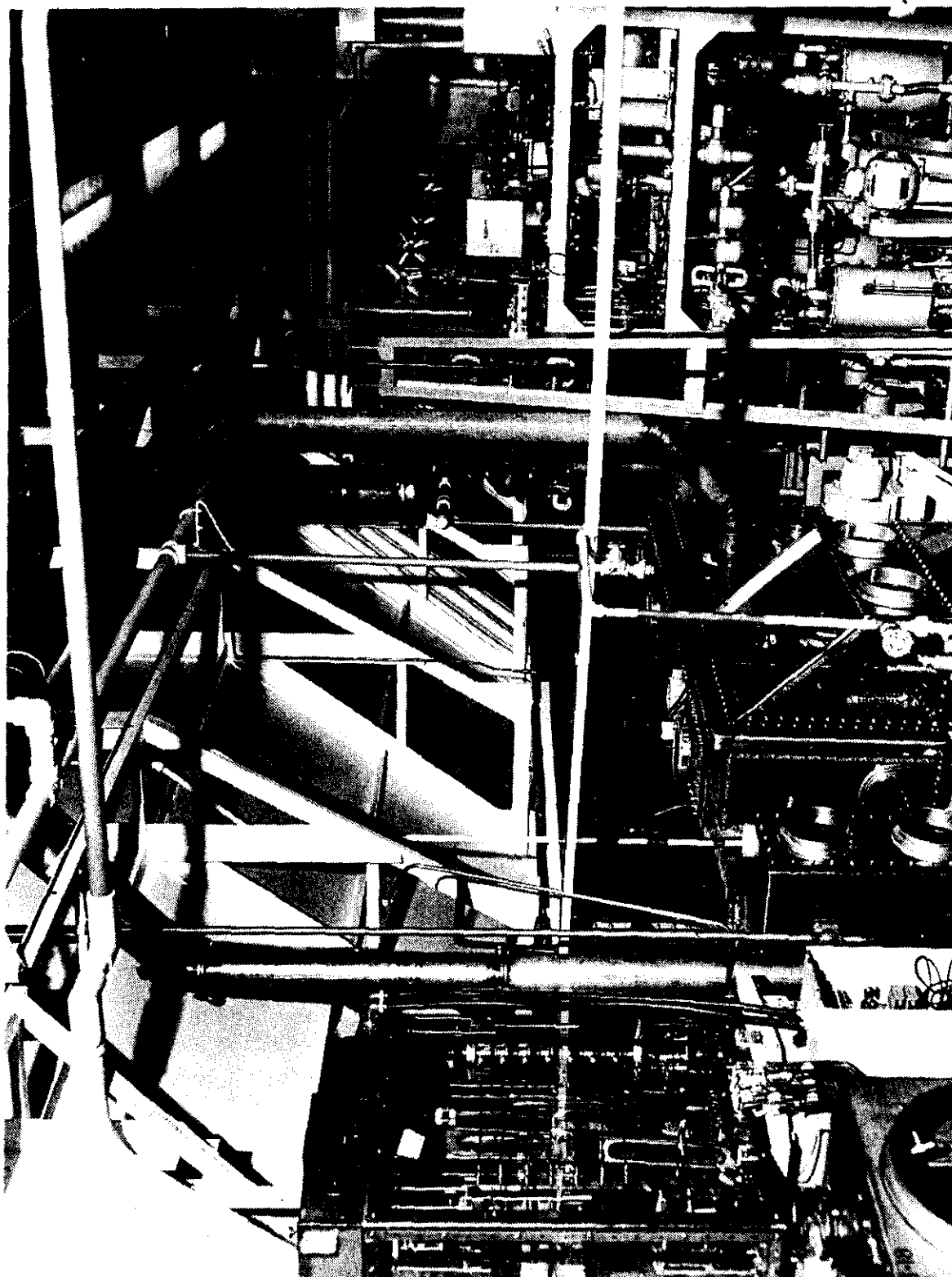
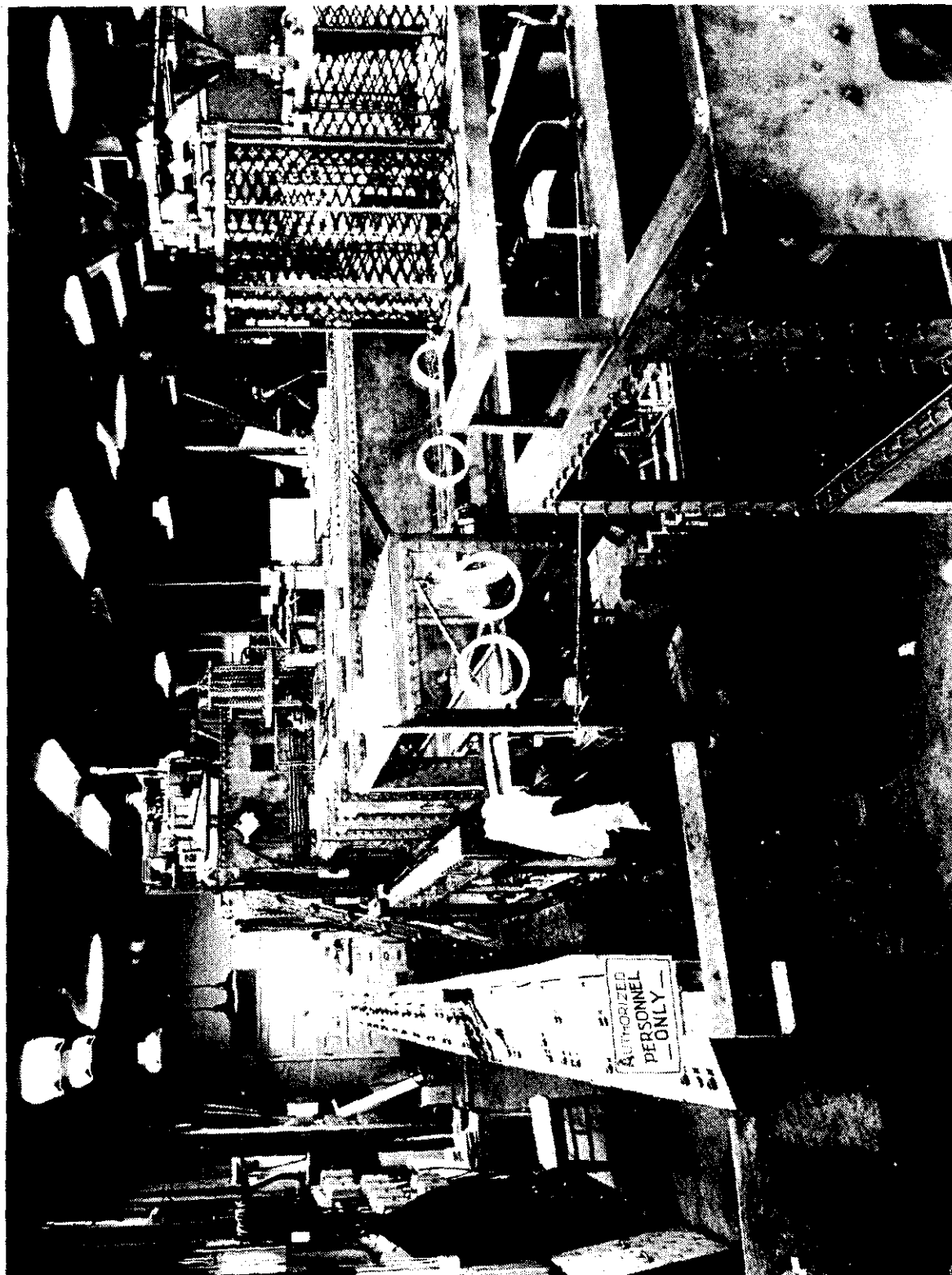


Figure 5-6. Installation of Project CG-551 Equipment, A-Line, October 1954.



During 1954, contamination problems persisted in the RMA Line. Routine hand exposures for A-Line work continued to be high. The most severe contamination incident of 1954 occurred on July 27, when plutonium metal turnings ignited while being removed from Hood 200-A (machining) on their way to an RG Line hood that was being used for temporary briquetting operations. According to a company report, the "entire area to the rear of the RMA [air Zone 3] was grossly contaminated and all production operations were suspended." Tasks II and III were decontaminated and restarted by July 29, but decontamination operations remained under way in Tasks IV and V until August 16. At that time, the entire RMA Line was released from working under assault mask conditions and the production of fabricated shapes resumed. Studies and recommendations concerning safe handling of plutonium metal were generated. Because a new briquetting hood was being installed in the RMA Line at the time the fire occurred, the problems associated with transferring plutonium turnings across air zones in the 234-5 Building were essentially solved shortly after the fire occurred. Also, the new RMA briquetting hood allowed turnings to be pressed "as soon as practical after they are formed, [thus] storage and handling of turnings...[was] kept at a minimum."¹⁹⁶

In December 1954, one other Class I radiation incident occurred in the RMA Line, when a person received exposure to airborne plutonium during the transfer of process material. In addition, in an event that did not result in loss of contamination control outside the hood (Zone 4 air), a furnace door was blown off as the result of a hydrogen explosion in Task II. The explosion was believed to have occurred because a new bank of hydrogen fluoride cylinders was not purged of hydrogen before the cylinders were placed in service. This explosion was the first to happen since the procedure to purge such equipment was adopted in the line in May 1953.¹⁹⁷

5.8 NEW TASKS I, II, AND III EMPLACED IN A-LINE

On January 12, 1955, the A-Line shut down for the installation of Projects CG-549 and CG-551, and did not resume production until late April. In May, June, and July, the line set all-time production records (see Section 2.10). During August and September, problems with high n/g/s (neutron counts per gram per second)^m plutonium feed material from the 233-S Building decreased output in the RMA Line. Many of the product pieces manufactured had to be remelted to lower the n/g/s to conform to AEC specifications. In October, the RMA Line set a new all-time production record for PFP. That record was surpassed in December.¹⁹⁸

Functional testing of the new Task I (Project CG-549) equipment in the A-Line began on February 24, 1955. Water and acid flushes were conducted in March. On April 4, the new equipment was "activated with process materials." Basically, it consisted of an oxalate precipitation reactor coupled to a drier-calciner, with operation on a batch basis. Initial operation was reported as "generally...satisfactory...[with] very low recycle losses...and satisfactory bulk densities." However, "chemical additions...[were] erratic and poorly controlled because of equipment shortcomings...At month's end, plugged transfer lines were being encountered in Task I." The spring and

^m N/g/s is a measure of radiation intensity.

summer were spent making equipment modifications to address these problems, and auxiliary hoods were installed for the chemical addition facilities to aid in contamination control. Additional lines also were emplaced "to facilitate the flushing of hood floors." Extensive criticality reviews of Task I operations also took place, with additional safeguards instituted. Additional cooling systems (heat exchangers, refrigeration units, and recirculating pumps) were installed for each oxalate precipitation reactor.¹⁹⁹

At the same time that new Task I equipment was installed under Project CG-549, new Task II and Task III equipment was installed under Project CG-551. As of March 18, Project CG-551 equipment for the RMA Line was accepted, and tests using uranium as a stand-in for plutonium began. Hot shakedown runs with plutonium took place in April. Early contractor reports indicated that "generally the [new] equipment is operating satisfactorily....Several difficulties such as [the need for] more power in diverter arms used for moving processing containers, cracking of refractories and sticking of slag to the button were experienced." Corrective measures were undertaken, and full operational processing was under way in May.

In October, difficulties were encountered when the orifices of the reduction furnaces at the argon manifold "were found to be tightly plugged...the resultant lack of argon purging of the pressure vessels prior to reduction...was responsible...[for producing] poor quality buttons."²⁰⁰ Also, in connection with Task III, when electrodeposition experiments failed to produce quick and usable results (see Sections 7.5 and 7.6), the 234-5 Building²⁰¹ instituted further changes in the existing reduction process.²⁰¹

Process changes early in the working experience with the new Task II equipment focused on increasing production capacity, primarily by altering equipment to allow double-batch hydrofluorinations to succeed. In the double-batching, first tried in mid-1954 with the old equipment, two AT batches were placed in each filter boat processed through Task II. In January 1955, 56 percent of the runs processed through Task II required rehydrofluorination. Ninety percent of these runs were double batches. Experiments undertaken during the shutdown time imposed by Project CG-551 modified the filters boats and undertook other changes to bring down the troublesome rehydrofluorination rate.²⁰²

In Task IV of the RMA Line during 1955, efforts were directed at developing a permanent mold casting process and at increasing production and reducing the amount of waste metal turnings through double-casting. In Task V (machining), studies focused on designing a remote, automatic lathe. In Task VII (coating), trials were conducted early in the year to compare various new thermocouple designs. It was thought that accurate temperature readings from thermocouples would allow better control of the application of the X-gas, and thus produce more uniform coatings. Iron and constantin wire thermocouples placed within the hollow Pyrexⁿ legs of an experimental tripod demonstrated the greatest accuracy and reliability over time. Placement of these wires in the base of the legs, outside of the intense induction field created by the plutonium, brought the desired stability of readings. At the

ⁿ Pyrex is a trademark of Corning Incorporated.

same time, an intense look at the overall RMA Line conveyor system (Task XII) was undertaken. A final report approved in the autumn recommended that a slat-type conveyor be substituted in the area serviced by two sections of the folding arm conveyor.²⁰³

The RMA Line in 1955 was marred by several Class I radiation incidents, the most serious types under Hanford Site classification standards. In May, two employees failed to perform personal surveys following a hood glove rupture and consequently inhaled plutonium. Also in May, a mechanic received a serious contaminated puncture wound "while rodding out a [plugged] jet in a [Task I] hood." Two more Class I events occurred in June, one involving a possibly significant internal deposition of plutonium by a utility operator following a Task II hood glove rupture. In the other June incident, batch size was exceeded in the A-Line when, "without proper analysis, Task II recycle waste was jetted into an RC [recycle] can already containing an acid flush" from hood equipment. At nearly the same time, another, less serious "overbatch incident" occurred in Task I. In June and July, six powder batches were either partially or completely "dumped on the floor" of Task II hood 9 as a result of sudden pressurization of the furnace there and "rapid ejection of the furnace door." In September, another serious case of plutonium inhalation occurred when an operator handled crucible fragments that were not properly sealed in plastic bags. In a November Class I incident, an uncontrolled spread of plutonium contamination to a vehicle, a burial ground, and a room in the 234-5 Building took place when a utility operator failed to properly monitor himself after removing waste cartons from the A-Line's waste storage hood. Lastly, in December the rupture disc was "blown off" of a mixer in a Task III hood "as a result of the introduction of a PuF_4 charge which presumably contained adsorbed HF" and water.²⁰⁴

5.9 PROJECT TO COMBINE TASKS I AND II EQUIPMENT IN RMA LINE BEGINS IN 1956; OTHER NEW DESIGNS AND IDEAS PROLIFERATE

The most significant project in the RMA Line during 1956 was the initiation of D.O. A-00356, Improved Task I and Task II Facilities, in April. In June, scope changes were made to the Task I-II equipment design, incorporating continuous treatment of Task I filtrate and storage of Task II fluoride in the existing Task III storage hoods. Additional space was provided for storing "castings and briquettes from the metal fabrication line." In July, D.O. A-00356 became Project CG-691, essentially to install a continuous Task I-Task II process. By year's end, it had been decided to install this process first on a temporary basis in Hood 9B of the old RG Line, to maintain operating continuity on the RMA Line, and to construct a similar process in Hood 9A in preparation for later installation in the RMA Line. "Incidental work" in connection with this project was under way in December.²⁰⁵

After laboratory experiments early in the year (see Section 7.7), actual trials with parts of the prototypical Task I equipment began in the A-Line. In July, a "U-shaped glass pipe prototype for continuous kills of oxalate filtrates was installed in the Task I hood to study the effect of backmixing and to make a continuous kill in large-scale equipment. The kill was complete, and no backmixing problems were encountered." In a parallel path,

shielding requirements and critical mass characteristics of continuous Task I-II equipment were evaluated.²⁰⁶

Throughout 1956, several other projects were begun in the A-Line to improve operations, including Project CG-727, Permanent Mold Casting—a modification of Task IV equipment. Other projects under consideration or begun included a major study of the installation of facilities for fabricating test and experimental weapons components; design of D.O. A-00330, Improved Conveyor System; D.O. C-85441 and D.O. C-85557, Improved Jumper Designs; and D.O. A-00414 (later ER-2786), Task V Improvements. This effort to replace existing Task V lathes with a final-shape machining lathe was discontinued in June.²⁰⁷ Other new equipment designed and drafted for RMA operations in 1956 included a prototype, manually operated vacuum pick-up device for handling uncoated plutonium metal pieces, a remotely operated final machining lathe to reduce worker exposure, a remotely operated Task V briquetting press, improved process ventilation machinery, a prototype transfer can for transporting material from one hood to another through Zone 3 of the line without using a plastic bag, changes to the duct systems and drive mechanisms of Task VII coating units to provide increased flow and better distribution of nickel plating around plutonium shapes.²⁰⁸

During 1956, the RMA Line continued to be the only operating metal production and fabrication line at the Hanford Site. In existing Task I operations, equipment performance was good with the exception of some ruptured diaphragms on air-operated valves, and very few changes were made throughout 1956. In January, reevaluation of the critical mass limits for the filter boat stations led to a reduction in the permissible batch limits. Polyethylene "fillers, which reduce[d] the free volume...[were] installed in the 'bathtubs,' with a resultant restoration of earlier batch limits." In December, an "improved lid filter was successfully installed in each of the boat stations." These new supernate filter housings reduced filtering time by fifty percent and, by allowing more efficient backflushing and thus lessening the plugging of elements, the decreased the frequency of filter changes.²⁰⁹

Existing Task II equipment in the RMA Line experienced more maintenance and operating difficulties. In February, furnace repairs were required because of corrosion by hydrofluoric acid. In June Task II was shut down for a "Class A overhaul" of the drives and motors of the two carriages. Despite this large preventive maintenance undertaking, "a more than normal amount of repair work was required" on the Task II equipment in August. Parts needing attention included the "Task II carriage, the balance elevator, and repairs to holes in one furnace door and to the hood bottom which was damaged by corrosion." A stainless steel plate was gasketing to the glove box floor beneath the furnaces. In December, repairs to "numerous heating elements" were necessary. Task II experienced an off-standard event in March, while a batch of oxide formed by the oxidation of plutonium chips from the machining operation was undergoing hydrofluorination. There was a sudden "furnace door ejection, accompanied by a ball of fire and the dispersion around the hood of burning particles." Process specifications for feed material to Task II were revised "in an attempt to avoid encountering this type of situation."²¹⁰

In Task III, operations continued in a fairly routine manner, with some process changes and repairs. In the summer, the hydraulic lift cylinder needed to be replaced and the crucible sanding and loader had to be

overhauled. Limit switch difficulties were experienced in December. In mid-year, an increase in Task III capacity was initiated through the use of larger crucibles and larger charges.²¹¹

Various other areas of the RMA Line experienced repairs and process changes during 1956. In Task IV (casting), the heating elements in all four units, along with two thermocouples and a furnace lift mechanism, needed replacement in January. In May, loss of vacuum and heat on several occasions necessitated replacing the heating elements and defective thermocouples and connectors. In June, "appreciable difficulty was experienced in Task IV" when heating elements failed on two units "following damage by a tilted stack during furnace loading." A complete overhaul of the vacuum system took place in July, and another heating element replacement was necessary in August. At year's end, Task I still was reported to have "difficulty...with heating elements and faulty thermocouple wells."²¹² Additional repairs were required to equipment in Tasks V, VII, and the RMA conveyor system (Task XII).²¹³

PUREX Plant plutonium product was processed in Task I of the RMA Line for the first time in February 1956. However, "the radiation contained in this feed due to residual fission products was higher than normal, and the exposure rates to personnel handling the metal" was greater than desirable or acceptable levels. "The metal exhibiting the higher exposure rates" was above the specified limits for offsite shipment (the limit being 1.6 rads per hour [R/h]) surface gamma activity), so it was "redissolved and recycled to the REDOX facility for further decontamination."²¹⁴ Throughout March, according to G.E. Hanford Co., both beta and gamma radiation from PUREX feed remained "a major problem" at PFP, and in April PUREX product solutions began to be sent to the 231-Z Isolation Building to undergo "preparation" for introduction into the RMA Line (see Section 1.3). After a major outage in the spring to emplace equipment to achieve better in-plant product decontamination factors, as well as other process improvements during 1956, PUREX was able to produce material suitable as direct feed to the RMA Line (see Section 1.3). Following the end of plutonium processing at T Plant in March 1956, the last T Plant products were processed in the RMA Line in April.²¹⁵

Serious contamination events in the A-Line in 1956 occurred in March when a Task II furnace door was ejected after over-pressurization, and in August when a process operator was "exposed to plutonium air contamination when he transferred packaged slag and crucible (S&C)^o cans to a larger plastic bag in preparation for RECUPLEX dissolver charging." The employee was not wearing respiratory protection. "Bioassay urine sample results indicate[d] that some [internal] deposition of soluble plutonium occurred." Other incidents in the line that year included a "high level of contamination on an employee's leg when an improperly packaged waste carton leaked while being handled" in January. In another January event, "several operators were exposed to airborne contamination when plutonium dust escaped from a hood through a loose flange." In May, a spread of plutonium contamination occurred

^o Slag is a solid residue that was left from the plutonium reduction task. Crucibles made of magnesium oxide were the forming structures in which the plutonium buttons were cast. The crucibles were broken into contaminated pieces when the plutonium buttons were removed from them.

from an "uncontrolled chemical reaction at Task I." However, "respiratory protection" minimized personnel exposure. There were five cases of skin contamination and another radiation occurrence in December.²¹⁶

5.10 RMA LINE REMAINS SOLE PROVIDER THROUGHOUT MUCH OF 1957-1961

Throughout much of the period from 1957 to 1961, as plutonium production rates continued to soar at the Hanford Site, the RMA Line remained the only operating plutonium metal production facility. The RMC Line did not begin operations until September 1960, and even then was confined to operating only Tasks I-III until the end of 1961 (see Sections 3.1 and 6.2).²¹⁷ Throughout this period, to support the vast production increases, several modification projects and process changes were emplaced in the A Line.

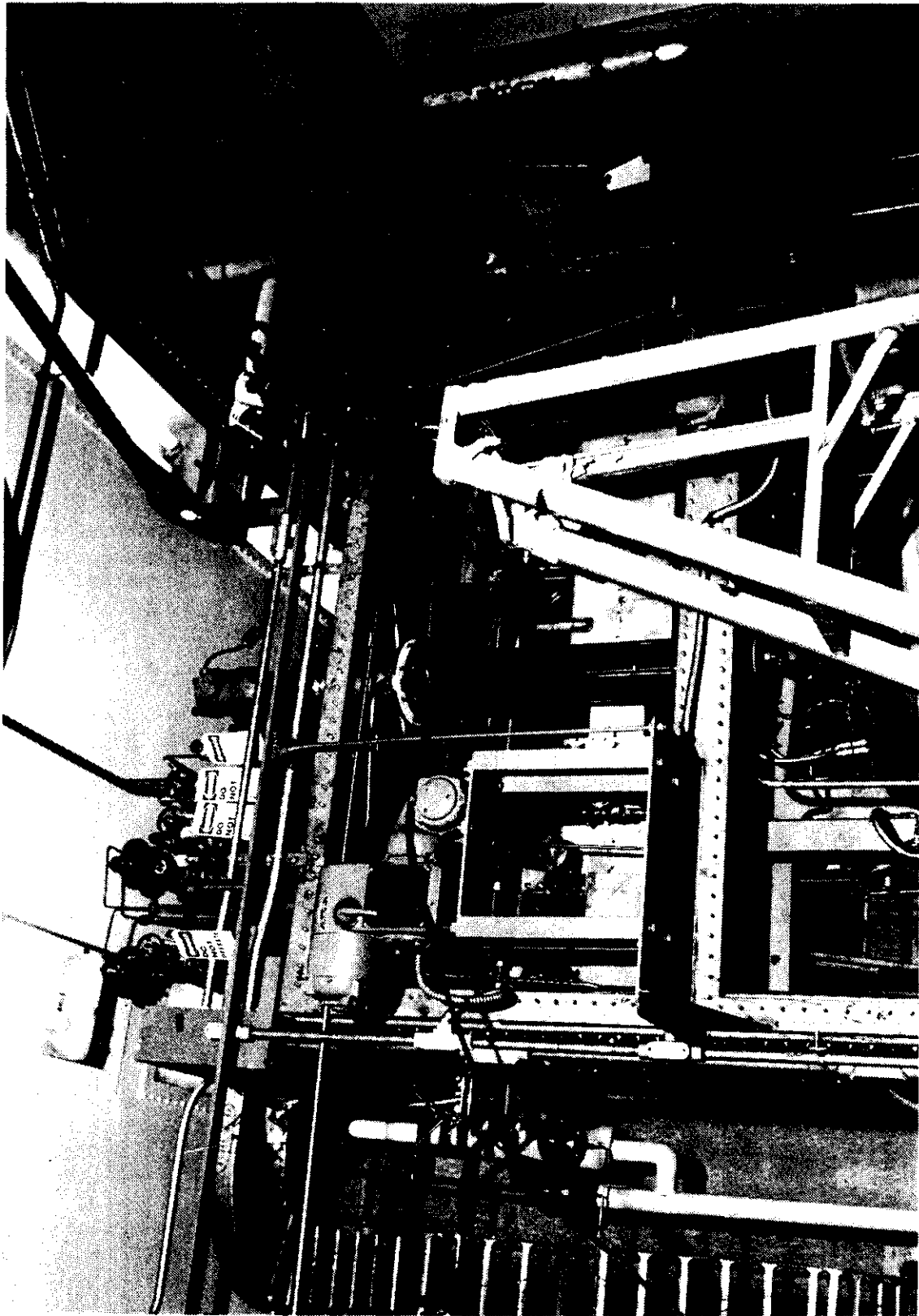
The most important improvement in the RMA Line during the period was the completion and startup of the continuous Task I-Task II process emplaced in Project CG-691 in 1957. Several modifications, primarily involving the use of a "continuous kill" process with permanganate, were transferred from the prototypical, continuous Task I-Task II hood in the RG Line (H-9B) to the new RMA Line continuous hoods (H9A and H7). By year's end, the continuous Task I-Task II process in the 234-5 Building was working so well that it was deemed "no longer necessary to maintain [standard] RMA Task II hoods for back-up," and they were being removed.²¹⁸ In 1959, according to G.E. Hanford Co., "process and equipment improvements increased the design rate of the continuous processing unit" (in Tasks I-II of the RMA Line) resulted in a vast rise in plutonium metal production over 1958.²¹⁹ (Figure 5.7)

Other noteworthy process improvements occurred in Task III of the RMA Line during 1957, where efforts to develop and test a permanent "ceramic reduction cell" (permanent mold casting) continued. This would minimize the need for ceramic recovery. Approval was received for procurement and installation of ultrasonic equipment in Task III to allow water pickling of buttons, and to reduce equipment losses associated with the use of corrosive nitric acid for pickling. Also, a chip briquetting press was built for RMA Line in mid-year.²²⁰

Despite good performance in Task I and II, high-beta-emitting PUREX feed, as well as the sheer volume of production, resulted in many instances of increased exposure in the RMA Line during 1957. This made rotating operators and setting dose rates for certain individual operations necessary. A January 1957 contractor report stated that "exposure rates in Task I and Task II are still relatively high...Task II probably offers the highest contamination potentiality of any location in the 234-5 Building." In December, two major contamination spreads in Task III resulted in 4 days of lost production time.²²¹

In 1958, in response to the 1957 exposure difficulties, Project CGC-800, Reduction of Radiation Exposure, RMA Line, was begun and completed. The project was undertaken when contractor reports repeated that "radiation exposure to all operators...continued to be a major problem." Indeed, a

Figure 5-7. Installation of Continuous Task I-Task II Equipment,
A-Line, July 1957.



5-year plan prepared for the Hanford Site in early 1958 flagged the resolution of RMA Line exposure problems as a major Site need. Project CGC-800 sought to reduce personnel exposure in the 234-5 Building by installing additional barrier-shielding between operators and Zone III (the area just outside the glove boxes themselves) in the Task I-IV space, extending the vacuum cleaning system being installed in the RMC Line to RMA Line Tasks I through IV, providing a new storage hood for plutonium powder produced in Task II, and relocating or modifying existing equipment to accommodate the new components. The project was seen as beneficial because it would improve radiological safety, and provide scheduling advantages as lower doses were received by operators in various tasks.²²²

During 1958-1959 Project CGC-826, Vacuum System Improvements, installed a large number of upgrades throughout the 234-5 Building vacuum systems (see Section 3.1), including new connections from the 291-Z Stack to service points in Tasks I, II, and III of the RMA Line. A key feature of the new vacuum system was its increased ability to sweep powders and other small debris from RMA Line hood floors, thus reducing radiation exposure to operators.²²³ Beginning in 1959 and continuing into late 1962, a series of modifications to modernize the RMA Line was undertaken as Project CGC-811, Additional Fabrication Facilities. These modifications provided equipment flexibility capable of processing fuels "with exposures from 1,000 to 10,000 MWD/T," and of fabricating many new weapons components. Casting operations, which had experienced many heating element failures and high reject rates caused by inclusions and voids, were completely overhauled in this project and four new casting furnaces were installed. The new casting equipment increased production capacity by allowing double castings in "stacked" fashion to be made at one time. Additional changes were made to the electrical circuitry in the mold heating system.²²⁴

In Task III, the RMA Line tested new vessels and crucibles during 1958 and 1959. In late 1958, stainless steel refractory vessels were successfully tested in an effort to eliminate the need for a "sand cushion" between the standard vessels and crucibles. A year later, larger crucibles were placed into use, greatly increasing button size. During the same years, casting reject rates rose so high that a special task force was assembled to focus on casting improvements for both the equipment on hand and design revisions for Project CGC-811. In February 1960, after nearly 2 years of operation, the platinum liner of the fluorinator tube of the continuous calciner-fluorinator (Task I-Task II equipment) in the RMA Line failed and was replaced. The replacement effort involved 3 days of lost production time.²²⁵

Throughout 1961, the RMA Line experienced ongoing equipment problems in the "foundry area" of fabrication (Tasks III and IV - casting and machining). Casting operations were carried out under the close supervision of the special task force until late in the year, when equipment changes improved performance. Adjustments to the electrical and hydraulic controls of lathing equipment were virtually constant. In March, a contractor report stated that "thermocouple and electrical failures in the casting equipment, and compressor and hydraulic pump failures in the machining hoods...continue." Also, finished shapes presented gauging and dimensional stability problems after fabrication. By late August, solutions were in place and fabrication performance soared.²²⁶

Serious contamination incidents in the RMA Line during 1957 through 1961 included the oxidation (with fire) of briquetted plutonium chips in August 1958, and the ongoing problem of breakthrough of fluorinator fumes from Task II filters. In August 1959, when 291-Z stack emission rose to an average of 106 μ Ci plutonium per day, both the primary and secondary filters on Hoods 9A and 9B were replaced. However, the inadvertent use of glass fiber filters instead of the proper Cambridge filters allowed stack emissions to reach 1,500 μ Ci plutonium on one day in the autumn. This high reading caused an investigation that led to the replacement of the glass filters.²²⁷

5.11 RMA LINE PROJECTS AND UPGRADES CONTINUE IN 1962 AND 1963

While plutonium production continued at a high level at the PFP throughout 1962 and 1963, additional modifications for increased safety and production were undertaken in the RMA Line and other areas (see Section 3.2). In the summer of 1962, in Project CGC-978, RMC Button Line Filtrate Handling Facility, ion exchange equipment located in the old Task I area of the RMA Line was converted to become part of the rework feed preparation for Task I processing in the RMC Line. In June 1963, lead glass shielding was installed around the feed and filtration hood for the ion exchange unit (Hood 7A). This reduced gamma radiation levels by 50 percent.²²⁸

In October 1962, two additional projects were authorized to fit the A-Line for a role in the fabrication of plutonium components for specialized weapons tests. Project CGC-983, Plutonium Ingotting and Auxiliaries Facility, RMA Line, provided facilities in the A-Line for ingotting feed (buttons), briquettes, and miscellaneous metal scrap; casting mold preparation, make-up, and breakout; and weight density determination of castings and ingots produced. Specialized equipment also was added to the 272-W Shop in this project (see Section 3.2). This project was completed in August 1963.²²⁹ Project CGC-984, Electrical and Hydraulic Equipment Mezzanine - RMA Line, installed mezzanine space along "D" wall of the RMA Line area to house motor control centers to provide for systematic distribution of electrical power and electrical cubicles, as well as hydraulic equipment. The equipment mezzanine was justified because prototype equipment for research and development in special weapons fabrication was being emplaced in the RMA Line. The new, individual prototype units would not be connected in a unified fashion to RMA systems as a whole. Therefore, additional power and hydraulic supplies were needed. The mezzanine also was fitted with a CO₂ fire protection system, concrete curbs, and bumper pads.²³⁰ In 1963, in Project CAC-987, Metal Stabilization Facility, a unique cell for research and development work for special weapons fabrication was authorized for the 234-5 Building (see Section 3.2).²³¹

Throughout 1962 and 1963, equipment difficulties in the RMA Line centered in the continuous Task I-Task II equipment, and in casting operations (Task IV). The continuous fluorinator failed in early 1962, and "plugged lines" were reported again in the autumn. Contamination problems led to the replacement of glove box panels in October and complete renovation of the Task I-Task II equipment in Hood 9-A during the winter of 1962-1963. Following this overhaul, continuous equipment performance was reported as "satisfactory but required considerable minor maintenance effort." New filters were placed in the lines leading to the filtrate pumps (to prevent

"fouling of pumps") and in the off-gas lines, and a new stainless steel reactor vessel and new valves were installed in early and mid-1963. However, more renovation work was required, particularly to the vacuum system, at year's end. "Foundry" difficulties (primarily with casting) were reported over and over, with line replacements in the cooling system and induction coils of the furnaces necessary both years.²³²

Mechanical and processing difficulties beset the Task III furnaces in 1962. In June, a contractor report stated that "approximately half of the furnaces were out of service during the last three weeks of the month...and about 30 percent of the product was below standard....some improvement has been achieved by reducing the size of the furnace charges. The steel cooling jacket of the...high-frequency generating unit failed due to corrosion and was replaced with one fabricated from stainless steel." In April 1963, the failure of a thermowell in one of the Task III reduction furnaces "resulted in slag being discharged from the pressure vessel to the hood. This resulted in fire damage to two of the hood gloves...As a result of...this incident and a previous similar incident, it has been decided that the thermocouples should be removed from the furnaces." Additional problems in the RMA Line during 1962-63 included a "blending problem of significant proportions" early in the period, when "a sharp rise [occurred] in the Pu-240 isotopic content of the feed" received at the 234-5 Building from REDOX and PUREX. This off-standard feed also caused difficulties in the RMC Line (see Section 6.2).²³³

The 1962-63 period saw few serious radiation events in the RMA Line. March 1962 witnessed the largest number of incidents, beginning when 40 liters of plutonium nitrate solution were drawn up into the vacuum header from the product feed system in the purification equipment. Later that month, a contamination spread occurred in Zone 1 of the 234-5 Building when the last of the very old Task I, RMA Line equipment was being removed. Another such spread took place when the condenser on a plutonium oxide dissolver plugged. In May, a glove ruptured on a skull^P-burning hood and "Pu oxide was inhaled by two operators in the time it took them to don masks." The following month, a pipefitter received "significant" plutonium deposition when his finger was deeply punctured by a wire contaminated with plutonium nitrate.²³⁴

5.12 MAJOR SITE AND MISSION CHANGES BRING RMA LINE CLOSURE AT END OF 1964

After President Lyndon Johnson's January 1964 announcement of a decreased national need for special nuclear materials (see Section 3.3), defense production fell slowly in the RMA and RMC Lines.²³⁵ At the same time, non-defense work was becoming more important at the PFP (see Section 13.1), and was most often reflected in orders for plutonium oxide blends rather than plutonium metal. The late-1965 decision to remove the weapons fabrication work from the 234-5 Building was not unexpected. Layaway (but not yet removal) of the fabrication portion of the RMA and RMC Lines (Tasks V onward) was undertaken in December 1965 and essentially completed in March 1966. Meanwhile, because of equipment problems and the decreased need, the RMA Line was taken out of service completely at the end of 1964. In

^P Skulls refer to the hardened residues left on molds by the molten casting of plutonium metal.

September 1967, glove box HA-39, part of the A-Line's fabrication equipment, was reactivated to grind plutonium-aluminum scraps from a special Hanford Site production experiment into turnings suitable for charging into the PRF's S&C dissolvers for plutonium recovery.²³⁶

5.13 REACTIVATION, PARTIAL REMOVAL, AND LAST OPERATIONS OF THE RMA LINE

The rest of the RMA Line remained closed until September 1968, when Tasks I through III equipment was cleaned out and reactivated to participate in expanded programs that prepared plutonium oxides in specified, tailored blends for commercial nuclear experiments and development (see Section 13.2). Oxides for early experiments for the development of Hanford's FFTF (see Section 13.3) were produced for the remainder of 1968 in the A-Line, with mechanical efficiency reported by ARHCO at 91.6 percent and product purity within specifications. From that time until the A-Line's final closure in December 1979, the RMA Line was known as "the oxide line" and the RMC Line was known as "the metal line."²³⁷

The Hanford Site produced approximately 13 metric tons of non-defense plutonium (Pu-239 in various blends with Pu-240 and other plutonium isotopes). Much of this amount, as well as much non-defense plutonium shipped to Hanford from off site, was processed in the RMA Line. In handling non-defense plutonium, the RMA converted nitrate to oxides, and blended oxides into multiple isotopic combinations specifically fitted to customer orders. Among the customers for non-defense RMA oxides during these years were some of the prime developers of commercial nuclear fuels and experimental projects in the nation. In the late 1960s, a special order for non-defense, plutonium oxide blend material was prepared as "test material for potential fuel fabricators" for the FFTF, the nation's prototype "breeder reactor," which was built in the 1970s at the Hanford Site. From 1973 through 1975, the RMA Line produced a large oxide order that comprised the feed material for pellet fuel for the FFTF's first and second core loads of fuel. The A-Line also supplied some non-defense plutonium oxides to EURATOM, a consortium of European governments. In a separate project, in 1972, Hood HA-40 F in the RMA Line was fitted with equipment to declad and cut up non-irradiated, zirconium-clad plutonium-aluminum fuel elements for plutonium recovery.²³⁸

During 1974 and 1975, clear, fire-resistant "glass" Lexan panels replaced some of the plastic windows on A-Line glove boxes as a fire prevention upgrade (see Section 3.4). In early 1975, a study was conducted of the RMA Line's capacity and upgrade needs if it were to process higher-exposure plutonium for the FFTF's third and fourth core loads. By autumn, a "prestartup quality review...in preparation for producing material for FFTF cores 3 and 4" was under way. New instruments, including a new temperature recorder for the reactor vessel, new recorder controllers on the first and second stage calciners, and conveyor and interlock upgrades were installed; blend and operating plans were prepared; and other modifications were undertaken in the preparation effort.²³⁹

During the first half of 1976, preparations continued in the A-Line for the campaigns to produce oxides for FFTF Cores 3 and 4. In July, "referee" samples were produced and sent for quality verification to laboratories at both the Los Alamos Site and the Hanford Engineering Development Laboratory

(the division of Westinghouse Corporation that held the contract for building and operating the FFTF).²⁴⁰ However, in September 1976, just after the operating accident in the 242-Z facility (see Section 11.3), the work of producing Cores 3 and 4 was given to the Savannah River Site (see Section 3.4). That month, the A-Line was placed in ready standby status, based on lack of feed. Decontamination and cleanout efforts began almost immediately. That December, while cleaning plutonium oxide out of Hood 9A-9E, a loss of contamination control occurred with subsequent inhalation of radioactive materials by personnel. Between May 1974 and May 1976, fabrication equipment was removed from the glove boxes that had performed Tasks V and onward (although these had not operated since 1964).²⁴¹

In 1978, the DOE gave direction to decommission most of the PFP complex (see Section 3.5). Stabilization of all scrap forms within the facilities was planned as a part of the D&D of the complex. As a result, the decision was made to restart the RMA Line to convert approximately 850 kg of plutonium nitrate stored in the 224-T Building and the plutonium nitrate that would be generated by the 1978-1979 PRF cleanup campaign (see Section 12.4). During early 1979, process specifications, control plans, flow sheets, oversight and risk evaluations, nomographs, startup criteria and requirements, and safety assessments were prepared. Operator training was conducted. Just glove boxes HA-7A, HA-8, HA-9A, HA-9C, and HA-9E, located in Room 224 of the 234-5 Building, would be the portions of the A-Line to operate in the oxide campaign. Glove boxes H-227-S and H-227-T in other parts of the building would be used for unloading and flushing the feed material, HC-4 and HC-6 in the RMC Line would be used for blending and staging, and some portions of the PRF would be used for filtrate concentration. Lucite panels remaining on some of these hoods were replaced with Lexan, additional lead glass shielding was emplaced, and glove box drain screens were installed "to provide an additional level of contingency for criticality prevention."²⁴²

The RMA Line stabilization run took place from September 7 through December 7, 1979, with 676 kg of plutonium processed. Cleanup of the line, with metal plates placed over many of the glove ports, was completed by year's end. In 1980, a plan was written to perform terminal cleanout on 12 glove boxes in the A-Line, by removing old equipment, loose or retrievable plutonium, and hydraulic fluids. The glove boxes were placed in a stable mechanical configuration and some electrical connections were disconnected. In July 1983, RHO reported that "terminal cleanout of the RMA Line is complete."²⁴³ (See Figure 5-8.)

In 1983, tentative plans were made to reactivate the RMA Line to process plutonium nitrate from the PUREX Plant. The PUREX facility was scheduled to reopen after a long closure, with a new internal facility (N Cell) that would process the plutonium nitrate PUREX product into plutonium oxide before shipment to the PFP. However, uncertainty about N Cell's performance led to the plans to reactivate the A-Line. A new flowsheet for oxide line operations and a safety analysis were written. However, N Cell operations performed well and the decision was made in 1984 to keep the RMA Line in standby status. It never again operated. Today the RMA Line consists of 24 glove boxes located in room 235 of the 234-5Z Building, with the control room in room 233.²⁴⁴ (See Figures 5-9 and 5-10.)

Figure 5-8. Oxide Produced in RMA Line's Last Campaign, December 1979.

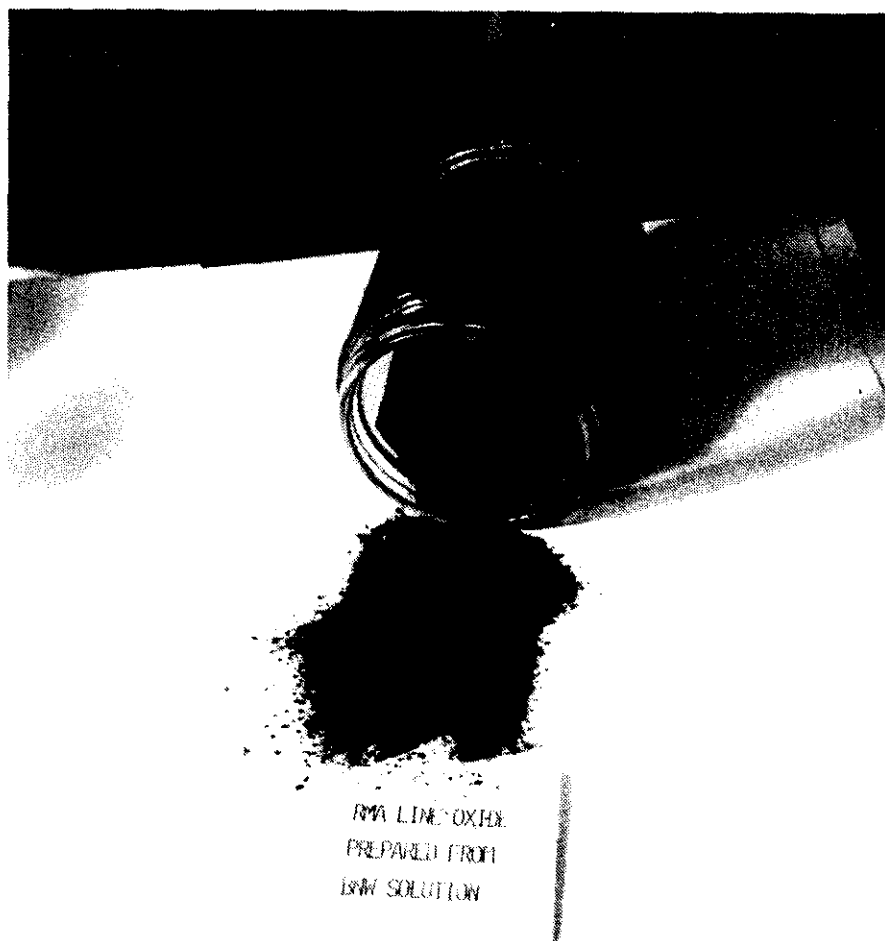


Figure 5-9. Seal-Out of Waste Package from A-Line, 1987.



Figure 5-10. Performing Sealout of Contaminated Material, Glove Box HA-20MB, 1987.



6.0 RMC LINE

6.1 GENESIS, CONSTRUCTION, AND DESCRIPTION OF THE RMC LINE

In mid-1955, during a period of continual expansion of the Hanford Site's production requirements for special nuclear material (see Section 2.10) and as the last in a series of major modifications was being designed for the RMA Line (see Section 3.9), the AEC decided to emplace a second button line in the 234-5 Building. The new line would operate only Tasks I through III of the process. It would not go on to cast and fabricate weapons pits. The thinking was that, because multiple improvements had solved (or were about to solve) the most difficult operating problems in Tasks I through III of the A-Line, the new line could incorporate these upgrades and begin production without anticipating major changes. In October 1955, preliminary design scoping and alternative equipment layouts began for the second PFP button line in the 234-5 Building, "to provide for forecasted increases in plutonium production, to assure production continuity, and to provide for short-term peak loads from the primary solvent extraction plants."²⁴⁵

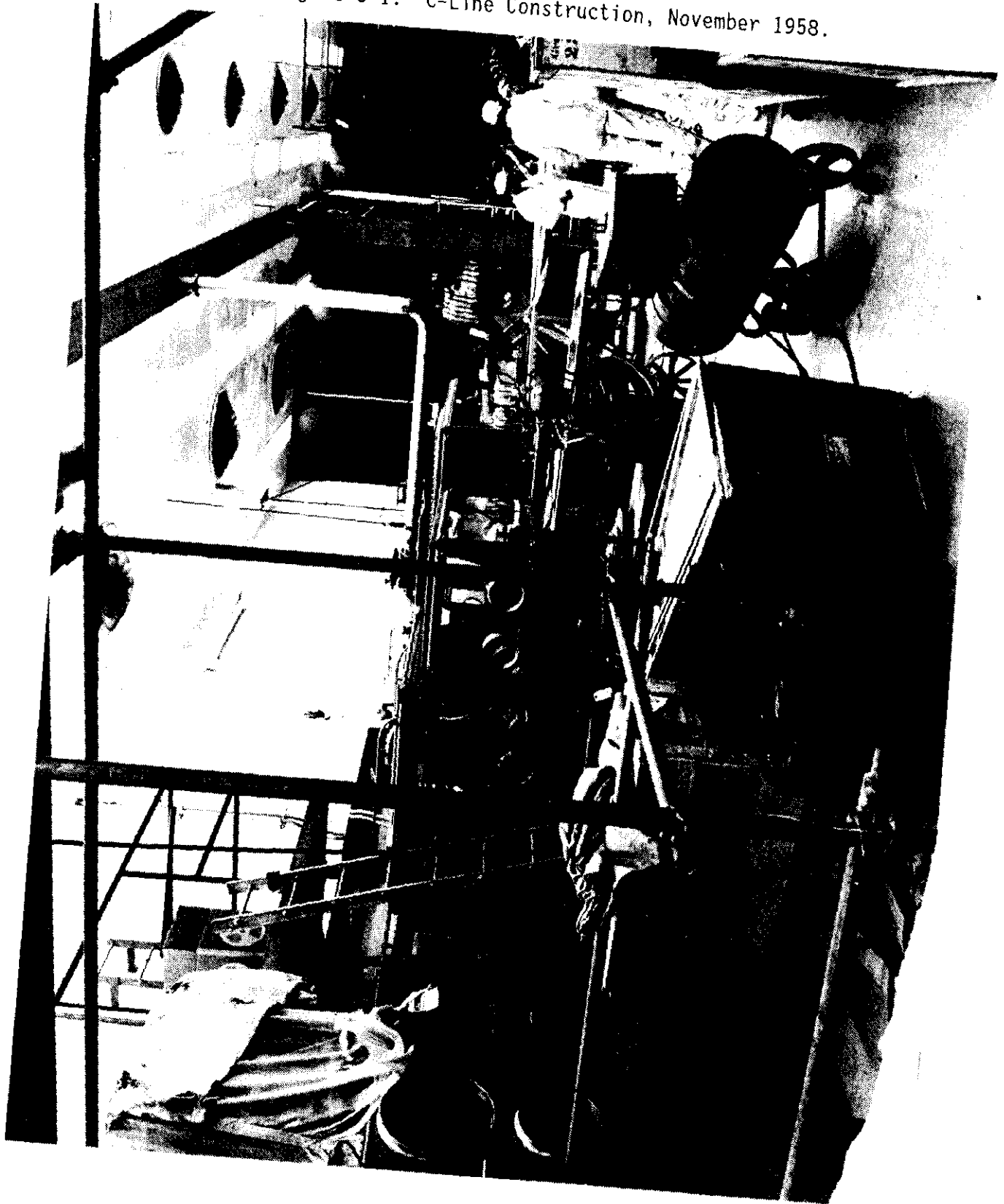
A preliminary budget document for construction of the new line was issued in January 1956, and by August it had been decided to place the equipment "in the RG area." By year's end, the program was being called the RMC Button Line, although as yet it existed only as engineering study E-33413 and did not possess full project status. Preliminary engineering studies were underway to define "the best arrangement of equipment and utilization of available space."²⁴⁶ Soon after the PUREX Plant, which was new in 1956, proved its vast production capacity, Tasks IV through XII were added to the new PFP line. Two projects were authorized in early 1957: CG-734, RMC Button Line; and CG-745, RMC Fabrication Line. Both were undertaken officially in April 1957, and completed in late 1959 at a total cost of nearly \$1.9 million. Soon, the two projects together became known simply as "the RMC Line" or "the C-Line." The RMC Line functioned to convert plutonium solutions to metal and then to fabricate actual weapons shapes from the metal. It differed from the RMA Line in that it had an automatic vacuum cleaning system that served Tasks I through IV, greater radiation shielding, and improved radiography facilities. The RMC Line was emplaced where the former RG and RMB Lines had stood.²⁴⁷ (See Figure 6-1.)

The RMC Line (both the button and fabrication components) consisted of a completely self-contained, remotely operated series of glove boxes very similar to the RMA Line. It was fabricated from high-grade austenitic,⁹ 304L stainless steel, with all welded construction, and was installed with seamless austenitic stainless steel piping and castings for corrosion resistance. All hoods except the conveyor hoods were fabricated with 1/4-inch-thick steel floors and ceilings, 1/4-inch bent angles for the framework, plexiglas panels "wherever possible to furnish maximum visibility," and molded Neoprene^r gaskets as air-tight seals around all windows and ports.

⁹ Austenitic is a generic category of stainless steel that is composed of austenite made stable by alloying with nickel.

^r Neoprene is a trademark product of the E.I. DuPont de Nemours and Co.

Figure 6-1. C-Line Construction, November 1958.



Lucite^s or Homalite^t ports equipped with plastic bags were provided for maintenance and equipment removals. The conveyor hoods were fabricated of 3/16-inch-thick stainless steel plate, with 3/16-inch bent-angle framework. The button line portion of the RMC conveyor was known as HC-1, and served 17 hoods and various tanks. It was 60 feet long, and was constructed of stainless steel slats mounted on a stainless steel frame. Ventilation piping also consisted of 304L stainless steel piping, 3 inches, 4 inches, or 6 inches thick in different sections. Lead glass, carbon steel, and plexiglas shielding were designed for the C-Line in 1957, but strengthened in 1959 because, according to G.E. Hanford Co., "at the time the RMC button line was designed there was insufficient knowledge...on whole body exposure to operators...Since that time, such factors as increasing production...higher reactor exposure levels, and more precise instrumentation in measuring neutron dose rates have resulted in the present severe problem of...exposure" (see Section 3.10). Carbon steel plates were added to the internal floors of RMC Line hoods, and supplemental shielding external to the glove boxes was added at many points.²⁴⁸

The front end of the RMC Line housed a maintenance hood fastened to the HC-1 conveyor hood, a PR can decontamination hood in Room 227, and a feed storage tank (HC-6). Hood HC-5 provided a cross-conveyor link to the RMA Line. The arrangement of equipment in the continuous Task I-Task II area of the C-Line (Hood HC-9B) was slightly different from that of the A-Line, based on process experience gained and lessons learned. In the original C-Line process, plutonium oxide progressed from Hood HC-9B to Hoods HC-10 and HC-11 for powder pan weighing and storage, then to Hood HC-12S for pressure vessel preparation, and then to Hood HC-13MD for charging of the pressure vessels (reduction vessels). Hoods HC-15A, 15B, and 15C were the "firing hoods" where the plutonium oxide was reduced to metal in furnaces operated under vacuum. Hood HC-16CC housed a tool that broke the crucible inside the pressure vessel to facilitate subsequent unloading of the pressure vessels, Hood HC-17DC contained the dumping and cleaning steps for the pressure vessels, and Hoods HC-17P was used for button "pickling" (acid treatment). Hood HC-17SBB housed the sampling and weighing of buttons, Hood HC-18BC functioned for button storage, and Hood HC-19M encompassed the vacuum cleaning system used to sweep out hood floors to reduce operator hand exposure. Hood HC-42 contained the dissolver operations used for metal that did not meet specifications. Between the end of the button line and Hood HC-42 sat the fabrication equipment. In general, the fabrication equipment of the RMC Line performed casting, heat treating, machining, and inspection operations, as well as preparation of off-standard metal for recycle, product conveyance and storage, and preparation of finished products for shipment.²⁴⁹

6.2 RMC LINE STARTUP AND EARLY OPERATIONS

After many months of cold startup tests and resultant adjustments, the RMC Line began routine processing with hot plutonium nitrate feed in October 1960. By November, the new line was operating so well that it was

^sLucite is a trademark of ICI Acrylics, Inc.

^tHomalite is a trademark of the Brandywine Investment Group Corp.

performing all of the Task I-II work and 80 percent of the buttons firing. In December, the new line was described by the contractor as "generally satisfactory," although distortion of the pressure vessels was reported in Task III, along with burning of the gaskets. "Modifications to the hydraulic system and changes in the argon purge" were made to correct these difficulties. However, during the early months of 1961, the RMC Line produced buttons of poor quality with high reject rates. Techniques and production levels improved as equipment was adjusted, and new methods of dissolving reject plutonium metal were invented, so as to produce a plutonium solution ready for rework. Throughout the year, the RMA Line continued to be the only operational fabrication line in the PFP, while RMC operations were confined to producing plutonium buttons.²⁴⁹

During 1962, the full RMC Line operated with increasing success, and by mid-1963 the new line was running in parallel with the A-Line. On April 7, the nuclear excursion in RECUPLEX suspended C-Line and all other operations in the 234-5 Building. "Limited fabrication activities" resumed on April 23, and button line operations resumed on May 18.²⁵⁰ As in the RMA Line, the RMC button line was troubled with the blending problem in 1962 and early 1963, when "a sharp rise [occurred] in the Pu-240 isotopic content of the feed" received at the 234-5 Building from REDOX and PUREX. Among the solutions to dealing with this off-standard feed was to begin blending it, in late 1963, with "unclassified" (non-defense-grade) plutonium, and such. The early operations period was marred by only one serious contamination event, a fire in a glove box in Room 227 in November 1963.²⁵¹

By 1964, the C-Line had taken over the bulk of metal processing in the PFP, and was operating on a 7-day work week schedule because of the high demand for production. An elite crew of four to six operators with one line manager per shift, operated the RMC Line. The attrition rate was very low, and C-Line operators generally were not rotated to other jobs with the PFP. From 1965 until 1968, the RMC Line was the only operating plutonium line in the 234-5 Building, and it remained the only metal line even after the RMA Line was reactivated in 1968 (see Section 3.13). The weapons fabrication program concluded in mid-December 1965, layaway, but not yet removal, of the fabrication portion of the RMA and RMC Lines (Tasks V onward) was undertaken immediately and essentially completed in March 1966. The metal conversion portions of the RMC Line (Tasks I-III) continued to operate, while Task IV was converted to bag-out and sealing for shipment operations.²⁵²

During the high production years of the early 1960's, upgrades were made to the new RMC Line. In July 1962, Project CGC-978, RMC Button Line Filtrate Handling Facility, was authorized and begun. It was needed urgently, because the closure of the RECUPLEX facility in April 1962 left the operating lines of the PFP with no facilities to which to send their filtrate for rework. This project was completed in September.²⁵³ At nearly the same time Project CGC-953, Personnel Protection, Storage Hood Shielding-234-5 Building was started and completed in the RMC Line. It provided for fabrication and installation of 10-inch-thick, water-filled shielding tanks around the three operating sides of storage glove boxes HC-22-SR and HC-45-S. The project was justified because, at its outset in February 1962, these two storage glove boxes were being used at four times their design capacity "to provide necessary aging to satisfy weapons specifications." This situation was increasing neutron radiation exposure to personnel working nearby, to the

point where the Site limit of 5 rem^u per year would be exceeded if corrective actions were not taken.²⁵⁵

Also in 1962, Project CG-811, Additional Fabrication Facilities, to work with high-exposure plutonium to produce specialized weapons test components, was completed in both the RMC and RMA Lines (see Section 3.1 and 5.10.). Under way since before the startup of the C-Line, these modifications provided equipment flexibility capable of fabricating many new weapons designs, shapes, and weights. A conveyor also connected the RMC Line with a special inspection facility, built as part of Project CG-811 on the northwest corner of the 234-5 Building.²⁵⁶ The RMC Line was fitted with a new paging system in 1964, and receiving glove box HC-4 was overhauled in 1966.²⁵⁷ Also in 1966, plutonium was removed from duct work and filter boxes downstream of Hood 9B, after build-up was discovered in those locations.²⁵⁸

6.3 RMC LINE OPERATIONS FLEXIBLE THROUGH MID-1973

Throughout the decade from 1963 through mid-1973, the RMC Line continued to operate on a mixed schedule, producing some defense-grade metal, and an increasing amount of non-defense-grade metal and oxides (see Sections 13.1, 13.2, and 13.3). For example, in 1966, weapons-grade plutonium buttons were produced throughout the early months of the year, but the C-Line was "cleaned and inventoried" on April 25. Three days later, "the processing of plutonium from N Reactor...[containing approximately 12 percent Pu-240 - a non-defense isotope] was started," and continued throughout most of the year (see Section 13.2).²⁵⁹ Late in 1966, a process test began in the RMC Line, using a double-lined reduction vessel to extend crucible life through several reduction steps, and to reduce the amount of material needing recovery processing. By April 1967, the new crucibles were working well, and showed a substantial decrease in solid scrap and a slight increase in plutonium yield. However, they developed problems in 1968.²⁶⁰ Throughout 1967, the C-Line operated to produce weapons-grade material approximately 64 percent of the time; the remainder of the time was spent in non-defense work. The non-defense work consisted mostly of blending and casting ingots for the ZPPR facility off Site (see Section 13.2).²⁶¹ During 1968, the RMC Line again worked in both defense and non-defense operations, producing a special lot of oxide material high in Pu-240 for non-defense experiments.²⁶²

In September 1968, in support of the expanded non-defense work, Task I-II portions of the RMA Line were cleaned out and reactivated. From that time until the A-Line's final closure in 1979, the RMA Line was known as "the oxide line" and the RMC Line was known as "the metal line" (see Sections 3.3 and 5.13).²⁶³ Non-defense work continued to increase in both lines during 1969-71, although the C-Line also produced defense metal derived from the PUREX product stream. During 1969, Process Test BL-69-1, Characterization of pressure vessel Operating Conditions, was conducted in the RMC Line, to "determine the conditions to which a pressure vessel is subjected

^u Rem is an acronym for roentgen equivalent man, but is not usually spelled in upper case letters. It is a unit of measure for the dose of ionizing radiation that gives the same biological effect as one roentgen of X rays. One roentgen corresponds to the release by ionization of 83.3 ergs of energy.

during firing." That February, ARHCO reported a "small fire...in furnace #1 when one of the leads failed and caused a short circuit. One lead melted through and water sprayed all over the hood. No contamination was spread [outside the hood]. The blaze was confined to the lines, and the coils and insulation for furnace #1 were replaced." However, C-Line performance was excellent overall, with three campaigns in March producing buttons with average yields of 98.4 percent, 97.8 percent, and 98.2 percent respectively. For a brief time beginning in mid-1970, the C-Line shut down because of lack of feed material.²⁶⁴ However, it was reactivated in April 1971 to produce weapons-grade metal in response to increased production at the PUREX Plant. Defense metal then was produced in substantial quantities for the remainder of the year, as well as a special order of high Pu-240 metal, for a "Deep Burn Californium" experiment at the Savannah River Site.²⁶⁵

Throughout 1972, weapons-grade metal was produced by the RMC Line in substantial quantities, along with some non-defense materials. The PUREX Plant shut down in May of that year, but residual PUREX inventory was processed through the C-Line until August 1973, except for a brief stand-down of the entire PFP complex between May and early July 1973 (see Section 15.3). That August, the RMC Line was shut down, cleaned of all "easily obtainable Pu" by line flushing and glove box brushdown, and its glove box ports were closed off with metal covers known as "pie pans." Restart of the PUREX Plant was anticipated in only 18 months (late 1973), with RMC Line restart soon to follow. Therefore, according to a contractor report, "no specific actions were taken to preserve the equipment integrity for later reactivation." Ventilation of the glove boxes was maintained "for containment purposes."²⁶⁶

Meanwhile, during mid-1973, design criteria were developed for 8 inches of additional shielding to "provide approximately 90 percent attenuation" of the neutron radiation levels in the "occupied areas" around the RMC button line portions and, later that year, the fluorinator off-gas water scrubber system in the C-Line was retrofitted with a recirculating water system for effluent reduction (see Section 15.3). Many plastic glove box panels were replaced with fire-resistant, Lexan windows during 1974-1975 (see Section 3.3).²⁶⁷ Studies in the additional shielding for the RMC button line area continued into 1976, but the shielding was not emplaced at that time because of the lack of missions for the C-Line.²⁶⁸ Between May 1974 and May 1976, several glove boxes and pieces of equipment in the fabrication portions of the RMC Line were removed and buried, as part of an ERDA-ordered cleanout of DMA equipment at the Hanford Site and at some other sites (see Section 3.4). During the course of this work in March 1975, a criticality prevention specification was violated while plutonium was being removed from glove box HC-40.²⁶⁹

6.4 TERMINAL CLEANOUT ORDERED FOR RMC IN 1978; RESTART ORDERED IN 1984

Throughout 1977 and 1978, glove box HC-21A in the RMC Line was used to sample ceramic-grade plutonium dioxide for FFTF cores 3 and 4 (see Section 13.3). This material was manufactured at SRP, and shipped to the PFP for blending and sampling, before delivery to the FFTF project. Glove box HC-21A was part of the old fabrication equipment of the RMC Line.²⁷⁰

In early 1978, the DOE ordered studies to scope a large project to decontaminate and decommission most of the PFP complex, including the RMC Line (see Section 3.5). Planning studies for this terminal cleanout study went forward during 1979 through 1982. However, the armaments build-up program of President Ronald Reagan, who had been elected in 1980, soon brought new defense programs to the Hanford Site. The PUREX Plant restarted in November 1983, and in mid-1984 the DOE gave direction for the RMC Line to restart to make defense metal. An intensive upgrades project was mounted, including 301 targeted items, with a projected startup date of June 1, 1985. A review team was brought in from the Los Alamos Laboratory to review the startup safety analysis for the C Line. Instrumentation and electrical systems on C Line glove boxes were inspected, repaired, or replaced, and furnace assemblies were dismantled for inspection and upgrading. Restart was achieved on July 1, 1985, and the line operated until October of that year. According to a contractor report, "the initial startup period...extended until the last week of September due to repeated operational problems and key equipment failures." Only approximately 13 percent of the total campaign output was achieved during this shakedown period. "The production run started in earnest on September 30, 1985, with the last [Pu nitrate]...load-in occurring on October 18." The total production output was about 63 percent of the target goal. Cleanout and shut down activities in the RMC Line took place through October 31.²⁷⁰ (See Figures 6-2 and 6-3.)

A post-campaign analysis by the contractor found that only 25 percent of the plutonium buttons produced were within specification limits, and that many of the impurities consisted of iron, nickel, chromium, carbon, and aluminum. HF gas escaped into Room 228A during the campaign, when a leak developed in a weld on the thermowell assembly on the HF supply line to Hood HC-9B. RHO recommended several modifications to C-Line equipment, as well as entire replacement of the vacuum drum filter, the fluorinator off-gas scrubber, and several lines in the RMC system. A list of 125 maintenance items was prepared, and then scoped down to the most important 40 items. By December 1985, engineering design had been initiated to rebuild or replace these 40 items.²⁷¹

6.5 LAST TWO RMC LINE CAMPAIGNS

The RMC Line restarted after multiple repairs in April 1986, and operated for 6 months making defense-grade metal. It was then shut down for a series of mechanical and safety upgrades. These upgrades included bracing the HF cylinder banks and Hoods HC-15-A, B, and C to withstand seismic disturbances and redesigning the HF gas interlock system and the Hood HC-15 furnaces. They also included obtaining new pressure gauges, temperature indicators, liquid level controllers, tubing, HF gas sensors, and HEPA filters; and upgrading hood lights and conveyors. The argon gas supply and the fire damper were changed, along with some lead glass glove box panels. In Hood HC-9B, additional upgrades included modifying the transfer mechanism and graphic display panel; replacing the calciner filters, the circuit breakers for the breathing air system, and the HF gas line penetration into the hood. Key modifications were made to the C-Line continuous oxalate precipitator, changing it to a mixed-suspension mixed-product removal draft tube precipitator. The salient reason for this change was to improve the particle size of the plutonium oxalate product. Other upgrades were made to feed

Figure 6-2. RMC Button Line, Equipment Inspection, 1982.

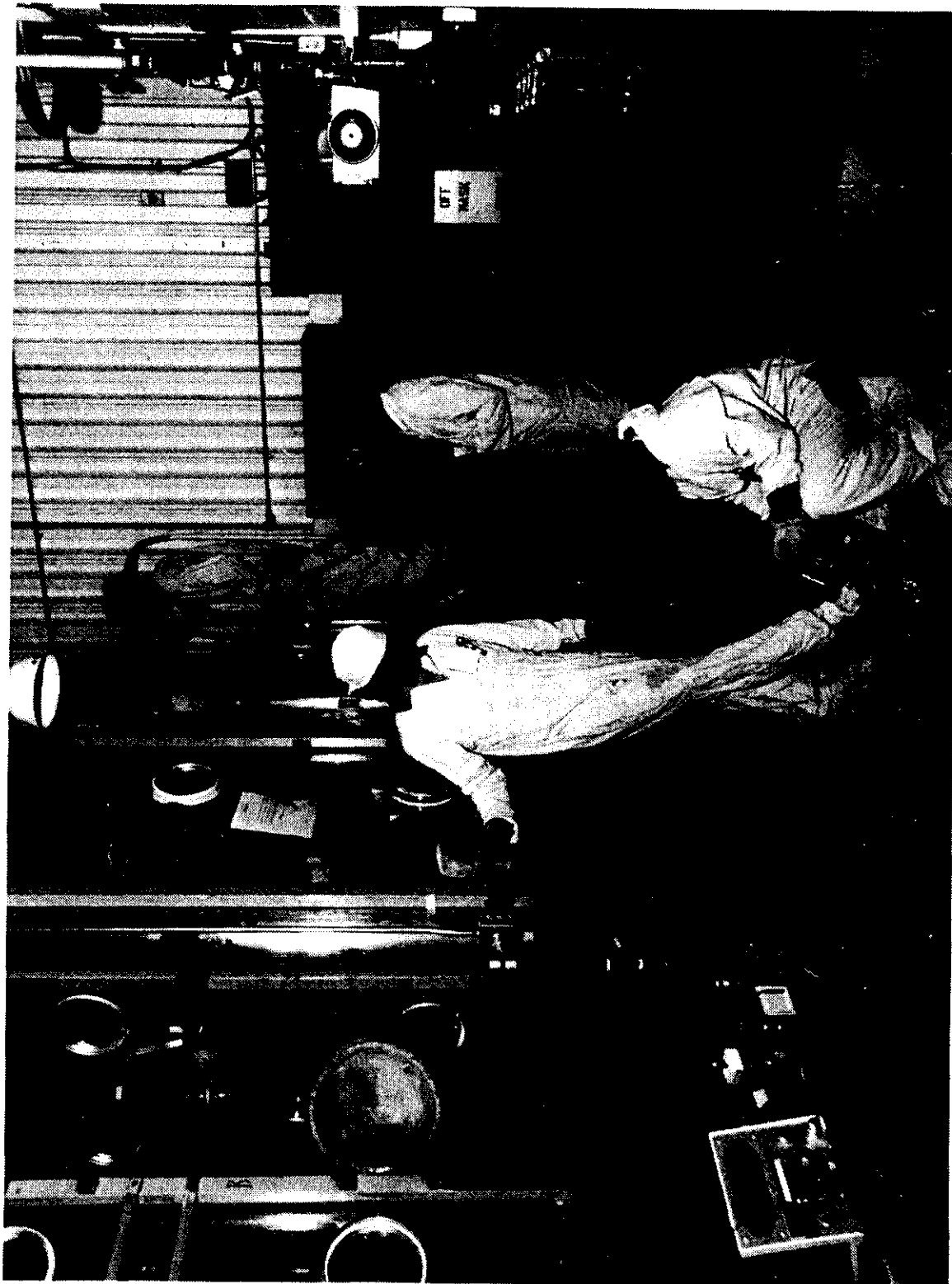
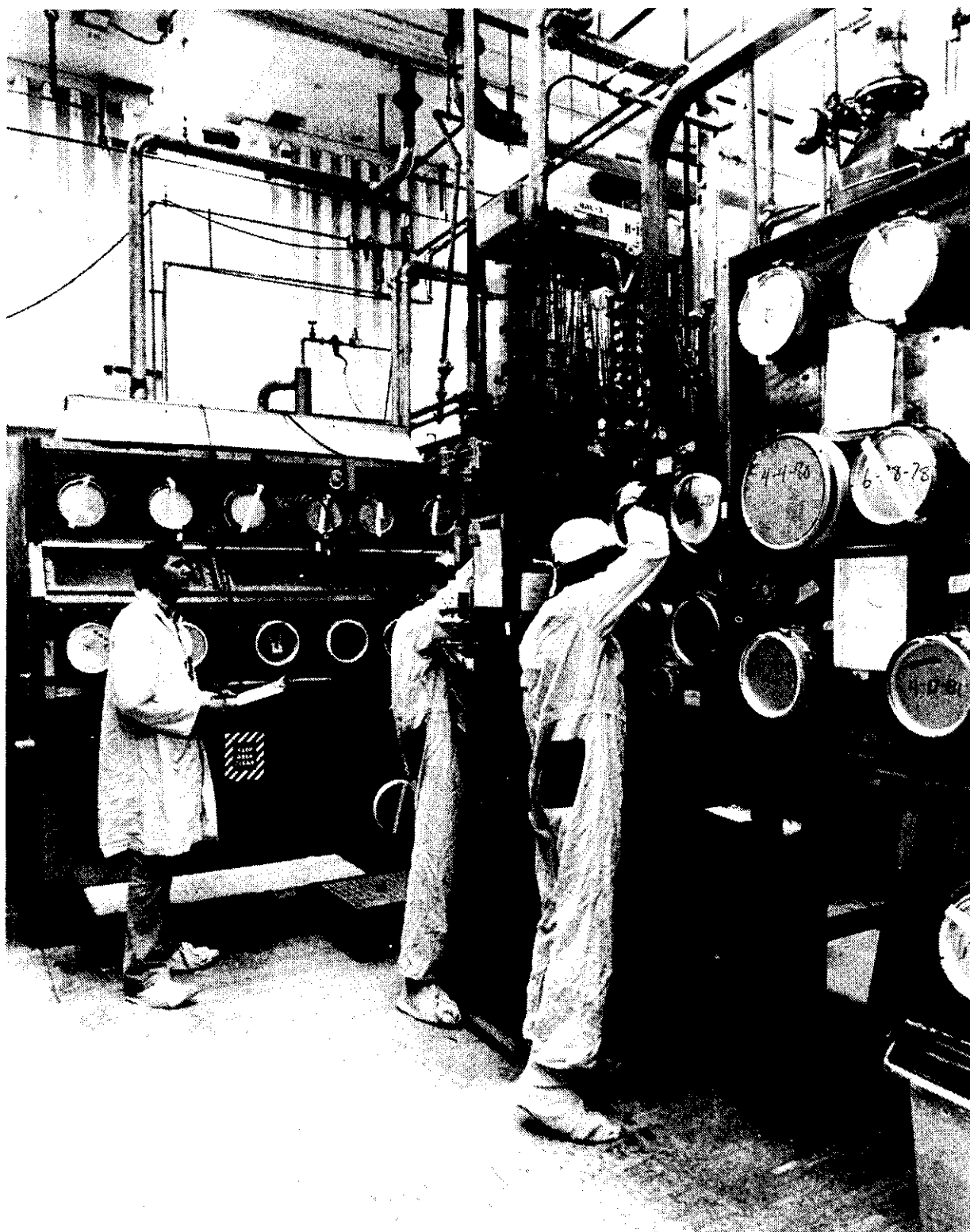


Figure 6-3. Operators Check Idle RMC Line Equipment, 1982.



blending systems in the 234-5 Building, to various other support equipment for the RMC Line, and to building systems in general. During the same period, quality assurance plans and safety monitoring plans were rewritten, management qualifications and operator training were reviewed, nuclear material accountability procedures were revised, and all preventive maintenance plans and RMC security plans were revisited.²⁷²

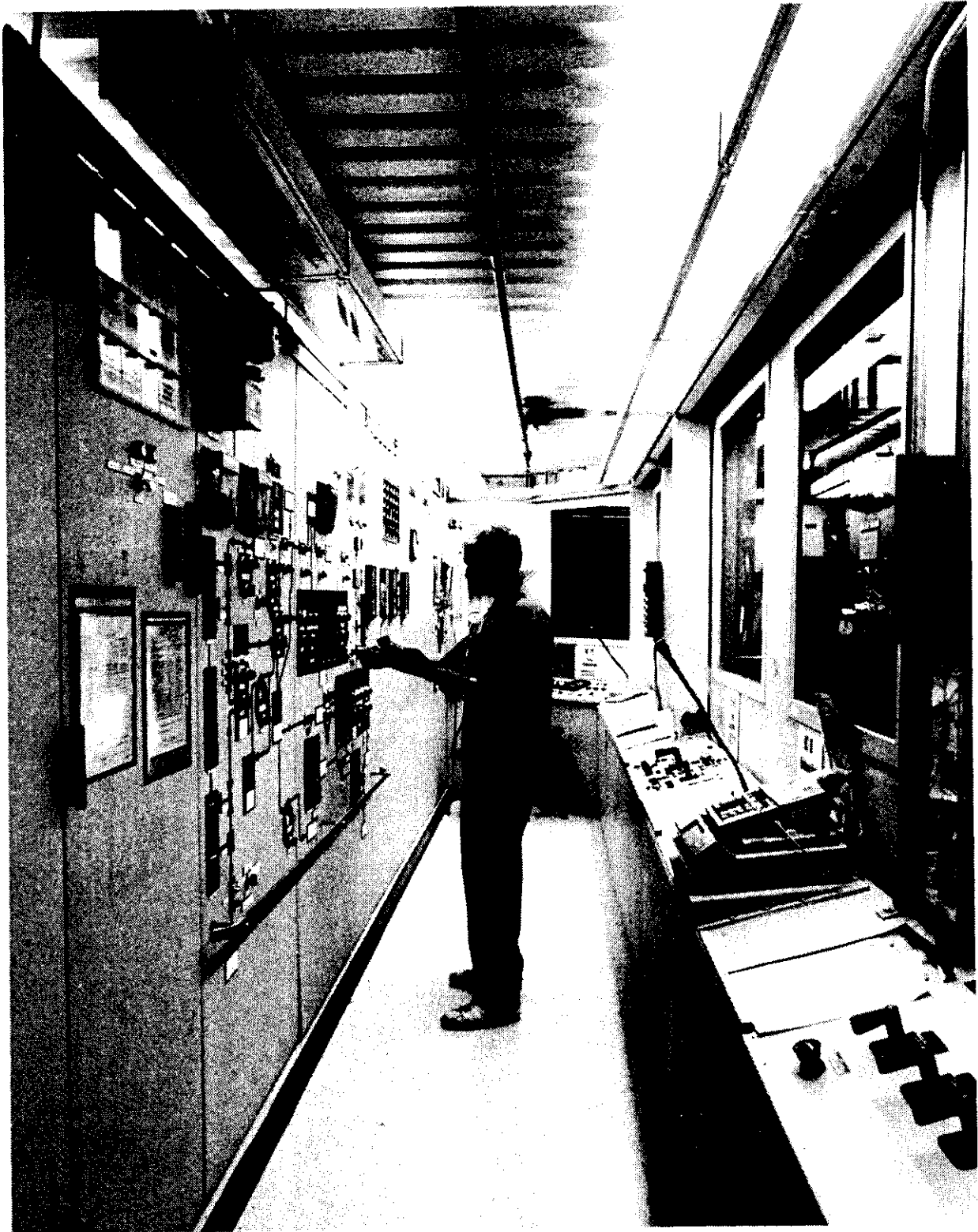
The final RMC Line campaign took place from July 1988 through June 1989, making defense-grade metal. Then, a new series of upgrades was planned for the C Line, but world and local events, especially the end of the Cold War, intervened (see Sections 3.6, 16.1, and 16.2). (See Figures 6.4 and 6.5.)

Figure 6-4. Plutonium Button Produced in RMC Line, 1988.



HNF-EP-0924

Figure 6-5. RMC Control Room, Last Campaign, 1988.



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7.0 PFP LABORATORIES

7.1 THREE LABORATORIES OCCUPY EARLY PFP

As originally constructed, the 234-5 Building contained only an analytical laboratory. Also known as the sample laboratory or the process control (sometimes simply "process" or "control") laboratory, this laboratory functioned to sample the plutonium product during various stages of the PFP process to ensure that materials were within specifications. All of the building's safety bases and criticality assumptions depended on knowing the isotopic content and amounts of the plutonium being handled. The analytical laboratory was located at the east end of the PFP, toward the south side. Phase II of Project C-198 (the PFP construction project) (see Section 2.5) included the completion of two more sample laboratory rooms, as well as construction of the developmental laboratory. This laboratory also was known as the Plutonium Chemistry Laboratory, or the process improvement, or R&D laboratory. It was located at the southwest corner of the PFP. Before a developmental laboratory was available in the 234-5 Building, early R&D for the PFP process was carried out in the nearby 231-Z Building (see Section 1.2).²⁷³

A third laboratory, a small plutonium metallurgy facility in Room 179, operated in the PFP Building only from late 1952 to late 1956, when it moved to the 231-Z Building (see Section 1.5). (After that time, Room 179 became part of the developmental laboratory.) The plutonium metallurgy laboratory experienced a gross contamination event in its main room during its first month of hot operations, November 1952, and operations were suspended for 2 weeks. By December, 18 hoods were in operation or near operation in the facility. The metallurgy laboratory examined the material properties of plutonium in its metallic state, studying alloys, tensile properties, stability, and fabrication and coating methods. All three early PFP laboratories began by working with open-faced hoods, but replaced most hoods with glove boxes over the years.²⁷⁴

7.2 PFP DEVELOPMENTAL LABORATORY UNDERTAKES EARLY PROCESS IMPROVEMENTS

As soon as processing began in the PFP in 1949 (see Sections 2.4 and 5.2) personnel in both the developmental and process laboratories directed their efforts to improving the accuracy of measurements, reducing product losses, and troubleshooting process difficulties that arose. An area of intense interest was the development of methods to recover and recycle plutonium from waste materials (see Section 8.0). A special investigative task aimed at the recovery of usable plutonium from S&C solids was undertaken in Room 41 of the 231-Z Building in the summer of 1949. By December, a contractor report detailed "early promise for success in solubilizing" the S&C material as well as the "highly gelatinous [silica] residue".²⁷⁵

Other key laboratory projects conducted in 1949 at PFP were directed at improving the various steps in the plutonium finishing process. The emphasis on developing process improvements in the 234-5 Building production lines continued for many years in the developmental laboratory. Among the earliest experiments were those substituting sulfate-free plutonium peroxide for

oxalate precipitation, and improvements in radiographic techniques to inspect plutonium shapes. Techniques to destroy the oxalic acid in the oxalate supernatant waste also were pursued to make more of the 234-5 process waste suitable for recycle through the 224 Concentration Building process. Instrument design for the very new, miniature "gloved boxes" and "junior caves" in the 234-5 laboratory also consumed much attention. However, attempts to find a "suitable material, other than platinum" for counting disks failed.²⁷⁶

During 1950, as the developmental laboratory opened in the 234-5 Building, many other initiatives in process improvement were undertaken. Chief among these, as the REDOX Plant neared completion, were studies of methods to "couple" the end product of the REDOX process with the beginning of the PFP operation. The object of the coupling effort was to eliminate the need for the final REDOX plutonium product solution to be processed through the 231-Z Isolation Building before going to PFP. By year's end, one laboratory procedure had been developed, involving evaporation of the REDOX product, followed by the addition of hydriodic acid (HI) and oxalic acid (H₂C₂O₄) to cause the precipitation of Pu(III) oxalate. However, a completely satisfactory and workable "peroxide process" that could be incorporated within 234-5 Building operations was not available. Other experiments investigated the feasibility of direct hydrofluorination of Pu(III) oxalate in the PFP process, "paving the way [for the] elimination of the oxidation step in the process."²⁷⁷ Other 1950 experiments were directed toward new methods of nickel plating finished plutonium surfaces. Some trials looked promising in the spring, but failed and were abandoned by year's end.²⁷⁸

7.3 PROCESS AND DEVELOPMENTAL LABORATORIES EXPAND OPERATIONS

In May 1951, the PFP process laboratory went from a two-shift to a four-shift operation to accommodate expected plutonium production increases. In November, after intensive training and effort with specific laboratory personnel, the backlog of chemical assays on cast metal pieces was reduced to zero.²⁷⁹ In the developmental laboratory, key studies in recycle techniques and process steps to bypass the 231-Z Building continued throughout 1951 and 1952 (see Sections 8.1, 8.2 and 1.2). Some inconclusive studies looked at various alternative methods of skull dissolution.²⁸⁰

In January 1952, laboratory rooms 185 (known as the "hot" lab) and 189 (including the decontamination hood) were completed. In March, the developmental laboratory organization moved from the 231-Z Building to the 234-5 Building (see Section 1.2). One month later, sample laboratory operations went to two-shift, 7-day per week coverage to accommodate the production increases at the Hanford Site. In May, two empty hoods in laboratory room 139 were gloved and placed in use. By October, the 234-5 analytical laboratory was doing 3,550 determinations per month, on approximately 692 samples.²⁸¹ In July, ER-2727 was initiated to design laboratory revisions to provide a 2,000- to 3,000-square-foot addition to the 234-5 Building to accommodate office and change house facilities. In September, the project became D.O. 100350 and changed scope to provide for a 3,700 square foot Development Laboratory annex to the PFP structure. The effort to build a developmental laboratory annex onto the 234-5 Building was

abandoned a short time later. A smaller annex (1,800 square feet) was later built in Project CA-750 in 1958 (see Section 7.8).²⁸³

Throughout 1952, developmental laboratory experiments to substitute Freon^Y 12 (CCl_2F_2 - dichloro-difluoro methane) for the troublesome anhydrous HF used in Task II of the RMA Line (see Section 5.3) remained inconclusive, and the hydrofluoric acid continued to be used.²⁸⁴ The use of filter papers and some stainless steel filters was investigated in the filter boats of Tasks I-II in an effort to reduce the frequency of repair work needed on the boats.²⁸⁵

Also in 1952, the "Los Alamos methods" for determining percentages of boron and carbon in plutonium metal were adopted at the PFP sample laboratory. At the same time, the TTA (thenoyl trifluoro acetone) extraction technique for recovering impurities from plutonium metal before spectrographic analysis was compared with the cupferron technique and the carrier distillation method then in use. In September, the TTA method was rejected because it offered "no significant advantages over present methods, and actually presents several undesirable disadvantages." Another investigation compared the new X-ray photometer technique for determining plutonium in metal castings with the older chemical assay methods.²⁸⁶ The new technique was adopted because of its speed and efficiency.

Serious contamination events in the 234-5 Building during 1952 included an explosion in a laboratory hood in Room 152 in February. A 4-liter bottle containing nitric acid and acetone wash solutions exploded while the hood door was slightly open, thus causing "gross floor and hood contamination." A small fire occurred in laboratory room 157 in August, and a contamination event during startup testing in laboratory room 179 (part of the plutonium metallurgy facilities) suspended operations there for 2 weeks.²⁸⁷

7.4 DEVELOPMENTAL LABORATORY SUPPORT AIMS AT KEY OPERATING PROBLEMS IN 1953

Throughout 1953, much effort in the PFP developmental laboratory was aimed at the corrosion problems experienced in Task II of the RMA Line (see Section 5.5). Tests using cerium as a stand-in for plutonium and substituting Freon-12 for "the corrosive HF" continued all year. In March, further trials began using CCl_4 vapor; similar tests with phosgene gas commenced in May. However, both test agents had their own drawbacks. Because both the CCl_4 and the phosgene produced plutonium trichloride, not plutonium trifluoride, they would add further steps to the process. Further, the phosgene was as corrosive as the HF at the elevated temperatures necessary in Task II. In July, according to G.E. Hanford Co., a study was undertaken of the overall impacts to the process of "routinely preparing PuF_3 instead of PuF_4 in Task II by fluorination with HF only [instead of HF and O_2]. This process would have the advantage that the process gas, containing no oxygen, should be less corrosive."²⁸⁸

A materials testing program focused on the Task II filter boats also was instituted to address the corrosion problem. These boats, constructed of

^Y Freon is a trademark of E.I. DuPont de Nemours and Co.

Hastelloy "C"²⁸⁹ with platinum liners, "required extensive maintenance" in 1953. This, along with expected production increases, "stimulated efforts to produce a new design embodying a twofold large filter cake capacity and a threefold large filtering area." Mock-ups were constructed early in the year, and much investigation of special alloys and manufacturing techniques was conducted. Eventually, a base metal boat clad with a precious metal lining was selected, and temperature studies were undertaken to further reduce corrosion.²⁸⁹

At the same time, experiments were undertaken in some completely new and different types of reduction operations. The electrolytic reduction of plutonium halides to plutonium metal from molten salt baths was pursued in the 234-5 laboratory, using cerium halides in place of plutonium. The work (which would be perfected later at Los Alamos) was hampered by equipment corrosion, which was reported as a "major problem."²⁹⁰ Other non-standard reduction techniques also were tested, but by year's end the contractor reported that such attempts were "proceeding poorly."²⁹¹

Developmental laboratory experiments in purification (Task I) aimed at the direct precipitation of Pu(IV) oxalate from REDOX 3BP solutions intensified throughout 1953 in support of Project CG-549. In February, changes were made in peroxide addition procedures in the Pu(IV) oxalate precipitation step in the laboratory, and in the Pu(IV) oxalate drying cycle. Higher temperatures became routine in the Pu(IV) oxalate strike in April, thus shortening the filtering time. By June, knowledge had progressed to the point that REDOX product material could be processed on a streamlined basis as standard practice in the 231-Z Building (see Section 1.2). At the same time, tests began in the direct precipitation of Pu(IV) fluoride by adding concentrated hydrofluoric acid to 231-Z Building product solution, "as a simple means of preparing material suitable for reduction purposes." New reactor vessels being designed for Task I were rescoped in December to change from steam to induction heating and from water to Freon cooling.²⁹²

Other developmental laboratory work during 1953 focused on improving photometric techniques for determining plutonium in metal yields, and on waste recovery methods and support to RECUPLEX development (see Section 9.2). Studies were undertaken to improve the accuracy of gamma scintillation assay and beta counts performed on plutonium samples. Sample laboratory activity increased after March, when the 231-Z process control laboratory closed and sent its work to the PFP analytical laboratory (see Section 1.2). The new plutonium metallurgy laboratory in the 234-5 Building officially began "hot" operations in the spring (although testing with hot materials had been underway since late 1952). The new laboratory studied the phase transformations of pure plutonium metal and of various plutonium-gallium alloys, and conducted tensile tests of plutonium metal specimens fabricated via different techniques. However, the year's main work in the plutonium metallurgy laboratory involved corrosion trials of several steel alloys for possible use in Task III of the RMA Line. Trials with various alloys sought

²⁸⁹ Hastelloy "C" is a trademark of Society National Bank. It contains nickel, chromium, molybdenum, and iron, with traces of other elements.

improved performance over that offered by Croloy 5^x, the mild steel used in the reduction "bombs" (vessels) in the RG Line.²⁹³

Laboratory contamination events in 1953 included a November contamination injury sustained by an operator working (via gloves) in Hood 14 in the plutonium metallurgy facility. The following month, an explosion in another laboratory hood resulted in a Class I radiation incident. According to G.E. Hanford Co., the explosion caused "widespread plutonium contamination" involving five employees.²⁹⁴

7.5 SUPPORT TO PROJECTS CG-549 and CG-551 DOMINATE 1954 LABORATORY ACTIVITIES

Throughout 1954, design and process development support to Projects CG-549 and CG-551 in the RMA Line (see Section 5.7) dominated laboratory activities at the PFP. A prototype Task I hood was fabricated and moved into the developmental laboratory by summer, to test new components of the reactor vessel used in the Pu(IV) oxalate process. Various methods of chilling and heating the reactor contents were tested. The tests resulted in a major project scope change from using an agitator to using an air sparging system for agitating the product material. Another scope change substituted an "air-lift, in place of the [planned] propeller-type recirculating pump," in the Task I precipitation vessel. By year's end, with the aid of a new drum-type filter, process chemists found that "as hoped, the filter cake can be dried on the filter under an infrared heater." Simultaneous experiments in the direct precipitation of Pu(IV) fluoride produced "poor results," and the step-wise process of precipitating Pu(IV) oxalate to form PuO₂ (plutonium dioxide) and then hydrofluorinating to achieve PuF₄ continued to be the method used.²⁹⁵

In May, a new Task II prototype hood also was moved into the developmental laboratory to begin testing. It employed a vertical furnace constructed of Elgiloy,^y an alloy primarily composed of cobalt, chrome, and stainless steel, to resist the highly corrosive atmosphere of Task II processes, and operated in a continuous calcination/fluorination flow. Pu(IV) oxalate was fed into the process via screw conveyors, vibrated, and dried (calcined) to PuO₂ powder, and fluorinated by passing HF gas through fine copper turnings sintered into disks lining the filter boats and holding the powder. In November, testing of this continuous calcination/hydrofluorination process using cerium as a stand-in for plutonium proved successful, as did laboratory testing of new Task III equipment in August (see Section 5.7).²⁹⁶ In terms of basic research for Task III, elimination of the standard reduction method in favor of the newer electrodeposition method was examined only to a limited extent. Early in the year, tests at PFP were halted until sturdy cell

^x Croloy 5 is a trademark of Babcock and Wilcox. It is composed of approximately 93 percent iron and 4 to 6 percent chrome, with trace amounts of carbon, manganese, silicon, and molybdenum.

^y Elgiloy is a trademark of the Elgiloy Limited Partnership of Elgin, Illinois. It is composed of 40 percent cobalt, 20 percent chrome, about 16 percent stainless steel, 15 percent nickel, 7 percent molybdenum, 2 percent manganese, and traces of beryllium and other metals.

facilities were available in the Hanford Site's 325 Radiochemistry Building. Likewise, studies of methods for preparing PuF_4 by the reaction between plutonium oxide and ammonium bifluoride, although promising, were not extended past the early months of the year, because of more pressing production needs.²⁹⁷

During 1954 the PFP developmental laboratory also conducted experiments in support of Task IV (casting).²⁹⁸ In Task V (machining), investigations went forward to find safer and more accurate methods of remote, automatic operations. Vertical spindle lathes and commercial "tracers" attached to vertical lathes were tested, along with substituting carbon dioxide for helium in Task V processes. Task VII (coating) experiments early in the year focused on the solubility of nickel in molten carbon-magnesium eutectic, and trials with "continuous coating" techniques proved somewhat successful. The plutonium metallurgy laboratory in the 234-5 Building concentrated on tensile tests of plutonium-gallium alloys, metallographic examinations of the microstructure of these alloys, and stress rupture trials and thermal cycling tests on reduction vessels.²⁹⁹

In May 1954, plutonium metallurgy laboratory operations were marred by a Class I Radiation Incident. Attempts to dissolve plutonium metal turnings in nitric acid "resulted in a violent reaction and a flash fire...The resultant pressure rise inside the gloved hood forced hood air and dust through small holes...producing widespread contamination of Room 179." Two persons received skin contamination and high plutonium activity in the air was experienced.³⁰⁰

7.6 OPERATIONAL SUPPORT TESTS CONTINUE TO CONSUME LABORATORY EFFORTS IN MID-1950's

Almost as soon as Project CG-549 and Project CG-551 equipment was installed in the RMA Line in early 1955 (see Sections 5.8 and 2.10), the PFP developmental laboratory became involved in efforts to devise process improvements. In the summer of 1955, to solve operating problems in the new Task II equipment and to eliminate the batch-size issue as an operating constraint, a prototype continuous reactor was tested in the developmental laboratory. By year's end, this spiral-feeder, continuous fluorination, prototype furnace had demonstrated the feasibility of continuous plutonium oxalate precipitation, filtration, and calcination, using two passes of the oxalate through the drier-calciner portion of the mechanism.³⁰¹

At nearly the same time, developmental laboratory experiments got under way to develop a "simplified" reduction process (Task III). A "continuous or semi-continuous process" was desired, as well as "equipment that won't need frequent replacement." Still looking to completely change the problematic Task III, HW scientists also fabricated and emplaced a Teflon² cell for plutonium electrodeposition experiments in HW's 325 Building. An electrodeposition technique that, according to the contractor, produced "very uniform, thin plutonium foils" was developed. The plutonium then was "isolated and decontaminated from inactive impurities, fission products, and

² Teflon is a trademark of E.I. DuPont de Nemours and Company.

other TRU [transuranic] elements." However, electrodeposition was not adopted on a production scale at the Hanford Site.³⁰²

Also in 1955, the PFP developmental laboratory investigated new stripping techniques for reject plutonium pieces. Ultrasonic fields were applied while dissolving rejects in the standard boiling nitric acid, as well as in commercial solvents. In all cases, the ultrasonic field shortened the dissolution time while preserving the integrity of the shape. The sample laboratory studied a new combination extraction-spectrographic method for measuring gallium in plutonium metal, but found the error rate too high and returned to the older extraction method. In October, a new spectrographic laboratory was completed and activated in the Hanford Site's 325 Radiochemistry Building, making analysis of plutonium metal samples for 30 elements routine and practical. At the same time, the nuclear safety requirements of the 234-5 control laboratory were scrutinized and tightened. In the PFP metallurgy laboratory, experiments focused on casting (Task IV). For these trials, the laboratory requested the fabrication of large pouring crucibles and liners, as well as special graphite molds coated with magnesia and sodium metasilicate, from the PFP crucible shop.³⁰³

PFP laboratory contamination events in 1955 including a Class I incident in August in which a 234-5 laboratory assistant received plutonium deposition from a piece of broken, contaminated glass. October witnessed two more Class I incidents, both in the analytical laboratory. In one case, plutonium spread from an analysis room through several rooms and corridors and into the women's locker room. In the other, a worker received an internal deposition of plutonium from improperly handling process samples. Floor contamination of the laboratory area also occurred. In September, a plutonium turnings fire occurred in the metallurgy laboratory (Room 179).³⁰⁴

During 1956, the most important aspects of A-Line operations investigated for improvement in the PFP developmental laboratory was Task I, where, in January, a "successful process demonstration was made of a continuously operated purification step. The precipitate was successfully hydrofluorinated and reduced in good yield." In the following months, several more trials were conducted. In each 1-hour run, 1 kilogram of plutonium oxalate material made two passes through the 3-foot-long calciner section of the prototype laboratory continuous calciner. According to the contractor, an "easily filtered, granular material with physical and chemical properties acceptable for hydrofluorination" was obtained. Tests later in the spring identified Dynel SD-9 as the filter cloth best able to withstand contact with the process solutions, and defined the conditions necessary for continuously "killing" the oxalate filtrates with potassium permanganate. That July, a prototype vessel similar to the laboratory model was installed in an RMA Line Task I hood and demonstrated successfully in large-scale equipment (see Section 5.9). Soon afterward, funds were allocated for Project CG-691, Continuous Task I-Task II in the RMA Line. That summer, scope changes were made to the Task I-II equipment design, incorporating continuous treatment of Task I filtrate and storage of Task II fluoride in the existing Task III storage hoods.³⁰⁵ Corrosion studies involving A-Line process equipment also remained an important laboratory activity.³⁰⁶

Throughout 1956, experiments continued in the PFP developmental laboratory in the continuous precipitation of Pu(IV) fluoride. In January, a

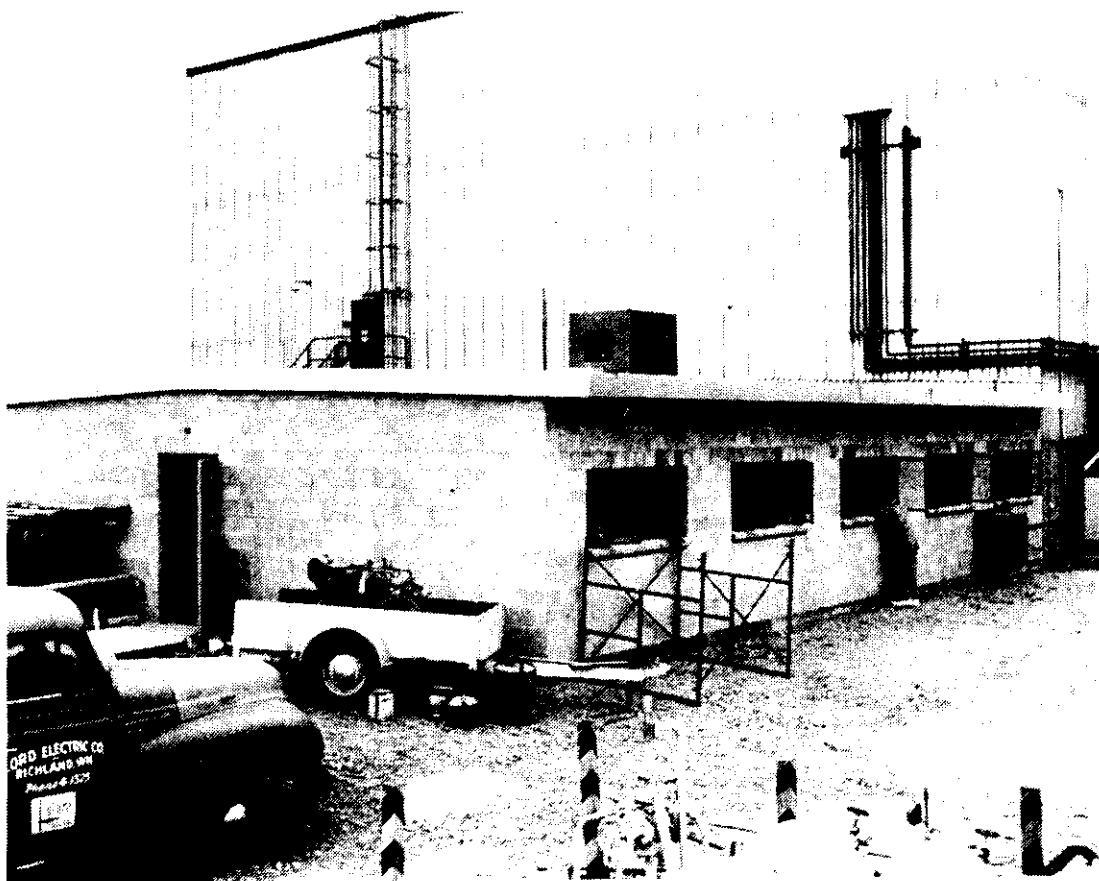
Throughout 1956, experiments continued in the PFP developmental laboratory in the continuous precipitation of Pu(IV) fluoride. In January, a new plutonium tetrafluoride precipitation process produced "readily filterable slurries with [low] waste losses." Metal impurities also were low, and washing the precipitate cakes with methyl alcohol "produced dry, powdery fluorides." In February, the laboratory tested drying the plutonium fluoride powder in argon and in Freon-12. However, the same month, the decision was made to discontinue precipitation of Pu(IV) fluoride "in favor of a continuous precipitation of the trifluoride. This process offers lower recycle and ease of drying." At the same time, a series of experiments in the production of "high-purity plutonium" was undertaken. The first reduction of plutonium fluoride in the program produced a "violent reduction reaction, upsetting the vessel and producing a loud report." By April, two laboratory-scale runs using hydrofluoric acid had "demonstrated the feasibility of continuous PuF₃ precipitation, and a readily filterable slurry was produced." Two months later, the high-purity plutonium program had successfully reduced Pu(IV) to Pu(III) using hydroxylamine hydrochloride and sulfamic acid.³⁰⁶

In terms of space and projects, studies were begun in 1956 on ER-2795, Office Annex to 234-5 Development and Metallurgy Laboratories. The undertaking was approved in late 1957 as Project CA-750, but with the metallurgy portion deleted because the metallurgy laboratory was moving to the 231-Z Building (see Section 1.5). During 1957 and 1958, Project CA-750 constructed an 1,800-square foot, concrete block, 1-story office annex for the developmental laboratory on the southwest corner of the 234-5 Building.³⁰⁷ In late 1958, as part of Project CGC-826, Vacuum System Improvements in the 234-5 Building, connection and service points to the analytical and developmental laboratories were made with a new, more robust, building-wide vacuum system. In the same project, completed in 1959, a supplemental vacuum system was installed for the two laboratories.³⁰⁸ (See Figure 7-1.)

From 1958 through 1960, the development laboratory at PFP (as well as the special cell in HW's 325 Building) continued to investigate the electrodeposition of plutonium salts as a practical alternative to standard reduction methods. Efforts to design reusable ceramic liners for reduction vessels continued throughout the period. At the same time, experiments were carried out to develop "a reduction step using plutonium trichloride instead of plutonium tetrafluoride.. [to] reduce the neutron radiation associated with plutonium fluoride." The continuous chlorination of plutonium dioxide to plutonium trichloride was successfully demonstrated in "large-scale equipment" in 1959. The process showed enough promise that experiments continued. During 1959, the 234-5 Building developmental laboratory began supplying high-purity plutonium nitrate to the Canadian AEC at Chalk River, Ontario, for experimental purposes.³⁰⁹ Other intense efforts in the PFP developmental laboratory during the mid and late 1950's were devoted to scrap recovery and RECUPLEX process improvement trials (see Sections 8.0 and 9.0).³¹⁰

In March 1959, two serious contamination incidents occurred in the PFP laboratories. In one incident, a flammable oil overheated and caught fire in a plutonium processing hood. In the other, according to a contractor report, an explosion in a hood during plutonium machining "generally contaminated the entire room."³¹¹

Figure 7-1. PFP Developmental Laboratory Office Annex Construction, October 1958.



7.7 PFP LABORATORIES EXPAND/UPGRADE DURING 1960's TO SUPPORT WEAPONS AND NON-DEFENSE PROCESSES

Developmental support and intense analytical activity characterized PFP laboratory operations during the 1960's. Throughout 1961, the developmental laboratory concentrated on ways to improve Task IV (Casting) operations in the RMA Line. According to a March 1961 contractor report: "Under study" at the time were "the chip stream, critical mass, double melting, continuous melting, and rejects. These five areas hold the best promise of improved performance." After August of that year, substantial improvements were noted.³¹² Efforts to improve methods in the continuous dissolution of S&C residues in RECUPLEX also went forward during 1961, as did extractant studies for the 242-Z Waste Treatment Facility that was under construction in the PFP complex (see Section 11.1). Additional work was directed at finding practical techniques for removing plutonium from 234-5 Building sump water (see Section 15.1).³¹³

During 1962 and early 1963, the blending problem caused by "a sharp rise in the Pu-240 isotopic content of the feed" received at the 234-5 Building from the REDOX and PUREX Plants wreaked havoc with process line procedures. This off-standard feed and the subsequent blending imposed additional analytical requirements that, along with the crush of other work in the building, drove the number of laboratory analyses to a record high in April 1963. A year later, the number of analyses set a new monthly record; that record was broken in December 1964. In 1965, defense cutbacks lowered the number of monthly determinations in the analytical laboratory to about half what they had been during the record-setting months.³¹⁴ To support the crunch of work, the laboratory received much new equipment in 1963 and 1967, including an oxygen gas analyzer in 1963, a new induction furnace in 1965, and master-slave manipulators in 1967.³¹⁵

Throughout the early 1960's, both analytical and developmental laboratory work also focused on support to non-defense work (see Section 13.0). The developmental laboratory also expended intense effort on PRF development (see Section 12.0). One area of PRF work that proved difficult was finding alternate methods of recovering plutonium from fabrication oil, a combination of lard oil used in the machining of plutonium metal parts, and the CCl_4 used to degrease the parts. The oil was especially difficult to filter and strip, and its processing increased the volume of hazardous chloride waste, which is difficult to dispose of. A recovery process had taken place in RECUPLEX, but was stopped after the RECUPLEX accident and closure. Also, graphite solids in the fabrication oil needed to be separated and processed by incineration. Early experimental work in processing chloride waste was done in Room 161 of the plutonium chemistry laboratory, Hoods 42 and 43, but it was discontinued in 1966 because the equipment corroded. In October 1967, Hood 60 in Room 179-B of the developmental laboratory was equipped with a Teflon floor and Kynar^{aa} coating and piping. Other glass equipment, and the stainless steel valving, piping and supports were painted with chloride-resistant Kel-F paint. The prototype laboratory process mixed the oil with extra CCl_4 and nitric-HF acid, then filtered for solids removal, then sent the resultant solution for reprocessing through solvent extraction columns in the PRF. Nevertheless, the process remained plagued by problems for many years. By 1975, efforts to recover plutonium from fabrication oil had stopped. In December of that year, tasks and procedures were completed in connection with loading this oil onto an absorbent substrate for burial as retrievable transuranic waste in the Hanford Site's solid waste burial grounds.³¹⁶

With the 232-Z Incinerator due to start up (see Sections 10.3 and 10.4), the chemistry laboratory also worked to perfect methods to recover plutonium from incinerator ash. Studies in the recovery of plutonium and Am-241 from aqueous waste streams being processed through the new 242-Z Waste Treatment facility consumed additional laboratory time, as did investigations of corrosion and the formation of hydrides in plutonium metal stored in plastic-lined containers. In support of non-defense work (see Section 13.1), a preparation facility for "special plutonium compounds" was proposed for Room 179-B of the developmental laboratory in 1964, but was not built.³¹⁷

^{aa} Kynar is a trademark of ELF Atchem North America Inc.

During 1962-1965, electrowinning studies in the reduction of PuCl_3 (plutonium trichloride) to plutonium metal, thus eliminating standard reduction with calcium and the subsequent need to recover plutonium from S&C waste produced, were pursued on a small scale in the plutonium chemistry laboratory. Reduction took place in a molten chloride salt bath inside a small glass cell with a tantalum liner. Ceramic cells also were tried. However, the plutonium metal product was "unconsolidated" (having the consistency of BBs rather than a full button), because of oxide formation in the electrolyte. The greatest difficulties concerned cell corrosion, and entrainment of off-gas solids from the electrolyte in the filters. For these reasons, electrowinning research was discontinued in the PFP developmental laboratory in early 1965. That year, studies in the conversion of U-233 in nitrate form to oxide and metallic form also were pursued briefly.³¹⁸

The 1963-1964 period of intense production and analytical laboratory activity was accompanied by some serious contamination incidents in the PFP laboratories. One incident occurred in June 1963, when a chemical analyst's face was sprayed with a dilute solution of plutonium nitrate from a sample vial that had pressurized. One year later, a rapid reaction occurred in a hood in Room 149 of the analytical laboratory when a package of unoxidized plutonium metal chips was added to a laboratory dissolver. The hood was pressurized and contamination spread through Room 149 and portions of the adjacent laboratory areas. Some of the contamination was released via gravity vents to the 234-5 Building roof and the surrounding ground area.³¹⁹

The late 1960's witnessed many developmental efforts in the PFP chemistry laboratory in support of both defense and non-defense work. Plutonium metal fire studies were conducted, and evaluations of methods to convert neptunium nitrate to neptunium oxide were undertaken for a research customer. Mold stack materials for the fabrication of fuel ingots for the Zero Power Plutonium Reactor were tested (see Section 13.2), as were methods for the recovery of rhodium, palladium, and technetium from PUREX supernatant waste. Research was pursued into the experimental fabrication of lithium aluminate pellets for special tritium-production trials in the Hanford Site's N Reactor, and tests were run "to determine capabilities for processing Pu-238 nitrate to the metal." Investigations were made into the radiolytic decomposition of plutonium nitrate solutions.³²⁰

In support of scrap recovery operations, the 234-5 chemistry laboratory during 1965-1966 sought to perfect a method for burning polystyrene cubes (PuO_2 powder mixed with liquid polystyrene and a solidifying agent) for plutonium recovery. The cubes, about 2 inches on all sides, were manufactured for physics experiments at the Hanford Site's 209-E Critical Mass Laboratory, which began operations in 1961. By 1965, a significant number of the cubes was accumulating. However, an early prototype burning hood in the 234-5 Building experienced a "potentially hazardous occurrence," according to the contractor, when smoke and fire emanated from a HEPA filter on the unit in June 1966. The prototype unit was shut down while laboratory efforts continued. In early 1968, a pilot burning campaign took place in Hood 227 in the PRF, but was discontinued quickly. Restart took place in March 1969. Eventually, the laboratory developed a two-step process involving distillation followed by burning. In January 1973, a new burning facility was started up in the PRF (see Section 12.3).³²¹ During 1967, the developmental laboratory worked to perfect a "single contact" method for dissolving plutonium-bearing

ash from the 232-Z Incinerator, before processing the ash in the PRF. However, a workable single-contact method was not found, and the ash continued to need multiple dissolutions.³²²

Studies in the molten salt reduction of plutonium dioxide to plutonium metal, bypassing the traditional Task III reduction process, were taken up once again in the PFP developmental laboratory in the late 1960's. The reasons for these studies concerned the desire to eliminate HF gas, a problem since the early 1950's, from the reduction process and to reduce fluoride-bearing waste streams. According to laboratory personnel, the HF gas corroded equipment and reacted with the fluorine in the plutonium fluoride powder used in the ordinary Task III process, releasing neutrons and causing personnel exposure. Also, the recovery costs associated with the traditional Task III waste streams added significantly to the cost of plutonium metal production. The new pyrochemical process explored in the PFP chemistry laboratory in the late 1960's eliminated magnesium salt from the flux, and produced the reduction using lithium chloride, sodium chloride, potassium chloride, and sodium fluoride. Still, the issue of chloride waste remained, and operations in the RMC Line continued to use the traditional Task III processing method.³²³

In the PFP analytical laboratory, a small ventilation system upgrade modification was installed in Project CAC-171, in 1966. During 1967, the PFP analytical laboratory worked intensively to develop a procedure based on alpha energy analysis to measure the plutonium content of the aqueous waste from the PRF. Tiny solids in this waste were "holding up" plutonium that was not being measured via the standard techniques (see Section 12.3). During the summer, both the analytical and the developmental laboratories became involved in verifying the new method. By August, the new procedure had been validated and was finding two to three times as much plutonium as the standard method.³²⁴

During these years, few serious contamination events occurred. In November 1966, a small fire caused by nitric acid on paper ignited in Room 143 of the analytical laboratory. In August 1967, a contamination spread occurred in Rooms 148, 152, and 153 and a corridor in the analytical laboratory, when a water line made of Tygon^{bb} tubing from a condenser inside a glove box ruptured. Contamination was washed out of the hood and even seeped onto the ground outside the 234-5 Building.³²⁵

In 1968, a small project was undertaken to emplace specialized equipment in a glove box in Room 145 of the PFP analytical laboratory to evaluate and perform quality assurance (QA) testing on plutonium oxides and mixed oxide (MOX - usually consisting of plutonium and uranium) prepared for commercial and experimental reactor use. Among the equipment procured for Project CGA-350, Powder Evaluation Facility, was a 10-ton powder compacting press, a sintering furnace, sieves, and ball milling equipment.³²⁶

^{bb} Tygon is a registered trademark of the Norton Company.

7.8 WASTE STUDIES, PUREX SUPPORT, AND PREPARATIONS FOR STAND-ALONE STATUS CONSUME 1970's

Throughout the late 1960's and early 1970's, much time and effort in the 234-5 Building developmental laboratory was devoted to studies in PUREX process chemistry, because the PUREX laboratory performed only analysis work. Then, from 1977 through 1979, the PFP developmental laboratory worked intensively to determine the optimal way for plutonium oxide conversion to take place in PUREX's N Cell. DOE Site managers had decided to D&D the PFP (see Section 3.5); therefore they wanted all plutonium processing activities consolidated in the 200 East Area near or in the PUREX Plant. During 1978 to 1983, a major undertaking installed a PUREX Oxide Conversion Facility as Project B-175. A central question in planning for the N Cell oxide conversion facility involved whether to use the standard oxalate precipitation method to convert plutonium nitrate to plutonium oxide or to use a newer method under study in the PFP laboratory. Known as "direct denitration," the new method used a horizontal bed screw calciner and co-calcined plutonium nitrate with calcium nitrate. According to laboratory reports, the new system was advantageous in terms of "ease of operation...simplicity of design...and adaptability to shielded remote operation." However, product characteristics included high impurity levels and a "sticky" powder. At that time, further developmental studies were not funded and the traditional oxalate system was emplaced in N Cell.³²⁷ (See Figures 7-2 and 7-3.)

Beginning in the early and mid-1970's, work in the PFP developmental laboratory focused increasingly on finding methods to characterize, minimize, and clean up waste. In 1970, a horizontal, in-bed combustion calciner was emplaced in a glove box in Room 183-A of the developmental laboratory to test methods of direct denitration of liquid, high-salt waste to oxides. Experiments with this calciner were part of the overall PFP effort to reduce the discharges of liquid waste to cribs during those years (see Section 15.3). Experimental operation was not highly successful. Other methods of controlling Z Plant liquid waste discharges were pursued in Project HCP-669 (see Section 15.3).³²⁸ In 1971, waste management practices in the analytical laboratory were upgraded when a plutonium waste concentrator was emplaced. The unit concentrated laboratory waste and drove off chloride ions before the concentrated waste was fed to PRF recovery systems.³²⁹ (See Figures 7-4 and 7-5.)

The PFP developmental laboratory supported the Z-9 crib soil mining and leaching plans from 1973 through 1976 (see Section 15.2), especially concentrating on all of the flow sheet revisions that were undertaken in those years as varying soil data and the changing availability of PRF solutions caused multiple project revisions. The analytical laboratory also worked to reconcile differing NDA results from Z-9 crib soil that were obtained using the state-of-the-art segmented gamma scan assay system (SGSAS) and a simpler system based on a sodium iodide gamma detector. Eventually, the barium-133 (Ba-133) source within the SGSAS equipment was relocated to increase the count rate, and the two systems came into closer alignment.³³⁰

Figure 7-2. Room 179, PFP Developmental Laboratory, August 1971.

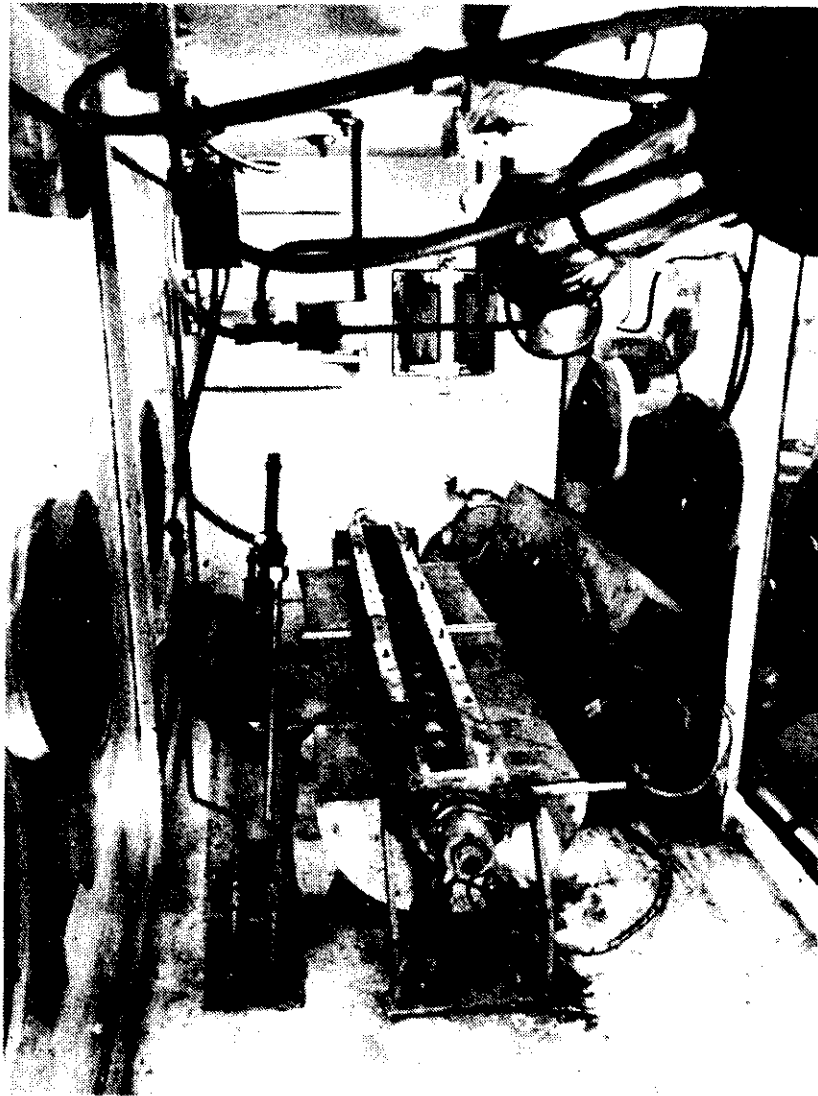


Figure 7-3. Experimental Screw Calciner for Direct Denitration of Plutonium Nitrate, PFP Developmental Laboratory, 1978.

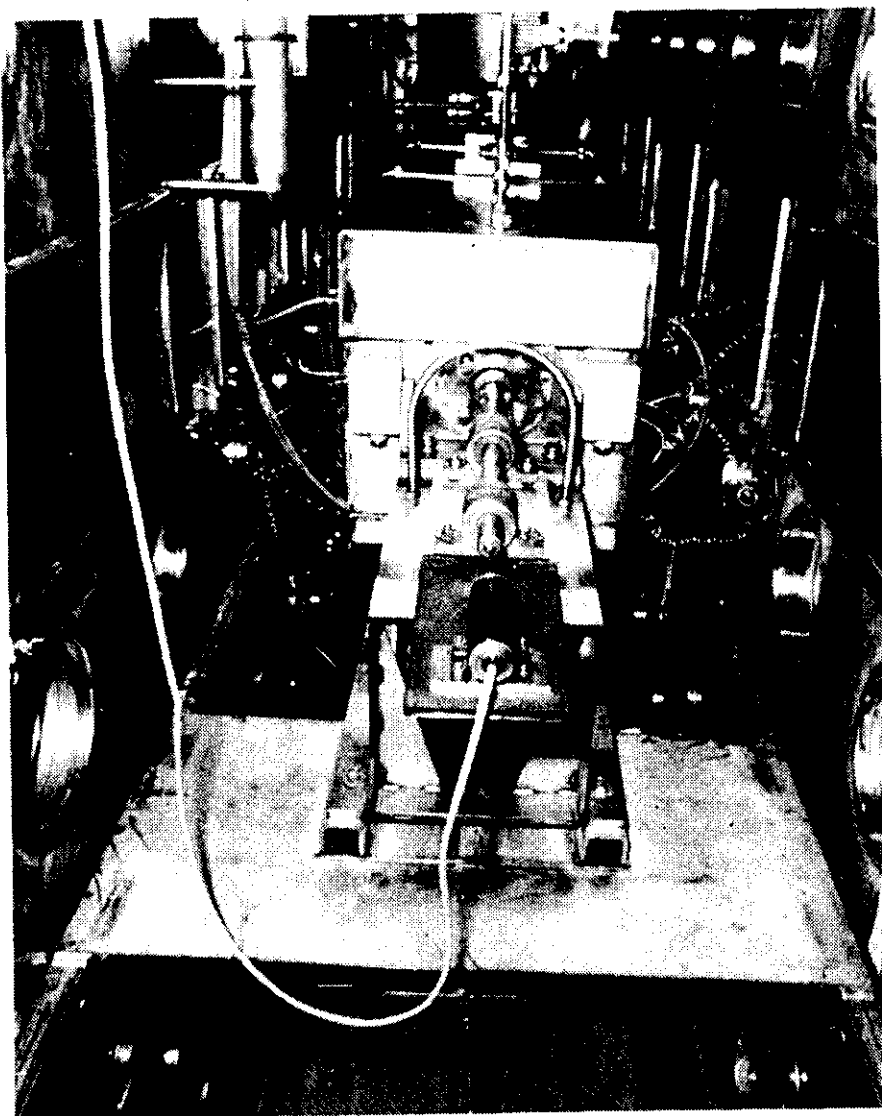
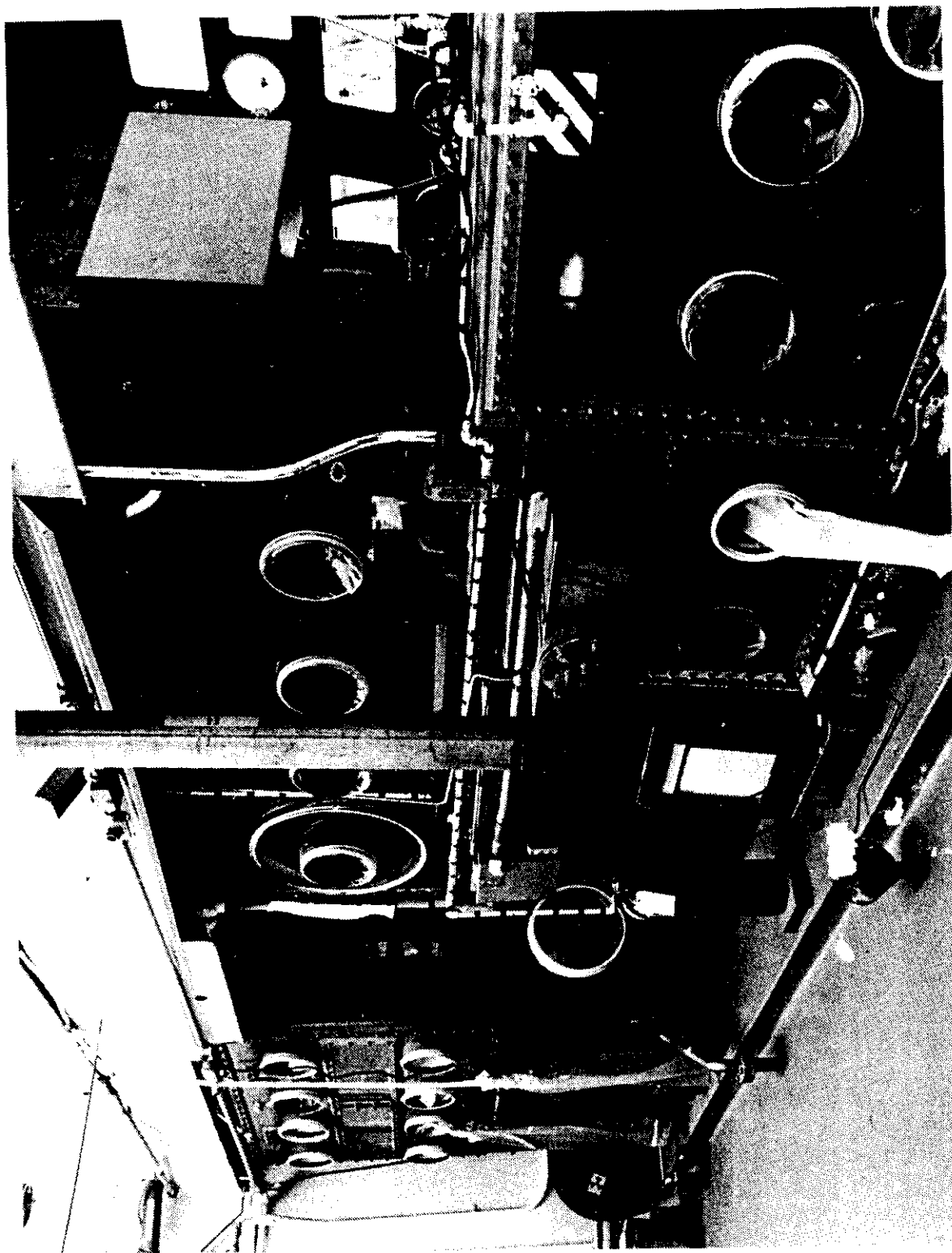


Figure 7-4. Hood 179-9 in PFP Developmental Laboratory, August 1971.



Figure 7-5. Room 179, PFP Developmental laboratory, August 1971.



During 1975 to 1977, the PFP developmental laboratory experimented with techniques for solidifying high- and low-salt aqueous waste at Z Plant (see Section 15.4). Studies evaluated various waste drying agents, a prototype drum drier and other equipment, temperature levels, the formation of gels and solids within the process, and evaluated concerns associated with the generation of potentially explosive "red oil" reactions^{cc} in the process.³³¹

Also during the mid-1970's, the PFP chemistry laboratory also established quality verification plans for the large amounts of plutonium oxides being produced for commercial customers and other contractors (see Section 13.3). When some oxides produced in the RMA Line during 1974 and 1975 tested out of specification (see Section 5.13), the laboratory sought to "develop stable oxides" and find methods of sintering aged oxides.³³²

The same laboratory, by this time also known as the Chemical Technology Laboratory, also worked to find alternative diluents for PRF operations. Throughout the mid-1970's, as planning went forward for the PRF cleanout and floor cleanup campaign (see Section 12.4), a diluent other than CCl_4 was sought for the facility's TBP, because the CCl_4 degraded quickly and resulted in organic waste discharges larger than desirable. Tests in the PFP chemistry laboratory quickly narrowed the choices of possible replacement diluents to 1,2,4-trichlorobenzene (TCB) and tetrachloroethylene (TCE). The two diluents were tested separately, and as a blend of 70-percent TCB and 30-percent TCE. However, according to a laboratory report, the replacements were "less than perfect." TCE was rejected because it was difficult to strip plutonium from the extractant using this compound, and TCB was rejected because of its high freezing temperature (10 °C). Studies also were conducted to use organic phase ion exchange to remove di-n-butyl phosphoric acid (HDBP) contaminant from the PRF organic solvent. Alternative Pu(IV) flowsheets were tested, as were changes to the plutonium-uranium partitioning flowsheet. However, no major changes were made in the PRF solvents (see Sections 12.3 and 12.4).³³³

Physical laboratory improvements during these years included Project HCP-640, which emplaced an automatic wet-pipe sprinkler system, and an associated electrical fire alarm system, for the PFP analytical laboratory and peripheral areas during 1969 and 1970.³³⁴ In 1971, open-faced hoods in the PFP laboratories were fitted with automatic sprinkler systems and collection facilities for sprinkler water.³³⁵ During 1970, a new glove box, designated Hood 6, was installed in Room 139 of the analytical laboratory to perform quality verification tests on the non-defense plutonium oxide products. In mid-1976, a computerized, laser communications link was established between the 234-5 Building and the 222-S Laboratory to acquire and transmit NDA spectral data for analysis.³³⁶ During 1974, several plastic panels in laboratory glove boxes were replaced with fire-resistant, Lexan glass windows.³³⁷ New procedures were adopted in laboratory quality control in 1969.³³⁸

^{cc} "Red oil" is sometimes produced when mixtures of nitric acid, TBP, and their degradation products react exothermically and rapidly.

In late 1976, a plan was designed to equip Rooms 179-B, 183-A, and 186 in the PFP developmental laboratory with new hoods, glove boxes, laboratory benches, and cabinets to support work in "actinide research and the spread of radionuclides in the environment." Space for this research was not available in the 222-S Laboratory, and "because of increased safeguard and security requirements," the work was directed to the 234-5 Building developmental laboratory. Groundwater migration of radionuclides, geochemistry work, and other studies of soils and sediments was included in the new tasks. Rooms 183, 184, 186, and 187 actually were modified, but Room 179-B was not upgraded at this time. Additions to laboratory equipment included new criticality drains, fire detection and suppression systems for the glove boxes and hoods, and constant air monitors (CAMs) and fixed filters near the new work stations. An automatic data processing (ADP) system also was proposed for the PFP analytical laboratory at this time.³³⁹ In February 1977, installation of replacement piping for the vacuum system for analytical laboratory Room 156 was completed.³⁴⁰

Off-normal incidents in the 234-5 Building laboratories during these years included an event in October 1975, when criticality prevention specifications were violated in two rooms managed by the PFP analytical laboratory in the 234-5 Building. Vault Room 192-A was being used, in part, to store sample sands from the Z-9 crib mining project (see Section 15.2). Room 197 was storing plutonium ash along with other materials. In both cases, storage specifications and criticality safety parameters were exceeded.³⁴¹ In January 1977, another violation of criticality specifications occurred in Room 152 of the analytical laboratory, when two 1-liter bottles of plutonium nitrate solution were found stored in a nonradioactive supply cabinet.³⁴²

A small engineering development laboratory (EDL) was emplaced in Room 202 of the PFP in the mid-1970s. The role of this facility was to design and test equipment, often in tandem with the 234-5 Building developmental laboratory, which developed chemical methods for operating the equipment. In 1978, a vacuum-powered floor cleanup system, known as the slurp system, for cleaning up the 236-Z facility floor (see Section 12.4) was developed and installed as a prototype in the PFP EDL. A simulated slurry was made for testing the system's vacuum requirement, solids settling rates, filtering capabilities, and organic removal capacity. The slurp system operated to physically vacuum batches of slurry from the PRF's floor, gravity-settle the larger solids, filter the smaller solids, and then interact with CCl_4 to remove entrained organics. The resultant liquid then could be processed through the solvent extraction system in the PRF.³⁴³

In 1978, as part of the DOE-ordered planning for deactivation of the PFP complex, it was decided that the 234-5 Building laboratories would remain in operation to support various missions. Among these missions would be the cleanout and processing of reactive scrap in the PFP facilities (planned to last through 1983), NDA for long-term storage of plutonium in the 2736-Z Vaults (see Sections 14.3 and 14.4), and many waste management missions including actinide effluents cleanup development, actinide waste and scrap stabilization and assay, low-level effluent and surveillance analyses, and off-gas hazards evaluation and reduction. However, the most important ongoing and future mission envisioned for the PFP laboratories was in process support and process development for the PUREX facility. As a result of the continued need for PFP laboratory facilities, two projects were undertaken in 1979 and

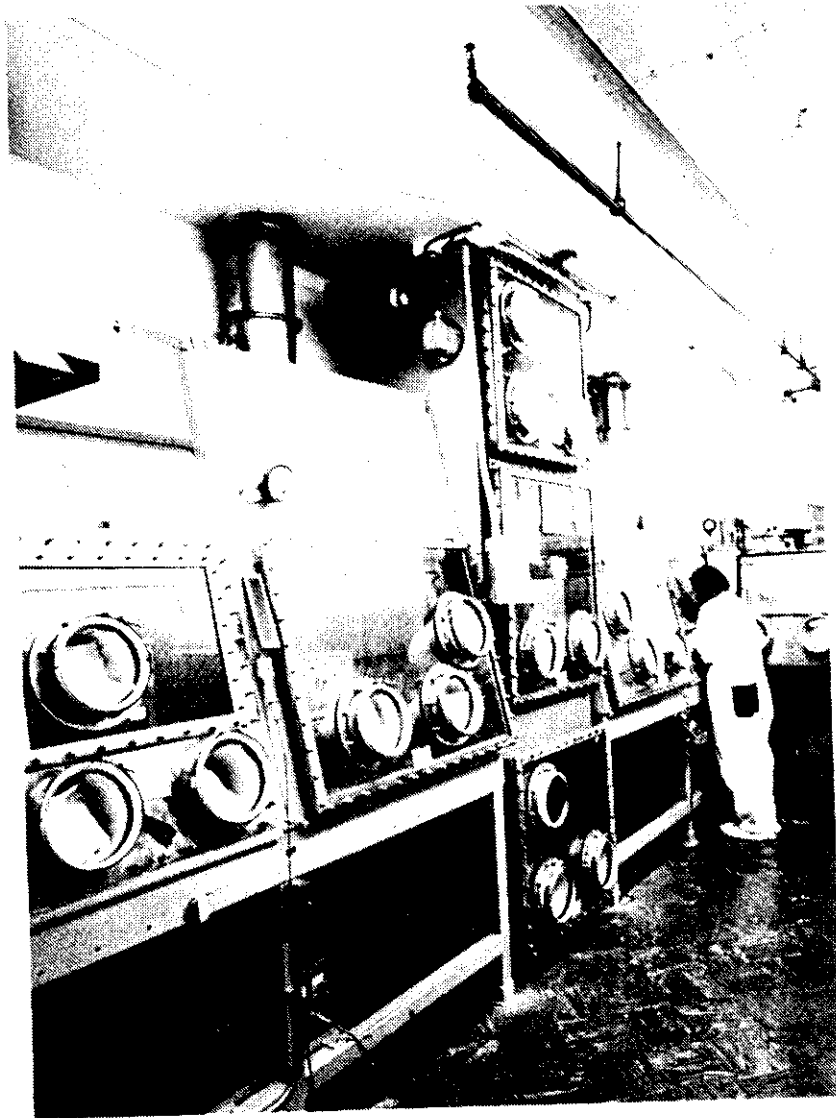
1980 to upgrade the laboratories and isolate them from larger 234-5 Building systems that would be shut down. Project B-252, Z Plant Laboratories Isolation, provided for new, separate ducts, dampers, and collection headers for the E-4 filters that served the laboratory glove boxes and hoods. Proposals to modify the E-3 filter system for laboratory rooms to achieve isolation from the building-wide E-3 system, to construct a new filter facility of proportional size to meet laboratory and support facility needs only (to replace the old 291-Z Building), as well as plans to emplace a new, double-encased, corrosion-resistant drain line from the laboratories to the 241-Z Sump were not funded at that time. Project B-185, Z Plant Laboratory Upgrade, emplaced modifications in Room 221-B of the 234-5 Building to provide space for equipment storage, system assembly, and calibrations for a portable NDA unit. As part of the larger Project B-184, Z Plant Fire Protection, hoods 4, 5, 6, 9, 10, and 12 in Laboratory Room 179 received water-based fire suppression systems.³⁴⁴

7.9 PFP LABORATORIES ACTIVE IN MULTIPLE PROCESS SUPPORT AND CLEANOUT MISSIONS IN 1980's

In 1984, further upgrades to the PFP analytical laboratory were ordered by the DOE, both to support the pending restart of the RMC Line (see Section 6.4), and to meet high demand from the PUREX Plant. As part of Project B-418, Z Plant Analytical Laboratory Upgrade, eight new glove boxes were installed in the laboratory. These and the existing glove boxes underwent a series of operability and leak tests and upgrades. In some cases, new CAMs, sprinkler heads, locking mechanisms, ventilation systems, and other safety devices were installed. A new fire suppression system also was installed in the open-face hoods and in ventilated work space in Room 156. This project installed a high-level plutonium nitrate standard preparation facility, a plutonium oxide dissolution facility, safety showers and eye wash facilities, new sinks and bench assemblies, motion detectors, and additional radiation shielding. It also created 530 additional square feet of laboratory space from existing space in the 234-5 Building.³⁴⁵ (See Figure 7-6.)

Through the late 1980's and into the early 1990's, the PFP laboratories worked to support the three PRF and RMC Line campaigns, as well as the modifications and upgrades associated with them (see Sections 6.4, 6.5, and 12.4). Laboratory procedures and sample and analysis plans were revised for these campaigns.³⁴⁶ Studies of red oil reactions were especially intensive in the 234-5 Building developmental laboratory. During the preparation and writing period for the PFP Environmental Impact Statement (see Sections 16.1 and 16.2), the 234-5 Building laboratories studied ways to analyze, verify, and stabilize the nearly 8,000 containers of plutonium-bearing scrap stored in the PFP complex. The laboratory's role in the final plutonium stabilization campaigns remains crucial. It is expected that the PFP laboratories will be deactivated once the stabilization campaigns are completed.

Figure 7-6. Room 139, PFP Analytical Laboratory, 1984.



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8.0 RECOVERY AND RECYCLE OF PLUTONIUM-BEARING SCRAP AT PFP

8.1 EARLIEST EFFORTS IN SCRAP RECOVERY

Nearly as soon as the RG Line began hot processing in the PFP in 1949 (see Section 4.2), efforts began to find ways of recycling and recovering plutonium from waste generated in building processes. Such studies were considered important because of the high economic value of plutonium and because they could result in better waste management practices. Techniques in the recovery of skulls (the hardened residues left by the molten casting of plutonium into metal) were investigated early. In October 1950, the AEC requested that the skull recovery experiments be accelerated and that an actual plant-scale process be designed. By December, Project C-422, Skull Recovery Facilities of Building 234-5, had been proposed. Recovery was to take place in Room 221 of the facility, inside Hood 32 of the RG Line, which would be moved from its then-current location and function for this purpose. (However, Hoods 40 and 41 actually became the skull recovery glove boxes.) Nitric and hydrofluoric acids would be used to dissolve the skulls in corrosion-resistant platinum or tantalum vessels. The recovered plutonium-bearing material then would be recycled into the 231-Z Building process.³⁴⁷

Many other waste types also received early attention at the 234-5 Building with an eye to recovery and recycling. Attempts were made to recycle 234-5 analytical laboratory waste, to decontaminate ("scavenge") crib waste, and to recover the purification (Task I) supernatant for evaporation and recycle into the 224 Concentration Building process. Other studies attempted to recover plutonium from "non-regular hold-up points in the wet chemistry." In March 1950, the "scow sweepings" from dry chemistry operations in Hood 8 (the HF step) that had accumulated since startup were removed to the 231-Z Building for treatment, then taken back to PFP and reduced into buttons. Although the buttons were very impure (high in copper, zinc, iron and nickel) they were stored for future recovery. In the summer, the practice began of collecting the lathe turnings from Hood 17 (the machining step) and recycling them into the casting operation at the rate of 250 grams per charge.³⁴⁸ At the end of 1950, Project M-802 to construct loading facilities in the PFP to move recycle material safely was begun.³⁴⁹

Throughout 1950, intensive research and experimentation was directed to recover S&C materials for recycle into the concentration process conducted in Buildings 224-B and 224-T. Slag was a solid residue left from the plutonium reduction operations and crucibles, made of magnesium oxide, were the forming structures in which the plutonium buttons were cast. The crucibles were broken into contaminated pieces when plutonium buttons were removed from them. A special investigative task aimed at the recovery of usable plutonium from these solids was undertaken in Room 41 of the 231-Z Building in the summer of 1949. By December, a contractor report detailed "early promise for success in solubilizing" the S&C material as well as the "highly gelatinous [silica] residue". By year's end, a preliminary recovery process was in use involving a hydrosulfite (or pyrosulfite) wash, followed by three leachings in hot nitric acid, a precipitation of plutonium hydroxide from an ammonium hydroxide-ammonium nitrate ($\text{NH}_4\text{OH}-\text{NH}_4\text{NO}_3$) solution, followed by filtering and dissolution of the precipitate in nitric acid, then extraction of the

plutonium from the leachings using a methyl isobutyl ketone (hexone) and aluminum nitrate mixture.³⁵⁰

In 1951 at PFP, the most important event concerning waste recycling operations and testing occurred in August when laboratory work aimed at coupling the REDOX end product and the bismuth phosphate product from the 224 Buildings to the 234-5 process, combined with ongoing efforts to generate a workable S&C recovery process and became the "RECUPLEX" process (see Section 9.1).³⁵¹ Other significant waste recovery studies and achievements at PFP in 1951 included the successful recycle of 234-5 purification supernatants, concentrated oxalate supernatants, and caustic scrubber solutions to the 224 Building process for plutonium recovery. This activity, along with recovery of laboratory waste in a special laboratory hood, proceeded on a routine basis beginning in February. Loading facilities to allow the transfer of recycled materials without spreading contamination were installed in the Task I area of the 234-5 Building in mid-1951.³⁵² By year's end, the Skull Recovery Facilities still were not finished.³⁵³

8.2 LABORATORY WASTE AND OTHER WASTE TARGETED IN 1952

The recycling of waste materials for plutonium recovery was intensified as an extremely important activity during 1952 at PFP. Beginning in January, caustic scrubber waste from the purification hoods (Hoods 5, 6, and 7) of the RG Line was processed through one of the recovery hoods (29, 30, 31, and 31), then sent to the 224 Building's plutonium recovery process. That month, six buttons (known as "X" buttons) were prepared from "scow cleanings, floor, and furnace sweepings" of the RG Line, but the impurity level of the product was so high that this trial was discontinued. In April, the practice of including a portion of metal turnings from lathing operations in the reduction charges was resumed. At the same time, an experiment in pressing the turnings into briquettes for recycle to casting was undertaken. However, even though the briquettes "processed into acceptable pieces," the briquetting practice was stopped "since the yield loss to recovery approximated 10 percent." In July, the processing for recycle of all stored concentrate supernates from past operations was completed, and two months later the recovery of plutonium from all 234-5 Building stored liquid waste likewise was finished. In August, filter papers from the filter boats used in the 231 Building were processed through RG Line Task II equipment. The paper itself was destroyed, but the plutonium oxalate on it converted to normal plutonium tetrafluoride, which was used to make buttons of normal yield.³⁵⁴

An assiduous program also was pursued throughout the year to process laboratory waste for return to either the 231-Z Building or 224 Building processes. In May, the old hydroxide precipitation method of preparing analytical wastes was replaced by a plutonium iodate precipitation. Improved distillation equipment also was installed for laboratory waste recovery that month. By August, a manual had been written to cover procedures for the recovery of plutonium from all forms of laboratory waste, except the solid portion of cupferron spectrographic residues. At the end of the year, 2,800 grams of plutonium had been recovered from laboratory waste in 1952, and 3,500 grams had been recovered since the startup of analytical waste recovery operations in August 1951.³⁵⁵

In November 1952, the Skull Recovery Facility commenced hot operations and performed so successfully that it recycled 1,000 grams of plutonium to the 231-Z Building process during its first month. In December, it recycled 1,830 grams plutonium and isolated 290 grams of americium-241 (Am-241) "without incident." The Skull Recovery Facility consisted of two glove boxes, designated Hoods 40 and 41, in Room 221 of the 234-5 Building. Hood 40 processed solid metal items (the skulls themselves) and Hood 41 processed scrap plutonium-bearing powders. The economic value of the Skull Recovery Facility was unquestionable when compared to the value of the plutonium recovered.³⁵⁷ As soon as the new facility was operational, the removal of obsolete recovery equipment (Hoods 29, 30, 31, and 32) from Rooms 221, 222, and 223 of Building 234-5 was initiated as ER-2732.³⁵⁸

8.3 WASTE RECOVERY OPERATIONS PROLIFERATE AT PFP

Throughout 1953, plutonium recovery from stored and current 234-5 Building waste progressed rapidly. At the end of January, the contractor reported the "dissolution of all stored oxidized turnings accumulated since startup...was completed, closing out this account of inactive material." Both plutonium and Am-241 were recovered from this material. The following month, the dissolver pot in Hood 40 of the Skull Recovery Facility failed when a "violent exothermic reaction" occurred just as the nitric-hydrofluoric acid addition was started. The platinum liner of the dissolver was "virtually destroyed." Rather than repair the damaged liner, it was decided to install more rugged equipment and a new dissolver was fabricated from 1/2-inch-thick 309 SCb stainless steel.^{ee} In April, dissolver operations in the Skull Recovery Facility were doubled to two runs per day, with Am-241 as one of the products recovered. The following month the contractor reported that "plutonium recovery from all returned metal samples from the Analytical Laboratory was completed at month's end." All future such recovery was planned to be "on a current basis." At the same time, experiments begun in the "direct recovery of metallic plutonium from molten skulls by remelting them in an open pot furnace" were said to "show some promise." However, there was some "flashing" in the process and low button yield.³⁵⁹

In June 1953, it was necessary for the 234-5 Building recovery facilities "to operate continuously so as to assist in providing a maximum amount of feed material required to meet the heavy production commitment." The following month, recovery processing of the "backlog of RG Line scrap metal material (hood sweepings, etc.) and scrap metal from Hood 200 [machining] of the RMA Line was completed." At the same time, the "open-pot type" method for continuous recovery of plutonium from skulls was investigated. In August, "all metal reduction particles and buttons stored as inactive materials were recovered, completing this portion of the inactive account." Recovery operations in Hoods 40 and 41 continued on a vigorous basis throughout the remainder of 1953, and the briquetting of scrap turnings from the RMA Line was resumed in November in an RG Line hood.³⁶⁰

^{ee} Type 309 SCb stainless steel is an alloy composed of about 55 percent iron, 22 to 24 percent chrome, 12 to 15 percent nickel, 3 percent manganese, and trace amounts of niobium, sulfur, and other elements.

Plutonium recovery from metal scraps and powder remained a high priority at PFP in 1954 and, pending the start of RECUPLEX operations, continued to be carried out in Hoods 40 and 41. Throughout much of the year, the recycle solutions generated in these hoods were sent to the 231-Z Building for reuse in its processes. However in April, recycle addition facilities were completed at the REDOX Plant, permitting the addition of recycle materials from the 231-Z and 234-5 Buildings to the REDOX process. Beginning in September, recovery operations in Hoods 40 and 41 were curtailed to conduct a control study of the effect of using recycle materials in the REDOX Process. The following month, recovery of skull material for recycle to the 231-Z Building, was resumed. A brief campaign of powder recovery was conducted in November to reduce the backlog in the 234-5 Building. Operation of the recovery hoods remained standard for the rest of the year, except for a special campaign in August to process the materials associated with the plutonium turnings fire of July 27 in the RMA Line (see Section 5.7).³⁶⁰

8.4 1955 RECUPLEX STARTUP DIMINISHES RECOVERY IN HOODS 40 AND 41

Existing methods of plutonium recovery using Hoods 40 and 41 went forward in the 234-5 Building during 1955, albeit on a smaller scale because of the hot startup of the RECUPLEX facility in July. Because of the stoppage of production operations in the RMA Line during the early months of the year, Hoods 40 and 41 were idle between mid-January and mid-April. Recovery personnel were assigned to help with start-up testing at RECUPLEX. During May, Hood 41 was converted from powder recovery to metal recovery operations, and dissolution of skull material was carried out on an "accelerated basis" in Hoods 40 and 41 during May and June. Off-standard buttons, briquettes, and castings also were dissolved. During July, a major cleanout in Hood 9, Task II yielded 13 kilograms of floor sweepings with a plutonium content estimated at 3 kilograms that needed dissolution.

Following the startup of RECUPLEX, Hoods 40 and 41 were used primarily for the dissolution of high-MWD/T (megawatt days per ton)^{ee} scrap. Sometimes the product material from the dissolution of high-MWD/T scrap in Hoods 40 and 41 could be fed directly into the RMA Line, but more often it would be fed through RECUPLEX first. Later in the year, high- and low-MWD/T material was split, with the low-MWD/T material going through Hood 41 and becoming feed for the A-Line, and high-MWD/T material going through Hood 40 and becoming feed for RECUPLEX.³⁶¹

During 1956, plutonium recovery operations at PFP continued in both RECUPLEX and Hoods 40 and 41 in the 234-5 Building. In Hoods 40 and 41, low-MWD/T scrap metal was processed to provide feed to the RMA Line, and high-MWD/T scrap from the A-Line was processed to become feed for RECUPLEX. Special, high-MWD/T scraps from the 234-5 laboratories also were processed, as were metal scraps from the fabrication of buttons from Savannah River Plant material and from the plutonium metallurgy laboratory in the 231-Z Building. Experiments in dissolving plutonium turnings resumed during the year after previous violent reactions. One new technique included first boiling the

^{ee}. Megawatt days per ton is a measure of the length and intensity of irradiation, to which uranium is exposed in a reactor.

turnings in caustic, then introducing the nitric-hydrofluoric acids needed for dissolution. Another method for using the plutonium turnings involved bypassing the complete dissolution process, adding calcium chloride and calcium fluoride in the eutectic ratio, and heating the material in the reduction step. Although this procedure seemed to produce "well-formed buttons," the resulting S&C material needed to be recovered in special laboratory processes because of the presence of chloride in the slag.³⁶²

8.5 SCRAP RECOVERY MISSIONS BECOME MORE VARIED/SOPHISTICATED AT PFP

In 1957, plans got underway to convert RECUPLEX from a prototype to a manufacturing facility (see Section 9.6). Essentially a replacement of the existing RECUPLEX equipment with larger and sturdier equipment, the manufacturing conversion project necessitated the closure of Hoods 40 and 41, which had shared space in Room 221 with the initial RECUPLEX equipment. RECUPLEX handled essentially all of the activities in the recovery and recycling of plutonium-bearing scraps at PFP from 1957 through early April 1962. (On April 7, 1962, a criticality event in RECUPLEX closed that facility permanently) (see Section 9.8.) From 1958 through 1964, four additional waste recovery facilities were constructed in the PFP complex, demonstrating the high value and priority placed on this work. These facilities were the 232-Z Incinerator (see Section 10.0), the 242-Z Waste Treatment Facility (see Section 11.0), and the PRF (see Section 12.0) constructed in separate buildings, as well as the RMC button line filtrate handling facility in the 234-5 Building.

In July 1962, soon after the RECUPLEX criticality, Project CGC-978, RMC Button Line Filtrate Handling Facility, was authorized and begun. Completed in September, this project installed continuous anion exchange facilities in the 234-5 Building for purifying and concentrating plutonium from the RMC button line aqueous waste, including Task I filtrate, Task III button pickling solution, and glove box sump solutions. During the interim period between the startup of Project CGC-978 equipment and the startup of the PRF (in 1964), the filtrate ion exchange equipment also processed miscellaneous waste from the 234-5 Building laboratory for plutonium recovery. Feed preparation and rate control equipment, transfer pumps and instrumentation, chemical preparation equipment, the ion exchange equipment, and waste receiving tanks were included in the project. The ion exchange equipment located in the old Task I area of the RMA Line, and the product stream from the filtrate concentration activities served as new feed for Task I processing in the RMC Line. In June 1963, lead glass shielding was installed around the feed and filtration hood for the ion exchange unit (Hood 7A), thus reducing gamma radiation levels by 50 percent.³⁶³

Some small additional scrap recovery operations took place in the 234-5 Building in the period between the RECUPLEX accident and the startup of the PRF. These operations included burning skulls in Room 227 and dissolution of the resulting oxides in small glass vessels in the 234-5 Building laboratory. This sequence was so successful however, that 138 kilograms of plutonium were recovered in December 1962 alone. At the time of the accident in April 1962, the button lines were being modified to accommodate the direct transfer of supernates and leaching solutions to PR (product) containers, for transfer to recovery facilities. After these modifications were completed in

May, the supernates and leaching solutions were canned and taken directly to the separations plants (REDOX and PUREX) to be fed in at the head end of those processes. However, the separations plants could not accept as much of this off-standard feed as was generated, so backlogs accumulated. A shortage of PR cans in late 1962 created further backlogs. By May 1963, the inventory of scrap powders was so large that PFP operations began refluorinating the accumulated powders and firing them into buttons (non-specification metal) for more secure storage. The commencement of test runs with stand-in materials at the PRF in December 1963 then provided the much-needed promise of relief from further uncertainties over scrap accumulations.³⁶⁴

8.6 PFP DEVELOPS ROLE IN OFFSITE SCRAP PROCESSING

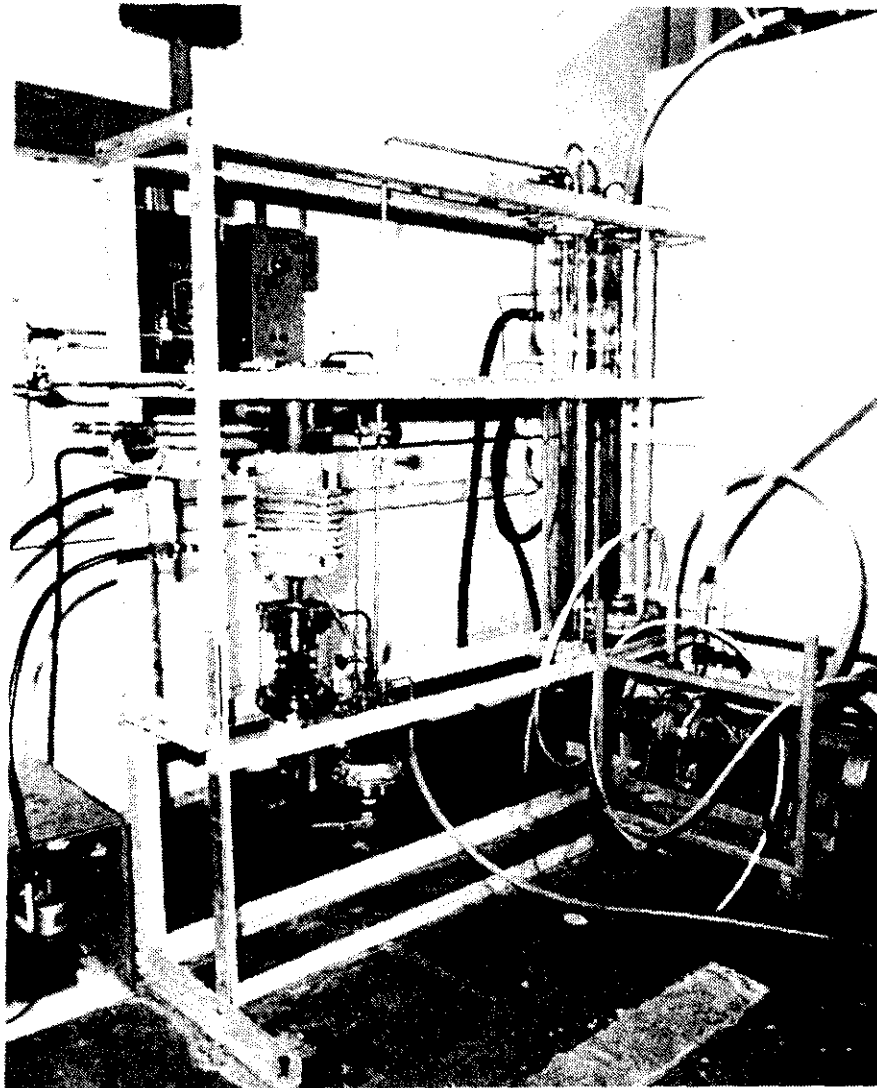
In December 1968, in response to a new AEC directive, the PFP began a campaign to identify, sort, and repackage various scrap liquids and oxides from polyethylene and other containers of short-term reliability into metal containers. Some of the 221 cartons of scrap repackaged that month had been generated at the Hanford Site and some had come from offsite shippers, as the PFP became more involved with the commercial nuclear industry and with research facilities across the world (see Section 13.2). Still, at year's end, the AEC appraisal noted that PFP needed to reduce "the quantity of plutonium discarded...[particularly] the solids problem."³⁶⁵

Between 1968 and 1972, new plutonium storage vaults (the 2736-Z facilities) (see Section 14.3) were constructed in the PFP complex and additional plutonium storage facilities were upgraded in the nearby 224-T Building. New plutonium-uranium partitioning equipment was emplaced in the PRF (see Section 12.3). A continuous americium recovery process was installed in the 242-Z Waste Treatment Facility (see Section 11.2), and the broken furnace in the 232-Z Incinerator was repaired (see Section 10.5). As a combined result of the advantages offered by these facilities, the AEC Richland Office (AEC/RL) was assigned responsibility for all scrap management activities (except Pu-238 scrap) in 1972. The Central Scrap Management Office (CSMO) was established at AEC/RL, with its first goal being the reduction of backlog scrap to a 6-month inventory (i.e., plutonium scrap received within the previous 6 months). This goal was considered important because of the problems associated with the buildup of Am-241 (an intensely radioactive alpha emitter) in aged plutonium scrap. Over the preceding years, the different goal of reducing the quantity of plutonium within scrap had "resulted in the processing of easily-processed scrap rich in plutonium and storage of lean, difficult-to-process scrap." In 1972, difficulties in storage and handling of this aged scrap in the PFP complex and the 224-T Building were becoming manifest. "Because of the radiation levels produced by the americium, essentially all of the stored plutonium will require americium removal before it can be utilized."

The CSMO program plan outlined an ambitious, complex, and interlocking project for scrap processing that utilized virtually all aspects of PFP equipment and operations, and eventually would recover plutonium from current PFP waste streams and from the soil in the 216-Z-9 crib for economic value. "Environmental restoration offers a real future for this new facility [CSMO]," wrote ARHCO in late 1972.³⁶⁶ Throughout 1972, scrap bearing fuel-grade plutonium residue continued to arrive at PFP from many offsite shippers. As

with other scrap receipts, the 1972 material was processed through the PRF for plutonium recovery.³⁶⁷ The PRF was shut down in 1976 for nearly 8 years (see Section 12.4). The CSMO mission at the Hanford Site was terminated in 1977, and, afterward, the receipt of plutonium-bearing scrap occurred only in small amounts on an occasional basis until the late 1980's when debates over the future of the PFP and the PRF halted most operations (see Section 16.1). In 1977, a small incinerator system for burning rags contaminated with plutonium and nitric acid was installed in Room 235-B of the 234-5 Building. The system consisted of two glove boxes capable of processing 8 pounds of dry rags per hour, storage facilities, and an off-gas treatment system.³⁶⁸ In 1994, a series of interim stabilization measures resumed scrap processing at the PFP (see Sections 16.1 and 16.2).³⁶⁹ (See Figure 8-1.)

Figure 8-1. Rag Incinerator in Room 235-B, 234-5 Building, 1977.



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9.0 RECUPLEX FACILITY AT PFP

9.1 RECUPLEX PROCESS AND FACILITY CONCEIVED

Although the recovery and recycle of plutonium-bearing waste had been ongoing at the PFP since 1950 (see Section 8.1), a salient step forward in this effort occurred in August 1951. At that time, laboratory work aimed at coupling the REDOX end product and the bismuth phosphate product from the 224 Buildings to the 234-5 process, combined with ongoing efforts to generate a workable S&C recovery process and became the "RECUPLEX" (recovery of uranium and plutonium by extraction) process. Efforts to accomplish these ends, and render 231-Z Isolation Building operations unnecessary, had been expanding and becoming more varied and reliable since 1950. By spring of 1951, PFP chemists were utilizing a new method developed at the Hanford Site using TBP diluted with carbon tetrachloride (CCl_4). The resulting solution could be recycled into the second decontamination cycle of the 224 Building process, and stripped with hydroxylamine sulfate or ammonium bifluoride and ammonium sulfite. The dissolved S&C material also could be recycled to the REDOX IIA column (second plutonium decontamination cycle), and processed through the final plutonium decontamination and concentration steps there. In July, these studies were combined to develop a "single solvent-extraction process for the coupling of REDOX and BiPO_4 [bismuth phosphate] product solutions to 234 purification together with the recovery of 234 slag and crucible wastes."³⁷⁰

The new process was "provisionally named" RECUPLEX, and semi-works experimental equipment was placed in HW's 321 Building to pursue the effort. The stand-in process material was uranium, not plutonium, but the objective of the process was defined as being to "produce pure plutonium solution in a concentration range from 40 to 60 g. [grams] Pu/l [per liter] and suitable as feed to the 234 Building operation." Key focal points of study concerned solvent extraction techniques, methods for filtering the gelatinous silica from the S&C dissolver solution, and corrosion problems associated with the process equipment. By October 1951, "significant gains" were reported in all aspects of process development work, and by year's end a feasibility report had been issued to emplace a plant-scale RECUPLEX process in Room 221 of the PFP.³⁷¹

9.2 RECUPLEX SCOPING AND DESIGN CHANGES OCCUR DURING 1952-1953

Planning and design for the RECUPLEX facility (designated ER-2714 in January 1952, but renamed Project C-496 in April) continued throughout 1952, but the scope was expanded many times. In March, G.E. Hanford Co. reported that "an enlargement of the original scope has necessitated changes in process equipment which have retarded the flow of design criteria." In June, the contractor reported that "contemplated process changes affect the majority of all process vessels and present design criteria [are] no longer valid." In September, designers realized that more space would be necessary for the RECUPLEX installation. By November, approximately half of the 102 vessels needed in the RECUPLEX process had been designed to meet the new criteria, and testing of the process itself was under way in 5-foot experimental pulse columns in HW's 222-S Laboratory. However, G.E. Hanford Co. reported the possibility of further design delays necessitated by "the possible need for

radiation protection features." The following month, it was concluded that equipment shielding indeed would be required "to reduce radiation intensities at hood faces to safe values." According to the contractor, "data [from the 222-S tests] indicating radiation readings greater than expected...[have] caused...serious interruption to the design effort." The question of waste disposal for the RECUPLEX facility was debated at length, but at that time under the assumption that the process waste would be tanked. By April, approval had been secured to use an existing, buried, high-level waste tank in TX Tank Farm as a backup facility, and to construct only a partially buried, single-walled, 250,000-gallon tank instead of a more expensive, completely buried, doubled-walled tank for RECUPLEX wastes.³⁷²

RECUPLEX design progressed with multiple modifications until it was completed in October 1953. In February 1953, a "major revision of the instrumentation...[was] undertaken to provide remote control." The following month, a decision by the G.E. Hanford Co. Radiological Sciences Department allowed "the substitution of a crib for the tank storage of CAW [current acid waste - from RECUPLEX] and thus eliminate[d] the neutralizing station." This decision, reported the contractor, "resulted in a savings of \$100,000 in RECUPLEX construction costs and an annual waste storage savings of \$40,000 to \$60,000." At the same time, after experimentation with a "prototype pulse generator for RECUPLEX pulse columns," the specifications for the production pulse columns were issued. In April, specifications for criticality control were issued for RECUPLEX design. At the same time, removal of old RG Line recovery equipment from Rooms 221, 222, and 223 was folded into the RECUPLEX project, and two revisions were made in the solvent extraction (SE) hood. One change eliminated a planned spare column; the other eliminated the ion exchange system and modified "the extraction battery to handle the uranium build-up in the supernates of Task I." These changes, according to the contractor, "delayed the design completion" by about 4 months.³⁷³

9.3 RECUPLEX CONSTRUCTION BEGINS, HALTS, CONTINUES

On May 1, 1953, with the design 80 percent complete, RECUPLEX construction began. At the same time, the design of the waste crib (216-Z-9) was completed and approved. The crib was covered by a tile-lined concrete roof "carried by concrete columns." The elimination of the waste neutralization station, G.E. Hanford Co. reported, made it "necessary to measure the pH in the waste receiver tanks in the Receiving and Blending [R&B] hood." By August, construction had progressed to 20 percent, and the only design work remaining concerned the chemical storage facilities for nitric acid, aluminum nitrate nonahydrate (ANN) and caustic soda. "These facilities," according to G.E. Hanford Co., would "eliminate drum handling required previously by piping chemicals from storage tanks outside the 234-5 Building into the tanks in the chemical make-up room." On October 31, construction on the RECUPLEX facilities was suspended "due to the shortage of construction materials." Because the California vendor was slow to deliver the vessels, there was a "consequent inability [at RECUPLEX] to maintain an efficient construction program." Construction remained halted at 27 percent on the main RECUPLEX facility for the rest of 1953. However, in December, construction was begun by a subcontractor on the CAW and silica waste crib. Meanwhile, an in-line monitor to measure the plutonium content of RECUPLEX waste was designed and demonstrated in the laboratory. According to the

Hanford Site standards of the day, it was set to activate an alarm if the plutonium content of the waste exceeded 1 gram/liter. As the last act of RECUPLEX activity for the year, D.O. 100681, was issued to prepare the acceptance test procedures (ATPs) for the facility.³⁷⁴

Construction resumed on the RECUPLEX facility in the 234-5 Building on March 8, 1954, following receipt of some of the delayed vessels from the California vendor. However, unfavorable delivery schedules and several additional design revisions kept construction slow through May. Also, a labor dispute with a subcontractor delayed construction of the waste disposal facility throughout the spring, but the CAW facility and the silica storage tank were in place by July. In the autumn, the United State Geological Survey (USGS) began installing monitoring wells near the CAW waste crib and tanks. By summer, RECUPLEX capacity was being reevaluated in light of the anticipated 4X program at the Hanford Site. It was decided that, based on the probable short-term nature of the 4X program and because the 231 Building could be used to supplement some RECUPLEX functions during this period, the design capabilities were adequate. In November, it was discovered that corrosion-sensitive mild steel had been used in the liners of the RECUPLEX in-line process pumps, and that these would have to be replaced before start-up. At year's end, construction of the RECUPLEX facility stood at 88 percent, with pressure testing, instrument calibration, and electrical and insulation work under way. A December decision to modify nine of the process vessels for "increased nuclear safety" presaged further delays in early 1955.³⁷⁵

9.4 RECUPLEX CHEMISTRY STUDIES CONTINUE

Throughout 1954, studies in RECUPLEX chemistry and in the durability of various alloys, filter media, cements, and other materials continued. One key problem concerned the deposition of silica, by hydrolysis of silicon tetrafluoride (SiF_4), in the condenser system of the S&C dissolver. The SiF_4 was formed by the reaction of wet hydrofluoric acid on silicon dioxide. The addition of aluminum to the dissolved slag prevented the volatilization of SiF_4 , but the amounts of aluminum needed could not be tolerated in the dissolver. Other salient studies concerned how to prevent the formation of solids in the solvent extraction columns, the rate of reduction of Pu(VI) by hydrogen peroxide in various RECUPLEX feed solutions, and whether to use a Haynes 25^{ff} or a type 309 SCb stainless steel alloy in the S&C dissolving system. Various cements also were tested for durability when exposed to RECUPLEX CAW, but "none...[was] completely satisfactory." Filter papers and filter cloths were tested for use in filtering the ANN solutions, and multiple pipe markers and electrical cable coverings were examined for their ability to withstand the vapors expected to be encountered in the RECUPLEX hoods.³⁷⁶

^{ff} Haynes 25 is a trademark of Society National Bank. It is composed of 50 percent cobalt, 20 percent chrome, 15 percent tungsten, 10 percent nickel, and traces of other elements.

9.5 RECUPLEX OPERATIONAL STARTUP AND DESCRIPTION

The RECUPLEX facility was completed in March 1955. Cold stand-in runs, along with correction of newly discovered maintenance problems, occupied April and May. Hot stand-in runs using uranium were initiated on June 7, and processing with plutonium feed material (supernates from Task I) began on July 11. Soon, batches of S&C filtrate from iodine-boosted reductions in Task III were added to the feed. A contractor report covering the earliest RECUPLEX operations stated that, "although several problems such as more complete removal of iodine from crucibles and slag material remain to be perfected, the process appears to be developing satisfactorily." The facility, the report continued, was meeting its design objectives, which were "planned to (1) find answers to the process problems, especially in feed preparation and product evaporation...(2) gain operating experience, and (3) [perform] as a semi-production facility, recover the plutonium from Z Plant recycle solutions which could not be conveniently handled in any other way." During its first full month of operations, August, RECUPLEX processed 22,000 liters of feed material and recovered 9.3 kilograms of plutonium in nitrate solution. That month, a glass vessel containing hydrogen peroxide exploded in the cold chemical addition area of the facility, and studies were undertaken to revise the feed make-up steps to eliminate the use of this substance.³⁷⁷

Throughout the autumn, RECUPLEX operated to process "all types of available feed," with an on-line efficiency rate that usually varied between 83 and 87 percent. Waste losses to the CAW crib (216-Z-9) averaged between 0.3 and 0.7 percent of the feed, sometimes climbing above 100 grams plutonium to the crib per month.⁹⁹ In November RECUPLEX product solution was fed into RMA Line operations for the first time. In December, the on-line efficiency rate dropped to 62 percent, in part because of a massive corrosion failure of the Teflon bellows in the pulse generator of one of the SE columns. The bellows alarm had become inoperative because of corrosion, so the bellows "failure was not noticed until an appreciable leak had developed at the flange between the two bellows." PFP officials were surprised at the extent of this early corrosion, and undertook a complete inspection, as well as a search for more corrosion-resistant materials. They found the mild steel dunnage used in various portions of the equipment supports to be corroding, in some cases leaving equipment without adequate support.³⁷⁸

The RECUPLEX facility, as started up in 1955, consisted of three large, stainless steel glove boxes ("hoods" in the vernacular of the Hanford Site), with Lucite panels. Hood operations were largely manual, with operators manipulating a control panel in the RECUPLEX room and using gloves attached to the hoods themselves. The majority of RECUPLEX feed was solid waste in the form of slag and crucible fragments, magnesium oxide sand used as liner material in the reduction crucibles, scrap powders from A-Line operations,

⁹⁹ The rate of release of plutonium reported here for the 216-Z-9 crib was considerably higher than other plutonium-bearing waste releases from the PFP, which had averaged barely 100 grams per year since startup. The amounts reported here for releases to the Z-9 crib are much lower than the amounts later mined out of the crib soil, and lower than would be indicated by samples taken out of the 241-Z-361 tank (see Section 15.X).

plutonium dross from Task IV, oxidized turnings from Task V, and remnants from metal samples. This material was taken to the S&C hood, where it was contacted with aluminum nitrate and nitric acid, dissolved, and filtered. Reflux-condensers, off-gas scrubbers and assorted receiver vessels and piping also were located in the S&C hood. Dissolved and filtered liquids from this hood were sent to the R&B hood, where they were blended with many other contaminated liquid feed streams. Most of the latter streams were generated as supernates from plutonium wet chemistry operations, clean-out solutions from filter boat flushes, in-line filter and vessel flushes, button-pickling solution, dissolved skull materials, analytical laboratory reagents, and off-standard product material from the 233-S Building. The R&B hood functioned as a feed preparation facility for the third RECUPLEX glove box, the solvent extraction (SE) hood. In the R&B hood, the dilute and concentrated streams were combined, the pH was adjusted, and the valent state of the plutonium was brought to IV. The plutonium-bearing liquid feed was mixed with 15-to 20-percent TBP in CCl_4 solution, and processed through a standard solvent extraction system in the SE hood. The solvent extraction system consisted of three columns, associated pumps and tanks, and feed and discharge vessels. The end product was a plutonium nitrate stream concentrated to between 80 and 100 grams/liter plutonium.³⁷⁹

9.6 RECUPLEX OPERATIONS SURGE FORWARD; PROTOTYPE BECOMES A MANUFACTURING FACILITY

Although the RECUPLEX facility experienced two serious contamination events in 1956, one of which closed operations for 5 weeks, and the facility also needed other difficult repairs, recovery operations surged ahead in both volume and complexity during the year. Studies were begun that year on ER-2792, Conversion of RECUPLEX to a Manufacturing Facility, ER-2795. The conversion effort became Project CG-723 in 1957, and essentially involved the replacement of existing equipment with sturdier, larger equipment and the augmentation of shielding and instrumentation.³⁸⁰

In January 1956, a RECUPLEX operator who was assisting a maintenance mechanic in replacing a process valve became "grossly contaminated" on one hand when all layers of his gloves (one neoprene glove covering two layers of surgical gloves) were penetrated by contaminated solvent (TBP- CCl_4). The RECUPLEX facility was shut down until early March for "a re-evaluation of operating conditions and hazards...[and] modifications to improve safety." Some of the procedural changes involved minimizing the contact of gloves with the solvents. At the same time, "gross amounts of plutonium...which had accumulated on the hood floors" after valve failures were cleaned out. The recovery facility then went on to process some off-standard PUREX product solutions (to remove excess niobium and zirconium), REDOX and T-Plant flush material, scrap metal solutions, S&C fragments from Tasks III and IV, and scrap powders. Because of the high niobium-zirconium PUREX feed, special lead shields had to be installed around the RECUPLEX control panels to allow operators to complete 8-hour shifts without exceeding radiation exposure limits.

In December 1956, a record total of 80 dissolver runs was made in RECUPLEX. The "entire backlog of casting crucibles was eliminated as of December 27, at which time efforts were directed towards the elimination of

the fluoride powder backlog." At the same time, laboratory tests showed that plutonium recovery from scrap sand paper and hood sweepings was feasible in RECUPLEX, and equipment design was underway to allow RECUPLEX to evaporate and concentrate filtrate from Task I. Major maintenance projects focused on the pulser bellows on the extraction columns, which failed many times in 1956, and a difficult summer program to replace the filter blocks in the waste tanks serving the S&C hood. The alundum blocks weighed about 100 pounds each and were cracked and extremely contaminated. Studies and feasibility drawings continued throughout the year in the equipment changes necessary to convert RECUPLEX from a semi-works to a manufacturing facility.³⁸¹

In January 1957, RECUPLEX completed recovery of the backlog of fluoride powders. At the same time, it functioned to decontaminate PUREX feed that once again contained "more than normal amount of fission product...levels," and to process hood cleanout material, special developmental laboratory fragments, 231-Z Metallurgical Laboratory waste, and miscellaneous 234-5 Building powders. By mid-summer, experiments in increasing the size of RECUPLEX dissolver charges were under way, and up to 10 crucibles were being placed in each charge. As a criticality prevention device, a special well to hold a neutron monitor was built for the D-10 dissolver tank. The monitor was emplaced in the autumn. At the same time, a defective dissolver weighing approximately 2.5 tons was replaced in a very complex maintenance operation. By year's end, tests to increase the size of dissolver charges up to 16 crucibles were discontinued because too many solids were breaking through the filters and causing system plugs. At this time, approximately 1,620 liters per day were being processed through the RECUPLEX solvent extraction columns. Dibutyl butyl phosphonate (DBBP), along with tetrabromoethane (TBE) was being tried in solution with CCl_4 as a new RECUPLEX solvent. Other tests evaluated replacing the CCl_4 with pentachloroethane.³⁸²

In late 1957, a study was conducted to determine the feasibility of recovering plutonium from Hanford Site waste residing in underground storage tanks. The process would have utilized 234-5 Building recovery equipment, but the study concluded that, while the process was technically achievable, it was not economically viable.³⁸³

RECUPLEX operations continued and expanded throughout 1958 and 1959. The manufacturing facility conversion project was completed in 1959. In March 1959, in Project CAC-798, Crib and Test Wells for 234-5 Building Wastes, test wells were drilled for the RECUPLEX waste facility to a depth lower than the 100 feet penetrated and sampled by the original test wells (see Section 15.1).³⁸⁴ New processing records were set frequently at RECUPLEX during the 1958 through 1960 period. In early 1958, the amount of plutonium returned to the "main processing stream" (RMA Line feed) from RECUPLEX averaged 60 to 65 kilogram, and approximately 1,600 to 1,950 liters per day passed through the RECUPLEX solvent extraction columns. Late that year, a continuous concentrator for A-Line Task I supernate was placed into operation. This saved one of the concentration steps in the RECUPLEX process. Shortly afterward, a fixed-bed, anion exchange prototype system was proposed for RECUPLEX, to achieve even higher concentration values. In November 1958, RECUPLEX production reached an all-time monthly high rate, greatly exceeding its scheduled production. Four months later, another record was set when the (higher) scheduled production amount was exceeded by another sizable amount.

At that time (March 1959), 94 kilograms of plutonium were recovered. That July, RECUPLEX set another record, producing well beyond its scheduled commitment. December witnessed another new record, at which time the contractor reported that "the backlog of recoverable material remains at a satisfactorily low figure." To meet increasing production needs, however, RECUPLEX operations moved from a 5-day to a 7-day work week in late 1960.³⁸⁵

However, high production at RECUPLEX was accompanied by a series of serious radiation events and a mounting number of equipment failures. Three "over-batch-size" events occurred between November 1959 and February 1960. In a separate incident in January a valve failure allowed "material from a critically safe extraction column to back up into a critically unsafe vessel." During the same month, a dissolver "pressurized as a result of the inadvertent loss of the inert gas blanket." According to a contractor report, because of these events and "high radiation levels," RECUPLEX shut down for an "extensive cleanup of hoods and equipment" in February. Six months later, both of the S&C dissolvers and the metal dissolver in RECUPLEX failed, and the pulser bellows on one solvent extraction column failed three times. Three months later, a large contamination spread occurred at RECUPLEX caused by the failure of "a line to the product concentrator." Six days of lost production time were required for decontamination and repair. At that time, a contractor report stated that RECUPLEX equipment "continue[d] to require excessive maintenance on leaking lines and valves." In December, one of the RECUPLEX S&C dissolvers again failed because of corrosion and had to be replaced.³⁸⁶

9.7 PLUTONIUM RECLAMATION FACILITY PLANNED TO REPLACE PROBLEMATIC RECUPLEX

In 1960, design began for the PRF (236-Z Building), which was conceived as an enlarged, safer and more flexible version of RECUPLEX. The PRF was needed at a time when production increases made additional capacity for plutonium recovery from scraps and waste desirable.³⁸⁷ As in the previous years, recovery operations in RECUPLEX were "plagued" by equipment maintenance problems during all the months of 1961. Dissolvers, concentrators, pumps, bellows, filters, valves, hood panels, and many other parts leaked and failed repeatedly, as contractor reports were filled with descriptions of "excessive" and "numerous" maintenance needs. Solids in the RECUPLEX CAW stream contributed to equipment plugging. A June contractor report revealed the decision to "dismantle and retire...present RECUPLEX equipment...[because] [t]he present RECUPLEX facility cannot handle the current load without undesirably high operating, maintenance and equipment costs. The progressive deterioration of the RECUPLEX facility is expected to result in not meeting criteria for operation." Six months later, another report stated: "The extensive maintenance effort required to keep plutonium recovery facilities operating has become normal."³⁸⁸

Despite these problems, RECUPLEX performance often exceeded the projected schedule by 50 percent or more. In January 1961, a boron trifluoride (BF₃) neutron counter was installed in the well of the replacement S&C dissolver to monitor the amounts of plutonium build-up. In May, a glove box in Room 227 of the 234-5 Building was "modified to permit the burning of plutonium metal skulls to obtain plutonium oxide." According to the contractor, this process change reduced both dissolution time for the skulls,

and "the hazards associated with the handling and storage of plutonium metal skulls." The following month, emphasis was placed on reducing the plutonium-bearing scrap metal inventory and 10 additional process operators began work in RECUPLEX. By July, the skull-burning activity had resulted in a 60-percent increase in the dissolution capacity for other types of scrap, and a "two-fold solvent extraction capacity increase resulted from a more concentrated plutonium flowsheet." At this time, "very high exposure levels" were noted at the supernate processing equipment in RECUPLEX. Leaks resulted in the accumulation of "hood floor wastes" to the extent that a hydrofluoric acid scrub column was installed in the solvent extraction hood "to aid in the processing of this material." By autumn, the solvent extraction hood was operating successfully, but a prototype, continuous S&C dissolver for the dissolution of plutonium oxide demonstrated "the need for several changes." Late in the year, the RECUPLEX facility was virtually overwhelmed by the arrival of 72 kilograms of plutonium scrap from the Rocky Flats Site, increasing "the active backlog of recoverable scrap...by 30 percent."³⁸⁹

9.8 1962 BRINGS NUCLEAR EXCURSION; END OF RECUPLEX

RECUPLEX operations continued to require "considerable maintenance efforts" throughout early 1962. In January, a prototypical air pulser was installed to replace the mechanical, bellows-type pulser on the solvent extraction column, because of the "excessive" failure rate of the older pulser. That month, a fire originating in welding slag occurred in the SE hood, but recovery presented such an urgent need that decontamination and restart took place in just 5 hours. In February, the BF_3 counter detected excessive neutron levels in the sump waste inventory, and processing was curtailed for 2 weeks while sludge from piping leaks was cleaned from the solvent extraction hood and corroded piping was replaced. Processing of the accumulated hood floor waste, additional tubing and piping leak repairs, and "the usual high incidence of leaks, plugged lines, failed valves and failed pumps" took much of March. Of "particular significance" that month was the 92 kilograms of plutonium that "were successfully processed directly from plutonium scrap metal dissolvers...to the button line."³⁹⁰

On April 7, a nuclear excursion occurred in the used solvent holding tank (K-9) in RECUPLEX. Three persons were exposed to high radiation levels (one approaching 110 rem [roentgen equivalent man]). All operations in the 234-5 Building were shut down until "limited fabrication activities" resumed on April 23. Button line operations resumed on May 18, at nearly the same time that the decision was made to permanently deactivate the RECUPLEX facility. In December 1962, a glove box in another part of the 234-5 Building was modified to dry the sludge from the floor of the RECUPLEX R&B hood. Decontamination work continued in 1963, but terminal cleanout did not take place until Project CGC-178, Removal of RECUPLEX Facility, was approved in 1966. According to the contractor, this project was "virtually complete" by June 1967, but final removal of plutonium from the RECUPLEX product concentrator was not completed until late 1970. A total of over 40 kilograms of plutonium was removed from RECUPLEX equipment. In 1976, additional plutonium was removed from the soil of the 216-Z-9 crib that had received RECUPLEX waste.³⁹¹

10.0 232-Z INCINERATOR

10.1 SOLID WASTE CONCERNS GENERATE NEED FOR THE PFP INCINERATOR

The 232-Z Incinerator was conceived at PFP in the spring of 1958, as a way to recover plutonium from "various miscellaneous solid wastes" generated at both the 234-5 Building and the 231-Z Building.³⁹² The incinerator also would be capable of and available for processing additional solid combustible, plutonium-bearing materials generated by the cleanup of "inadvertent spills" at the REDOX and PUREX facilities. Candidate waste would include cartons, filters, rags, paper, gloves, clothing, tools, and small equipment components. Plutonium-bearing materials first would be hand-sorted into burnable or leachable fractions. According to the project proposal, the combustible materials would be incinerated, then the plutonium would be recovered by a wet leaching of the ash. Non-combustible materials would be leached in heated nitric acid and then water rinsed. The leachate and rinse solutions would be transferred to RECUPLEX (later PRF) for solvent extraction refining (recovery of plutonium) (see Sections 9.0 and 12.0).

At the time the new project was proposed, some leaching of plutonium from highly contaminated solid wastes was being performed in Room 227 of the PFP. However, the equipment being used in that room was not designed for a leaching function, and it could not process nearly as much material as was available as candidate feed. At that time, scientists at the Hanford Site estimated that 6 kilograms of plutonium per year were discarded with contaminated materials. The national demand for, and economic value of, plutonium was high, so recovery of the costs of incinerator construction was expected within 15 months of startup. Further, there was a desire to limit the contamination of "real estate" (waste burial grounds on the Hanford Site) and to ensure long-term radiological safety of the area by not continuing to place highly contaminated waste in the ground.³⁹³

Consequently, as of June 1, 1958, HW operators began to store, rather than bury, highly contaminated solid waste of the type expected to be candidate feed for an incinerator. A preliminary project proposal was generated that month for Project CGC-813, Plutonium Recovery From Contaminated Materials. The proposal requested that the endeavor be approved quickly because considerable accumulation of feed was expected and "these materials will present hazards of fire and contamination spread."³⁹⁴

10.2 DESIGN OF THE 232-Z INCINERATOR

In July, HW and AEC officials visited the Rocky Flats Site to examine a plutonium-burning incinerator being designed there. The Rocky Flats incinerator was to be a manual, batch-type device, operated on a campaign basis. It consisted of a conventional industrial incinerator that had been altered by lining it with a stainless steel sheet and substituting a stainless steel grate. This unit was inclosed in a glove box located below a standard dry box with an airlock for the introduction of combustible materials, and a canning and bag-out facility for removing the ashes. The single glove box also served as the sorting (feed preparation) and ash collection area. The incinerator was manually fed and the fire was lighted by a match. (Later, an

auxiliary gas-firing feature was added.) During burning, the lid of the incinerator was open about 4 inches to permit the addition of more materials as needed to maintain a robust fire. Observations as to when to add materials were made through a glove box panel. During operation, the pressure and air balances were controlled manually by operating a bleed valve that supplied forced air. For most materials, ordinary air was supplied, but oxygen was added when plastic materials were being burned to reduce the amount of soot formed. The off-gases from incineration were treated with a caustic scrub, but no subsequent attempt was made to recover plutonium from the scrub solutions. The dry ashes, along with hood sweepings and leach concentrate underwent plutonium recovery by dissolution in nitric acid, followed by standard extraction using TBP. It was estimated that 100 to 500 grams of plutonium per day were recovered at Rocky Flats.³⁹⁵

Soon after the trip to Rocky Flats, HW scientists prepared a process design document that detailed an incineration facility very similar to that at the Colorado atomic site. The facility at the Hanford Site was to consist of five hoods (glove boxes). They would be used for sorting and drying contaminated materials, leaching or washing noncombustible materials, incinerating combustible materials and canning the ashes, or providing contamination barriers around the scrubbers (filters) and the blowers. The incinerator would have both primary and secondary combustion chambers. Simple caustic and water scrubber filtration was provided, along with a bank of glass wool filters. The entire operation was to be enclosed in a single-story, concrete building of approximately 2,100 square feet^{hh}, with an automatic carbon dioxide fire suppression system provided for the waste carton storage room. The building process waste was to be transferred to one of the 234-5 facility waste holding tanks (D-6 tank) via a buried, 3-inch 304 stainless steel line. Condensate and cooling water from the 232-Z facility would be combined with similar streams from the PFP, and routed to the 216-Z-11 ditch for surface (crib) disposal. By the time design scoping was completed, it was estimated that 2.5 cubic feet of solid candidate waste was being accumulated per day, and a sense of urgency was expressed about the project.³⁹⁶

However, in December 1958, HW officials reevaluated and compared the merits of the simple box-type incinerator with that of an externally heated, tunnel-type incinerator. While "it was recognized" that the box-type incinerator had fewer mechanical parts and "probably would require less maintenance," the majority of HW personnel "preferred the tunnel-type incinerator from the standpoint of safety and operability."³⁹⁷ By January 1959, considerable design revisions were under way, including the use of electrical heating, a continuous wire-mesh belt feed system, a muffle-type incinerator, a mechanical feed chopper, increased building ventilation, and a more complex off-gas scrubber and filtration system. These changes were undertaken to "improve operability of the proposed plant and to minimize nuclear safety problems." The revisions made the original beneficial use date of February 1, 1960, completely unattainable.³⁹⁸

In the spring of 1959, project revisions, work specifications, and work authorizations were issued to proceed with construction of the continuous-feed

^{hh} The actual size of the 232-Z Building as constructed was 1,960 square feet.

(conveyor-belt) incinerator, a prototype design in plutonium-burning incinerators. At this time, a destructive distillation unit (DDU) and a circular, single-chamber gas-fired incinerator were in use at the Oak Ridge Site (an AEC facility in Tennessee) but only for burning uranium-bearing waste. Another radioactive waste incinerator, located at the General Electric Company's Atomic Power Equipment Department at San Jose, California was still in the construction stage. It would burn only thorium and uranium-bearing waste. The joint AEC-NDL (Nuclear Defense Laboratory, part of the U.S. Department of Defense) prototype incinerator project at the Edgewood Arsenal in Maryland would not start up until 1965-66, neither would other prototype incinerators, including the one at the Harvard Air Cleaning Laboratory. Incinerators for contaminated waste that had operated at various AEC sites were small, simple, batch-type operations.³⁹⁹

10.3 DESIGN MODIFICATIONS ADDED AS SOLID WASTE ACCUMULATES

At Hanford, a bank of HEPA or "absolute" filters were added as back-up to the glass pad filters that originally were to have formed the primary barrier. The 232-Z incinerator exhausts did not feed into the main 291-Z stack, but were filtered independently by 232-Z systems. To reduce fire danger and provide corrosion resistance, many materials now considered hazardous and dangerous were incorporated. Such materials included asbestos cement underground ducts and piping, asbestos cement floor filter boxes, glass asbestos fiber membranes in the HEPA filters, lead alkyd-based paints for the filter frames, and many other substances now regulated by the U.S. Environmental Protection Agency. By April, 125 boxes totalling 560 cubic feet of candidate waste for the incinerator were being stored in the World War II "magazine" vaults (the 213-J and K Vaults) in the southeast end of Gable Mountain. Predictions estimated that the total would rise to 400 boxes totalling 1,800 cubic feet by mid-1960. The rising economic value of plutonium, combined with the increased efficiency expected from the new type of incinerator, was expected to enable the facility to pay for itself within 10 months of operation. Again, expedited action on the incinerator project was requested by Hanford Site engineers.⁴⁰⁰

Throughout the two years beginning in the summer of 1959, various aspects and attributes of the incinerator system were studied and debated by Hanford Site personnel assigned to the project. One such aspect was the off-gas scrubber system. In September 1959, the Rocky Flats Site designed a new dry scrubbing system, to replace the caustic and water scrubber system that had formed the basis for the Hanford Site design. The Rocky Flats decision was based on continual plugging problems as salt from the off-gases built up on the scrubber components. However, after much discussion, Hanford Site engineers decided to modify rather than replace their wet scrubber apparatus. They substituted a diaphragm or bellows-type valve, added control valves in several locations, substituted various types of gaskets (including adding more asbestos-based gaskets to minimize leakage), and included many other modifications to the flow lines of the system.⁴⁰¹

Still, prestart tests conducted in 1961 in a 300 Area research building at the Hanford Site showed disappointing results for the wet Peabodyⁱⁱ scrubber. Without the regular use of in-place filter cleaning practices, it was estimated that the 232-Z scrubber would require weekly filter replacement, to maintain a 90 to 95 percent absorption rate for nitric acid vapors.⁴⁰² A regular filter cleaning schedule was put in place. However, further steps that would have filtered the scrubber solution through paper pulp to remove fly-ash and other suspended particulates, recycled (burned) the filter cake through the incinerator itself, and sent the clarified scrubber solution through an ion exchange process in the PFP's 242-Z Waste Treatment Facility (see Section 11.0) for plutonium recovery were not implemented.⁴⁰³

Another aspect of overall 232-Z operation that received much attention before startup was that of the neutron monitoring devices that would be used. In September 1960, specifications were drawn up for a prototype instrument to be built distinctly for the Hanford Site incinerator project. It was a BF_3 tube with at least 200 feet of coaxial cable, without pulse transformers or preamplifiers, that would display a linear count rate with a variable base line or discriminator level. These neutron counters were to be provided for the chopper, the feed bin, the leaching hood, and for the (used) scrubber solution tank (in a moderator under the tank). An additional, portable BF_3 instrument was to be provided for the entire facility to check build-up of plutonium-bearing deposits anywhere at any time. Such instruments were procured and tested successfully in August 1961.⁴⁰⁴ Material balance and accountability for the 232-Z facility was maintained by surveying the feed waste boxes with a "package" neutron counter located in Room 161 of the 234-5 Building, then surveying the dry, canned ash that existed at the end of the incineration process with another package neutron counter.⁴⁰⁵

Other design changes were made in the 2 years before startup, in the interest of criticality safety, fire protection, cost savings, and other considerations. For example, spacers were installed in the bellows-type expansion joints at both the feed and discharge ends of the incinerator tube to prevent the bellows from filling with too much dry plutonium oxide powder. Specific inspection and cleanout and bagging procedures were established for the housing around the chopper feed mechanism because of the potential of plutonium buildup. Hood sizes and locations were changed, as was the ash hopper slide valving. Spacing of shelves for the storage of waste cartons was reconfigured, and the sumps for the three leaching pots in the leach hood were double-walled so that their effective diameter could not be increased by a leak through a single wall. Thirteen heat-detecting fire alarm devices were placed throughout the 232-Z Building, and a saw of the type used by surgeons to remove casts was procured to open boxes and cut up material in the chopper. This precaution was taken to ensure that rubber gloves and/or operators' hands could not be cut inadvertently by this instrument. Standard room air monitors were provide throughout the facility, and pressure and liquid level alarms were installed in various parts of the scrubber liquid circulation system.⁴⁰⁶

Throughout the summer and autumn of 1961, additional prestart acceptance tests and modifications of the 232-Z incinerator went forward, including

ⁱⁱ Peabody is a registered trademark of the Peabody Engineering Corporation.

changes to the "endless traveling belt" feed system. This apparatus was mounted on two stainless steel pulleys, one that served as a friction drive and one that served as an automatic tightener.⁴⁰⁷ It was made of high-nickel, high-temperature-cast 314 stainless steel mesh, and was rushed through design, testing, and modifications to address concern over the accumulating backlog of solid, plutonium-bearing scrap.⁴⁰⁸ After only a few days of testing, the belt showed "rapid deterioration...apparently the result of increased operating temperatures (1,000 to 1,090 °C) [centigrade]." It was quickly recommended that the maximum continuous operation temperature of the primary combustion chamber be kept below 820 °C (1,650 °F - fahrenheit), and that of the secondary combustion chamber be kept below 900 °C (1,650 °F).⁴⁰⁹ Further, the incinerator backfired at slow belt speeds, the vibrator chute that was supposed to deliver chopped feed to the belt did not deliver it, the feed bin chain was not sturdy enough, the feed mechanism did not seal the inlet of the chopper, and various valves, jets, insulation sections, and other components needed modifications.^{jj, 410}

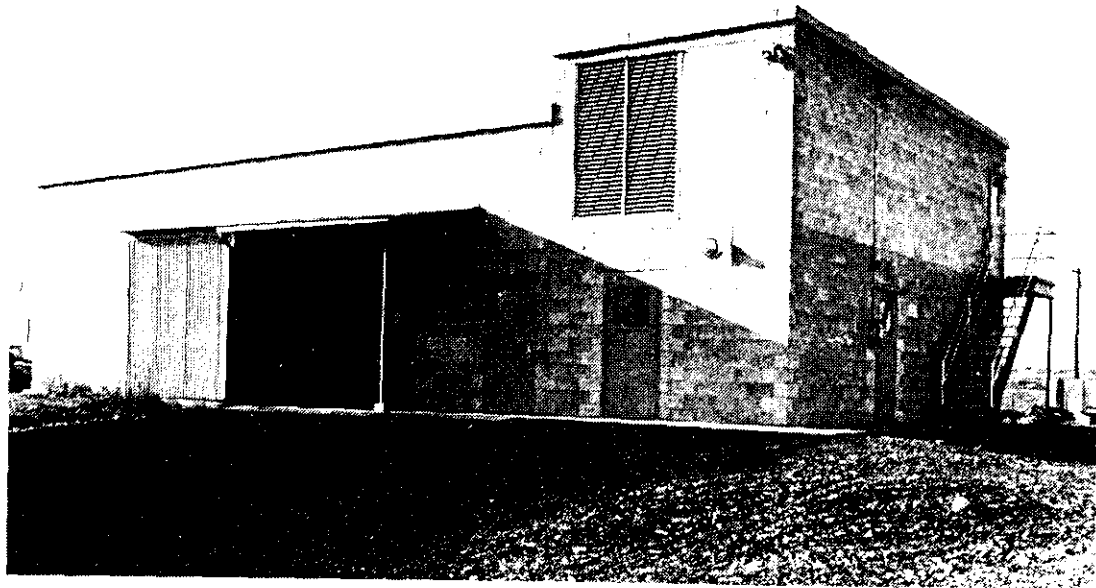
10.4 STARTUP AND EARLY OPERATIONS OF THE 232-Z INCINERATOR

Finally on January 8, 1962, full-scale operations with actual waste materials began at the 232-Z Building. Because of personnel limitations, the facility operated only 1 shift per day, and only 42 cartons of waste were incinerated during the first 3 months. Leaching operations proceeded smoothly, with plastic and rubber gloves and miscellaneous metal parts being washed in nitric acid and ANN, rinsed, and then the leach solution removed from the 232-Z Building for further processing and plutonium recovery. At the incinerator itself, however, the interwoven wires of the 314 stainless steel conveyor belt began to fail within just two months of startup. It was believed that thermal cycling had caused corrosion and an accumulation of scale on the belt. Furthermore, the belt continually jammed or slipped and needed tightening, and the chopper blades also needed frequent replacement. "Tramp" metal (small pieces or chips) in the chopper also threw sparks into the feed bin, causing fires. (See Figures 10-1 and 10-2.)

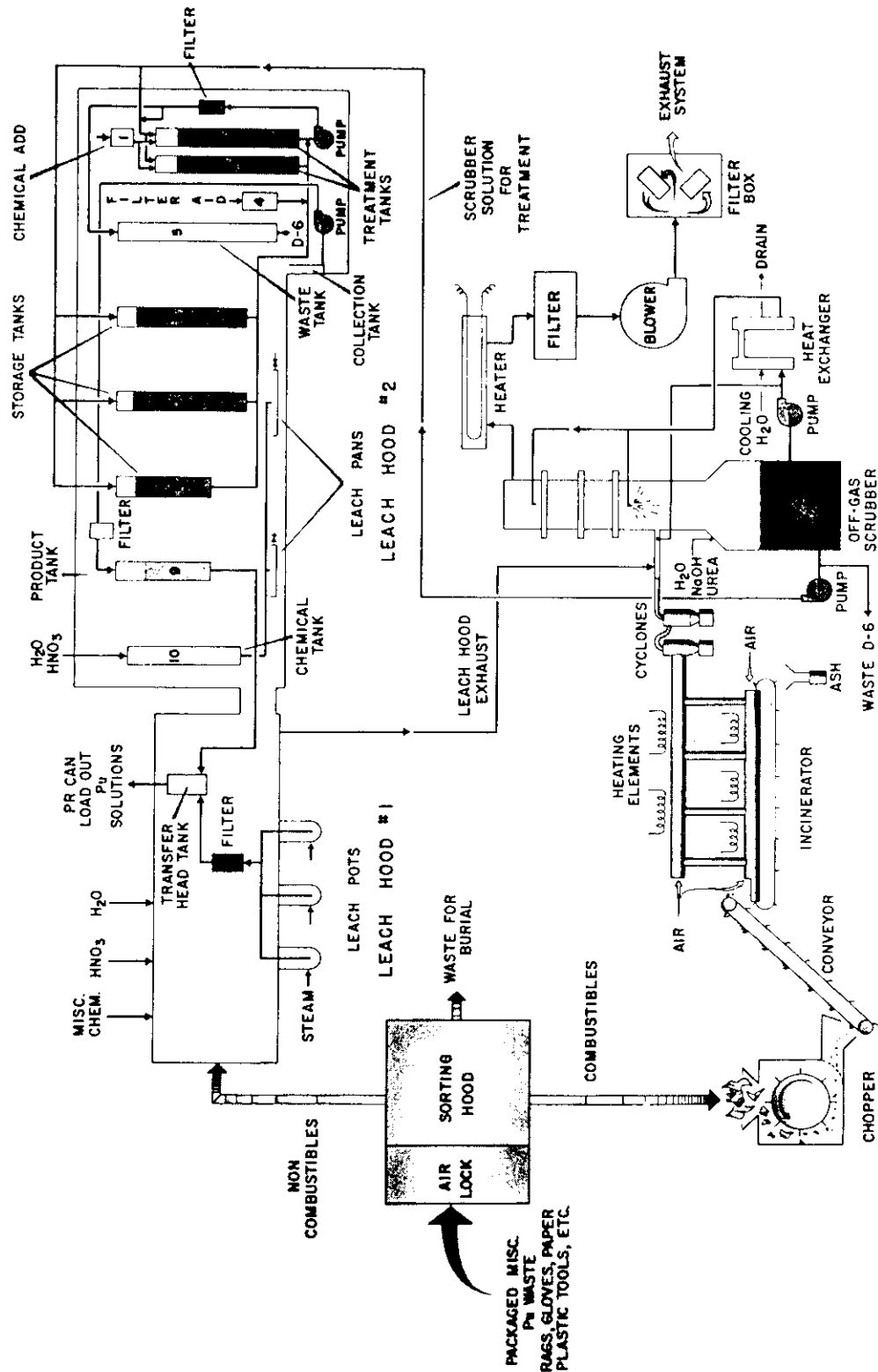
The cumulative effect of these problems was that operational time ranged from zero to 12 hours per week. Hanford Site engineers were already writing specifications for new belt materials and drive mechanisms, when the nuclear excursion at RECUPLEX stopped all PFP operations and prompted a reevaluation of criticality controls at other Hanford Site facilities.⁴¹¹ As a result, many additional checks were made on the sampling and analytical procedures used in 232-Z operations, and the post acceptance report for the facility was postponed from mid-1962 into early 1963. Operations in the building were closed for the last 3 weeks of April, 2 weeks in May, and again for 3 weeks in June. Almost as soon as incineration resumed in late June, the scrubber cell pump failed and spread contamination throughout the facility. The cleanup from this event shut down operations for nearly 2 more weeks. Again, belt

^{jj} The 232-Z Incinerator process operated such that feed was sent through the chopper into a bin from which it then exited via a rubber belt with cleats, it then fell onto the vibrating chute, and then moved onto the continuous wire mesh conveyor belt.

Figure 10-1. 232-Z Incinerator Building, New, 1962.



10-7



jamming shut down activities for a week in August, and operations throughout the rest of the year were spotty, never achieving more than 17 hours per week of operating time.⁴¹²

Reevaluation of incinerator operations, and safety and criticality prevention measures took place throughout 1962. By late 1962, with the final acceptance documents still not approved, additional engineering funds were requested to solve problems with the "feed belt, bearings, alignment, and the back-firing of the feed at the entrance to the incinerator."⁴¹³ Additionally, new and more sophisticated leaching equipment that would use an ultrasonic process for agitating the plutonium-bearing materials in a recirculating stream of chemicals was recommended. Mechanical agitation of bulk materials bearing plutonium contamination was recognized as less safe, and the capacity of the 3 existing, 6-inch leach pots was inadequate to handle to volume of non-combustible waste awaiting processing.⁴¹⁴ Yet, despite all the problems, the 232-Z facility did recover enough plutonium to achieve economic payback of its costs within the first operating year.⁴¹⁵ (See Figure 10-3.)

10.5 REPAIRS TO THE 232-Z INCINERATOR INTERRUPT PERFORMANCE

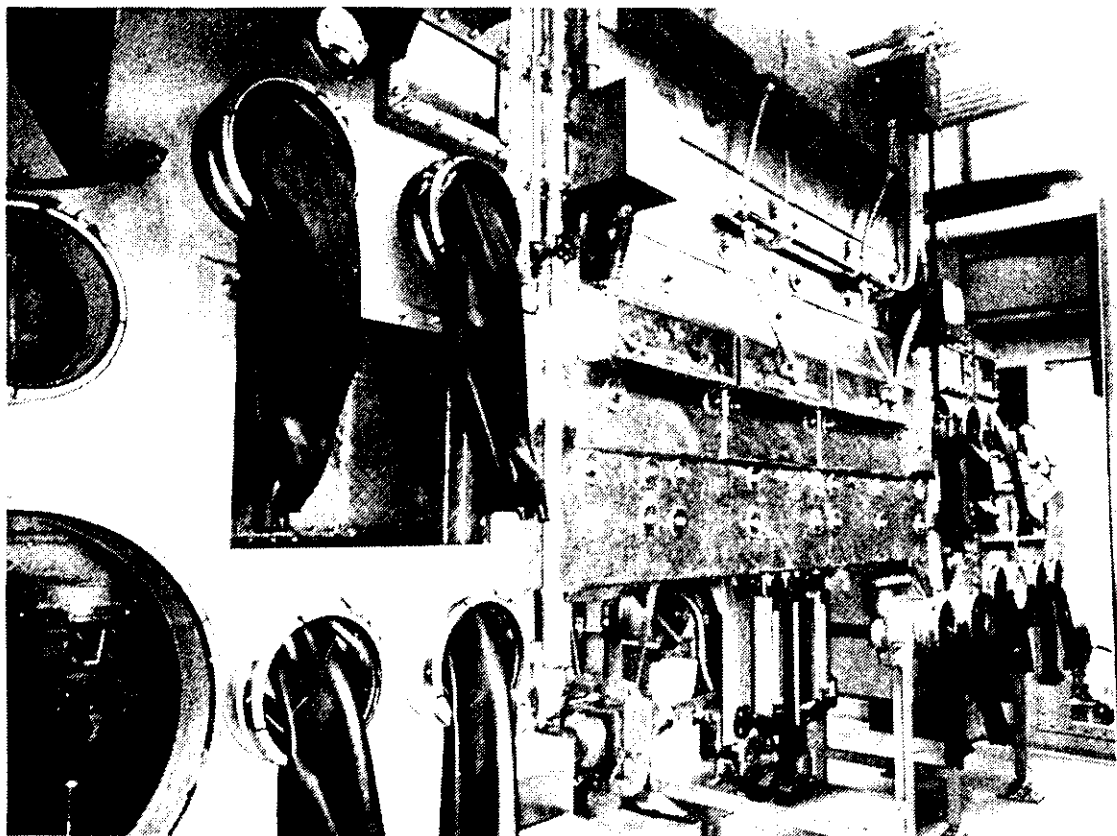
On January 25, 1963, a routine radiation survey of the incinerator glove box revealed loose contamination on an electrical junction box for the furnace heater elements. Subsequent investigation revealed that the vertical furnace flues were cracked at the points where they were welded to the burning chamber. Two repair alternatives were proposed: complete replacement of the existing combustion chambers with new units, or the simpler rewelding of the vertical furnace flues along with redesign of the expansion bellows, removal of additional structural restraints on expansion (involving redesign of the fire brick arrangement and of some piping), and reinsulation without a cementing mortar.⁴¹⁶

Because of the high demand for the facility, the latter alternative was chosen. By early spring of 1963, combustible plutonium-bearing waste was being accumulated at the rate of approximately 50 boxes per month, and about 1,535 boxes currently existed as a backlog. This waste was being stored in various locations including the electrical gallery of the inoperative B Plant, and some ammunition "igloos" left behind west of the PFP by former Army artillery guard units. Prolonged storage of this waste was considered undesirable.⁴¹⁷ Repairs and contamination cleanout went forward throughout the spring and summer. Approximately 260 grams of plutonium removed from the incinerator chambers and nearly 35 grams per foot were removed from the front portions of the exhaust line leading from the incinerator to the scrubber.⁴¹⁸ The incinerator returned to full service on September 17, 1963. Because of continual problems, however, on October 22, 1963, the 314 stainless steel mesh conveyor belt was replaced with a belt made of Nichrome V^{kk} (an alloy containing 80 percent nickel and 20 percent chromium). This belt in turn was replaced with an Inconel 600^{ll} belt on February 11, 1964.

^{kk} Nichrome is a trademark of the National Westminster Bank.

^{ll} Inconel is a trademark of Inco Alloys International, Inc.

Figure 10-3. East Side of Burning Hood, 232-Z Incinerator, 1963.



Inconel 600 is a nickel alloy that contains chrome, iron, and trace amounts of other metals. The new belt became brittle and failed on April 20. It was replaced with a stainless steel belt from spare parts, which in turn was replaced with another Nichrome V belt on July 14, 1964, and changed again on December 16.⁴¹⁹

During late 1963 (after restart) and all of 1964, incinerator operations in the 232-Z facility in fact were plagued with numerous interruptions because of various mechanical problems. Off-gas heaters, the electrical incinerator heating elements, bellows, the rubber feed belt from the chopping bin, temperature indicators, scrubber circulation pumps, and other soft components burned out and had to be replaced. Also, scrubber filters plugged, the rotating drum chopper bound up and jammed, chopper blades wore out, temperature differentials in the combustion chambers curtailed operations, and miscellaneous other difficulties were experienced. By far the most problems were encountered with the incinerator itself, however. Repeatedly, smoke issued from the combustion chambers, metallic couplings failed, numerous shutdowns occurred to remove soot buildup from the chambers and the flues, and the belt needed to be shortened and/or freed from jams on many occasions.

Sometimes the conveyance moved jerkily or stopped altogether, and frequent clean-outs of the housing at the feed or discharge ends were necessary.⁴²⁰

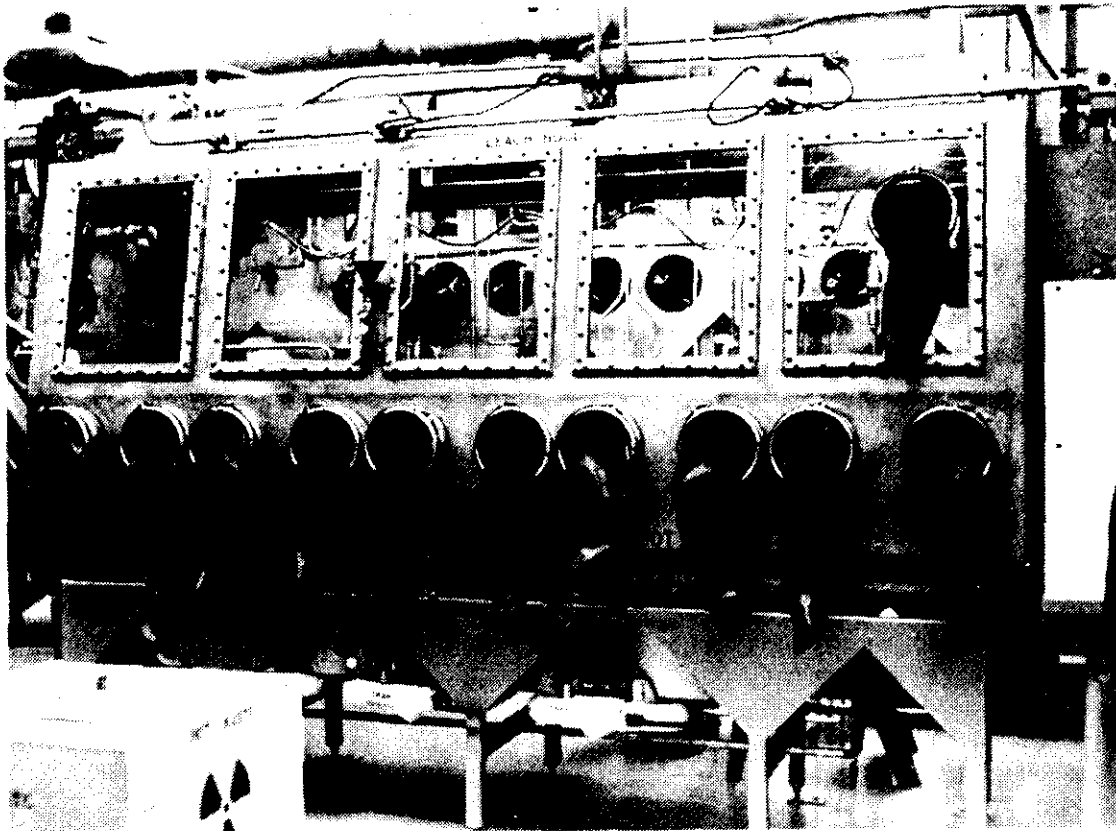
Operating reports from November and December 1963, termed performance "erratic due to a number of problems."⁴²¹ On December 17, a fire in the chopper hood burned up the rubber conveyor belt and transition bellows, and interrupted operations for the rest of the year. Another fire occurred in the chopper glove box in April 1964 and, as a result, a water-fog spray fire extinguishing system was installed in this glove box later that year. Pressurization of the ash-discharge part of the primary combustion chamber became a problem in August 1964, when ashes and "clinkers" that still were burning were discharged into the ash can and onto the glove box floor at "considerable velocity." It was not unusual to find biweekly reports reading: "Incinerator operation during this period was very erratic due to problems with the incinerator belt, the feed belt, and other miscellaneous items."⁴²² Finally, the suggestion of a millwright to cut a hole in the belt's drive drum housing to allow for inspection and cleanout of foreign matter proved to be one of the most effective ideas of 1964. In view of the numerous difficulties, less than 100 boxes of waste were processed through the incinerator during calendar year 1963, and 974 boxes were processed through calendar year 1964.⁴²³

10.6 LEACHATE FACILITY WORKS WELL WHILE INCINERATOR OPERATES ERRATICALLY

The performance of the leaching facility in the 232-Z Building was fair during 1963 and excellent during 1964, as a new leach hood for washing used anion exchange resins was placed into service on January 30, 1964. Together with the original leach hood, the new equipment processed almost continually throughout that year. Rubber gloves, metal objects, plastic sheets, solutions from Hanford Site laboratories, and materials from the cleanup of a large, late-1963 fire at HW's 233-S facility were processed successfully.⁴²⁴ (See Figure 10-4.)

Incinerator operations during the first half of 1965 progressed in unusually smooth fashion, with approximately 700 boxes of waste being processed during the first week of July. The backlog was reduced to just under 400 cartons of waste. Smoking, backfiring, and temperature differentials within the incinerator itself continued as occasional problems, along with jamming of the chopper feed belt, the frequent need to replace chopper blades, and difficulties with the pumps, filters, and valves of the scrubber off-gas system. A fire involving four glove boxes and a plastic bag port occurred on July 5. Contamination spread within the 232-Z Building and into the exhaust filters.⁴²⁵ However, on July 10, a heating element failed and the incinerator was shut down for repairs. While repairs were going forward, maintenance workers noted that the vertical flues were "broken loose" from the burning chambers. Further inspection inside a temporary greenhouse revealed the virtually complete separation of the four flues from the chambers, with large and destabilizing cracks that necessitated complete replacement of the furnace. Concluding that the 314 stainless steel "alloy for the furnace...had insufficient ductility to relieve stresses within the furnace configuration," Hanford Site scientists decided to replace the entire

Figure 10-4. Leach Hood, 232-Z Building, 1964.



unit with a new one made of Incoloy 800^{mm}, an iron alloy containing 30 to 35 percent nickel, 19 to 23 percent chromium, and small amounts of other elements. Further, a new furnace design would "permit freedom of movement between the component parts...[and would be] free of external restraints." The all-welded construction was replaced with ball and socket joints and slip joints at the top and bottom of each flue tube riser. With waste cartons being generated at the rate of 30 to 40 per month, and being stored primarily in the abandoned ammunition igloos west of PFP, the replacement project was pursued on an urgent basis.⁴²⁶

By the time the 232-Z incinerator failed in July 1965, it had recovered 157 kilograms of plutonium (or the contents of 2,400 ash cans). In view of these favorable results, and of the unfavorable waste carton storage conditions, quick repair was desired. However, fabrication to Hanford's tight specifications using the Incoloy 800 material was more difficult than expected, and the new incinerator was not available for startup until October 17, 1966. During the repair period, the fire brick and heating elements also

^{mm} Incoloy 800 is a trademark of Inco Alloys International Inc.

were replaced, and the inside of the incinerator glove box was painted with a strong polyvinyl-chloride contamination fixant. Meanwhile, leaching operations in the 232-Z facility went forward efficiently.⁴²⁷

At the startup of the Incoloy furnace in the 232-Z facility, it was decided to operate at slightly lower temperatures (below 820 °C [1,500 °F]) than had been used with the 314 stainless steel furnace to prolong the furnace's operating life. However, problems soon surfaced again. Abnormal air rates, difficulties with the ash distribution mechanisms, soot buildup, and plutonium accumulation in the scrubber components all manifested themselves during late 1966.⁴²⁸ On July 18, 1967, the new incinerator failed from thermal fatigue and embrittlement, especially in the upper (secondary) combustion chamber. As an expedient, 321 stainless steel was used to fabricate a new upper combustion chamber, because fabrication with Incoloy 800 was a specialized and time-consuming process. Further, the broken primary cyclone was replaced, the upper and lower chambers were welded together, much insulation was replaced, and temperature sensors formerly located on the outer wall of the incinerator were placed directly in the off-gas. Operations resumed on October 6, 1967, with maximum temperature guidelines of 800 °C.⁴²⁹

The combination Incoloy 800 and 321 stainless steel furnace then operated for over 2 years before it failed and was rebuilt in early and mid-1970. During those 2 years, problems with the off-gas scrubber system were the most frequent, with other temporary shutdowns caused by one major fire in the HEPA filter and localized fires in the chopper and the feed end of the incinerator glove box itself. The wire mesh conveyor belts continued to need tightening, spot welding, and periodic changeouts. The lack of good air flow control remained a basic design flaw.⁴³⁰

10.7 FINAL OPERATIONS; SHUTDOWN OF THE 232-Z INCINERATOR

Following the 1970 rebuilding and restart, the 232-Z incinerator operated for approximately 3 years. In 1972, an automatic wet-pipe fire suppression system and an attendant electrical detection and alarm system were added to the 232-Z Building, but were not installed in hood or cell areas (except for the scrubber cell) because of criticality considerations. In 1973, the 232-Z Incinerator was shut down as part of an overall PFP review of "interfaces with the environment." From 1970 through 1973, fires and other interruptions were minimized by the use of the temperature thermocouple that was located in the off-gas stream. However, the frequent alarm activations and consequent shutdowns cause a relatively low throughput rate, and the incinerator averaged only 2 hours per shift actually burning. The alarm was set to trip whenever a temperature spike occurred, no matter how short in duration. In practice, this meant a shut down every time a piece of fly ash contacted the thermocouple, followed by a complete inspection of the incinerator. Also, plugging of various parts of the scrubber system remained a constant problem, along with corrosion failure of scrubber components caused by contact with the strong sodium hydroxide-urea scrubber solution. Ten replacements of major scrubber parts proved necessary in the 2 years before the 1973 shutdown.⁴³¹

Although many suggestions for the improvement of incinerator operations were made throughout 1974-76, the 232-Z facility never restarted. As part of overall plans for environmental protection upgrades in the PFP complex in the mid-1970's (see Section 15.3), a double-encased drain line from the 232-Z facility to the 241-Z Sump was planned as Project B-118 in 1976. However, this drain line was not emplaced when the decision was made to not restart the incinerator.⁴³² Ventilation and filters were maintained in the 232-Z facility for contamination control, and in October 1979 an airborne contamination release occurred when the E-3 (operating area) HEPA filters were being changed.⁴³³

In 1980, a conceptual design report on the D&D of much of the PFP complex identified the 242-Z and 232-Z facilities as the places to begin terminal cleanout work. The work was begun in 1982, when the wall-mounted, combustible gas analyzer was removed from the facility. Some other cleanout steps were taken during 1983. The glove box assemblies were disassembled, electrical service was disconnected, and the panels were replaced on the leaching hood. In July 1983, RHO reported that "terminal cleanout of the 232-Z Incinerator is 74 percent complete...and miscellaneous glove box cleanout is 43 percent complete." Further steps were taken during 1984, including installation of sheet metal blanks on the sorting and leaching hoods, extension of heat detector and fire alarm coverage, and relocation of CAMs to preferred locations within the facility. Wiring modifications and additional CAM relocations and fire protection improvements were made during 1985 and 1988. Also in 1988, a monitoring enhancement plan was developed for the facility. A remediation project management plan was issued in 1989. However, the campaigns to restart and operate the RMC Line and the PRF during 1983 through 1989 (see Sections 3.6, 6.5 and 12.4) consumed plant resources and 232-Z cleanout was not completed. As characterization studies proceeded throughout 1989, Hanford Site managers determined that the old facility did not meet modern seismic requirements, and a specific source term reduction plan was developed in 1990.⁴³⁴

Instrument and filtration modifications and upgrades, multiple surveillances, and other activities have taken place since that time. Plutonium source term reduction work currently has achieved a specified ending inventory for the facility, but final D&D plans have not been determined.

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11.0 242-Z WASTE TREATMENT FACILITY

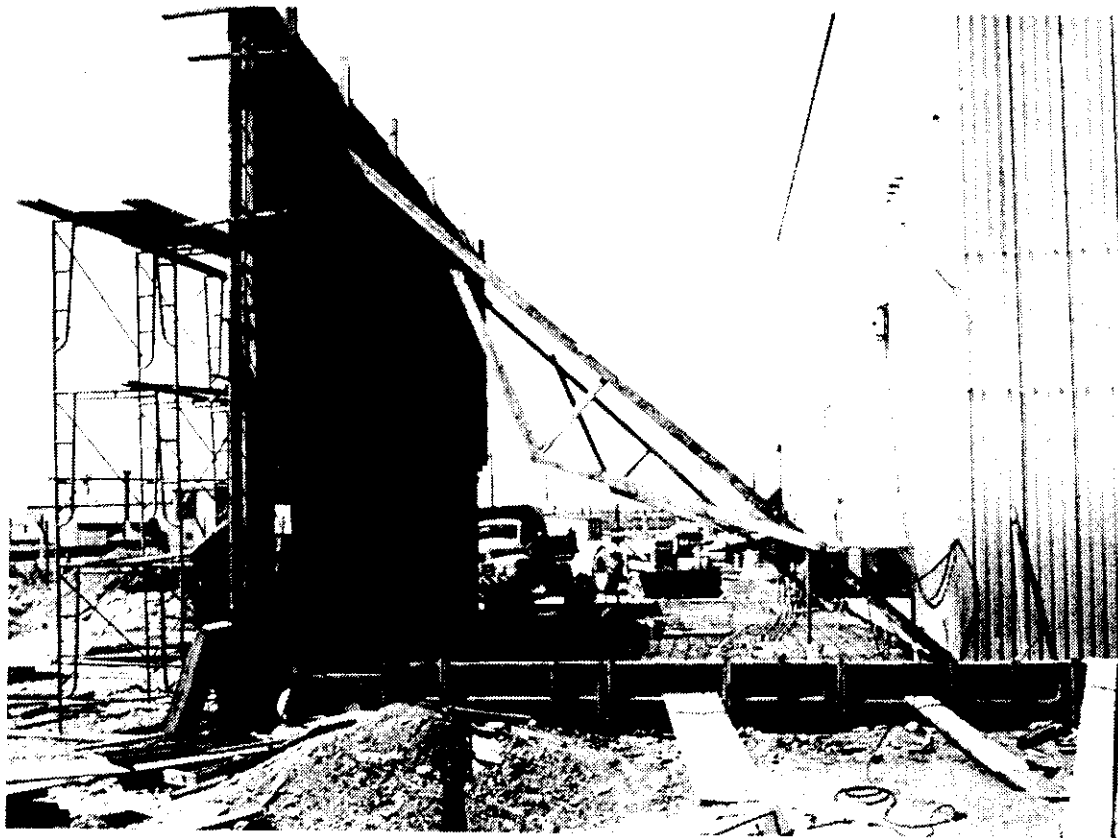
11.1 JUSTIFICATION, CONSTRUCTION, AND DESCRIPTION OF 242-Z FACILITY

As an extension of the overall effort to reclaim plutonium from waste at PFP, the 242-Z Waste Treatment Facility, Project CGC-912, was proposed in 1960 and completed in 1963. The structure recovered plutonium from aqueous waste produced in the 234-5 Building and later in the 232-Z and 236-Z facilities, via the 241-Z Sump. The 242-Z Waste Treatment Facility was proposed after studies showed that the 216-Z-9 crib, which received supernatant waste from RECUPLEX, had accumulated 14,638 grams of plutonium by the end of 1959. Also, the 216-Z-12 crib, which received general process waste from the RMA, RMC, and other PFP operations not including RECUPLEX and which had been in service only since March 11, 1959, had accumulated 1,276 grams of plutonium by the end of that year. "On occasions," revealed a 1960 G.E. Hanford Company report, "the plutonium content of the sump waste [from 234-5 operations] increases by a factor of from 10 to 100 times the normal amount...The plutonium content of the sump and solvent extraction waste represents a significant amount of plutonium which is now being disposed to ground, with the resultant hazard to ground water and possible shortening of crib life. The value of the lost plutonium is also very significant." The following year, in 1 month, over 400 grams plutonium were sent to the 241-Z Sump facility and, hence, to Site soils. At that time, a chemical flow sheet was developed for 242-Z operations.⁴³⁵

The 242-Z facility was a 1,000-square-foot building located on the south side of the southeast corner of the 234-5 Building. It was 40 feet wide, 26 feet long, and 23 feet high. The south portion of the building was 40 feet wide and 10 feet long and consisted of a tank room (tank cell). This room extended the full inside building height. The north portion was designated the control room, and had a mezzanine over its west half for chemical addition tanks. The building was constructed of structural steel with an aluminum panel outer sheath, rock wool insulation and 16-gauge sheet steel. The floor was concrete, and the south wall was reinforced concrete. The rest of the building had plaster inside and insulating material wall panels outside. The roof was slightly peaked and composed of metal decking covered by insulation and built-up asphalt and gravel. (See Figure 11-1.)

The equipment in the 242-Z Building consisted of a cation exchange column (IX) sized to process sump waste at an instantaneous rate of 150 liters per hour (W-1), a solvent exchange column designed to process the RECUPLEX waste stream at a rate of 125 liters per hour (W-2), two solvent extraction waste receiver tanks (W-3 and W-4), a product tank, a sump tank, three chemical addition tanks, process glove boxes, and an instrument control panel. A pipe trench and piping to connect the new facility to the 234-5 Building and the 241-Z waste facilities pipe trenches and piping also were provided, along with pumps and utilities. Planning and construction for the 242-Z facility were under way in April 1962, including tests on dibutyl butyl phosphonate (DBBP) as an extractant for plutonium from RECUPLEX CAW, when a criticality event occurred at RECUPLEX on April 7.⁴³⁶

Figure 11-1. 242-Z Building Construction, July 1961.



The following month, in a justification review, the CGC-912 project was deemed by G.E. Hanford Company to be of continuing importance because a new plutonium recovery facility, the PRF (see Section 12.0) was being constructed to replace RECUPLEX. However, intensive criticality reviews of the 242-Z facility were undertaken, focusing on conversion to annular, geometrically favorable column designs. Additional neutron monitors, samplers, and filters were added to the design, as well as interlocks and flow rate regulators to prevent various solutions from coming together within the process. With these modifications incorporated, the facility began operations in late 1963.⁴³⁷

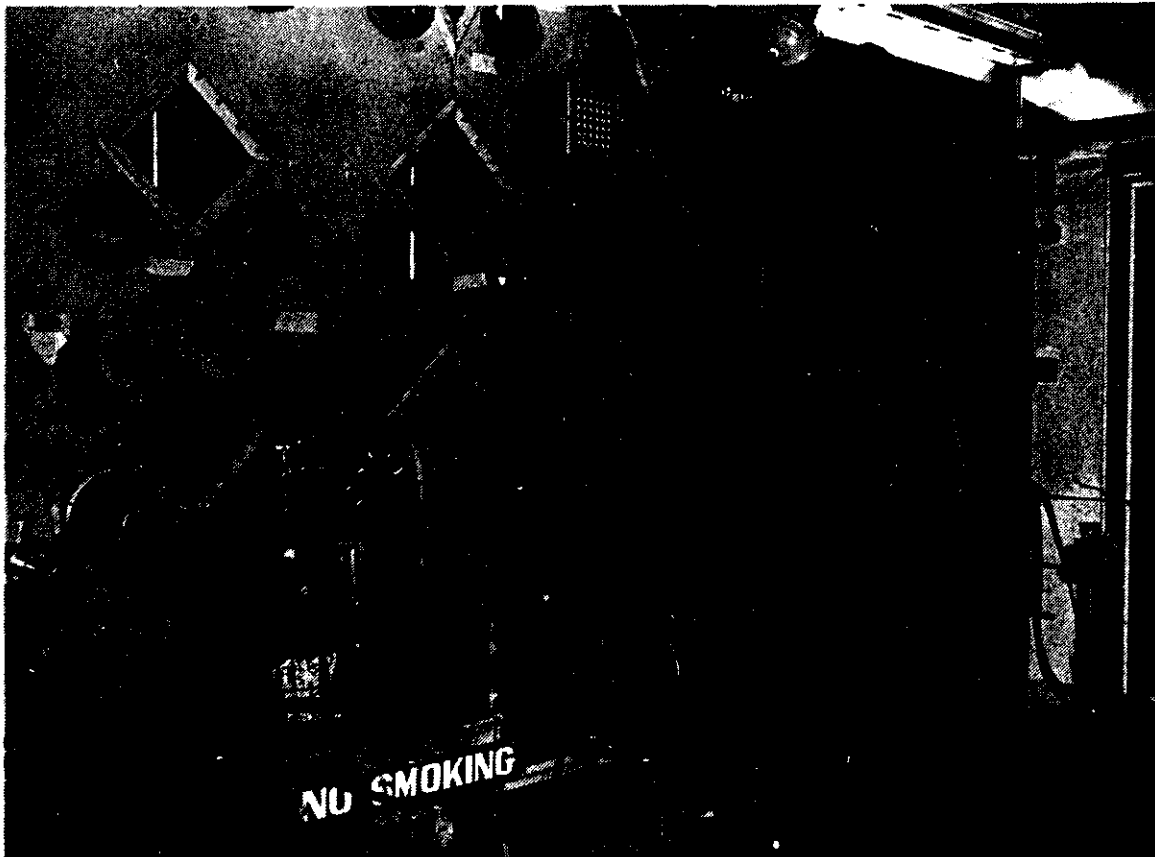
11.2 MODIFICATIONS AND PERFORMANCE AT THE 242-Z FACILITY

In 1964, an americium (Am-241) recovery system was emplaced in a glove box in the 242-Z facility it became operational in May 1965. The small, batch-type system functioned to receive acidic aqueous waste from the 242-Z solvent extraction column, neutralize the acidity with sodium hydroxide, and to coextract plutonium and Am-241 in an ion exchange system using 30 percent DBBP and 70 percent CCl_4 . The product-bearing organic phase was batch-stripped with water to remove the Am-241. The resulting aqueous phase

solution was further diluted with water to reduce the nitric acid concentration, concentrated in a cation exchange americium concentration column (W14), washed with ammonium nitrate (NH_4NO_3), and loaded into product cans as americium nitrate. In 1969, Project HCE-637 was undertaken to convert the Am-241 recovery operation from a batch to a continuous process, and to increase the purity and recovery of americium from the waste stream. A second cation exchange column (W14A) was added, and the project was completed in December 1970. Also in 1970, Project HCP-640 emplaced an automatic wet-pipe sprinkler and associated electrical fire alarm system for the operating area of the 242-Z facility.⁴³⁸ (See Figure 11-2.)

Performance in the early years of facility operations was generally good. For example, 617 grams of plutonium were returned to the process feed stream for RMC Line operations from 82,690 liters of aqueous waste feed in June 1965. In October of that year, 270 grams of plutonium were returned as feed from 81,172 liters of aqueous waste processed, and 56 grams of plutonium were returned from 56,787 liters of aqueous waste in December. Also, 8.6 grams of Am-241 were recovered from the same waste stream feed to the 242-Z facility in June 1965, 15.2 grams were recovered that October, and 8.3 grams were recovered in December. From 1966 through 1968, rates remained approximately the same, averaging about 65,00 liters of feed and yielding about 200 grams of plutonium and 7 to 8 grams of Am-241 per month. Rates dropped in early 1969 however, when the processing of plutonium-bearing ash from the 232-Z Incinerator was suspended for several months in the PRF.⁴³⁹

Figure 11-2. 242-Z Glove Box Construction, March 1964.



In the summer of 1965, the W-2 solvent extraction column, by this time processing aqueous waste from the PRF, began to experience plutonium hold-up. Gamma scans of the waste treatment vessels showed about 1,500 grams of plutonium build-up. After repeated acids flushings of the column, a process test was conducted over 3 months in the autumn. The test demonstrated that the polyethylene Raschig rings with which the stainless steel column was packed were absorbing the DBBP-CCl₄ organic extractant, thus gaining about 10 percent in weight and volume. Additional monitoring and sampling schedules were instituted so that liquids leaving the geometrically favorable column would not enter the geometrically unfavorable W-3 and W-4 waste receiver tanks without detection.⁴⁴⁰ Tests performed 2 years later found that small, insoluble solids not digestible in the 242-Z facility also were responsible for plutonium hold-up and accountability discrepancies. Just as in the PRF, the "solids issue" remained a problem for many years, especially in the geometrically unfavorable waste receiver tanks.⁴⁴¹

Throughout 1968 and 1969, neutron monitors on tanks W-3 and W-4 alarmed frequently, but repeated cell entries with neutron and gamma recounts could not find excessive plutonium build-up in the tanks. Plutonium levels in the two tanks hovered between 200 and 770 grams each, while some monitors indicated the presence of 1,500 to 2,400 grams each. Engineers puzzled over many possible causes for the high readings. During March and April 1969, 6-inch-square holes were cut in the tops of the W-3 and W-4 tanks, to allow for "direct" observation and sampling of bottom residues (sludges). Measurements taken at that time found approximately 20 liters of sludge in each tank, with plutonium levels varying from 1.5 to 50 grams per liter. The sludges were removed, dissolved, and processed through the PRF. The tanks then were flushed and 800 more grams of plutonium were removed. Intense monitoring of these tanks remained an ongoing activity at the 242-Z facility.⁴⁴²

In 1971, plans were made to replace several of the vessels and tanks in the 242-Z facility with geometrically favorable units as an aid in criticality control. However, not all of these plans were carried out. Planning also went forward during 1972 to emplace a solids-handling facility to remove solids that could not be dissolved from the 242-Z process streams. In late 1973, the screen on column W14A failed and the column was removed, but when higher americium content feed became available, a replacement W14A column was installed in December 1975.⁴⁴³ During 1974, several new and modified instruments were emplaced in the 242-Z facility. According to ARHCO, attempts also were made to address the "hydraulics problems" in the columns to increase solvent flow rates.⁴⁴⁴

In April 1975, ARHCO reported that neutron readings on the organic tank in the 242-Z facility "were found to be increasing and the waste treatment facility was shut down...in order to survey the tank for a potential buildup of plutonium." When the high neutron counts were found to be caused by the presence of Am-241, a new detector system was requested that "would not be affected by alpha-neutron reactions caused by high americium levels." Later that year, a document identifying process technology and equipment needs in the PFP complex pointed to the necessity of installing all new waste treatment solvent extraction columns in the 242-Z facility and of discovering the reasons for the "continuous overflow of the WS1 column." Also, according to ARHCO, the 242-Z facility needed to eliminate the upflow loading process for

the W-14 column because this process was believed to be causing resin damage (alpha radiolysis of the W-14 resins).⁴⁴⁵

11.3 CHEMICAL EXPLOSION BRINGS END OF 242-Z OPERATIONS

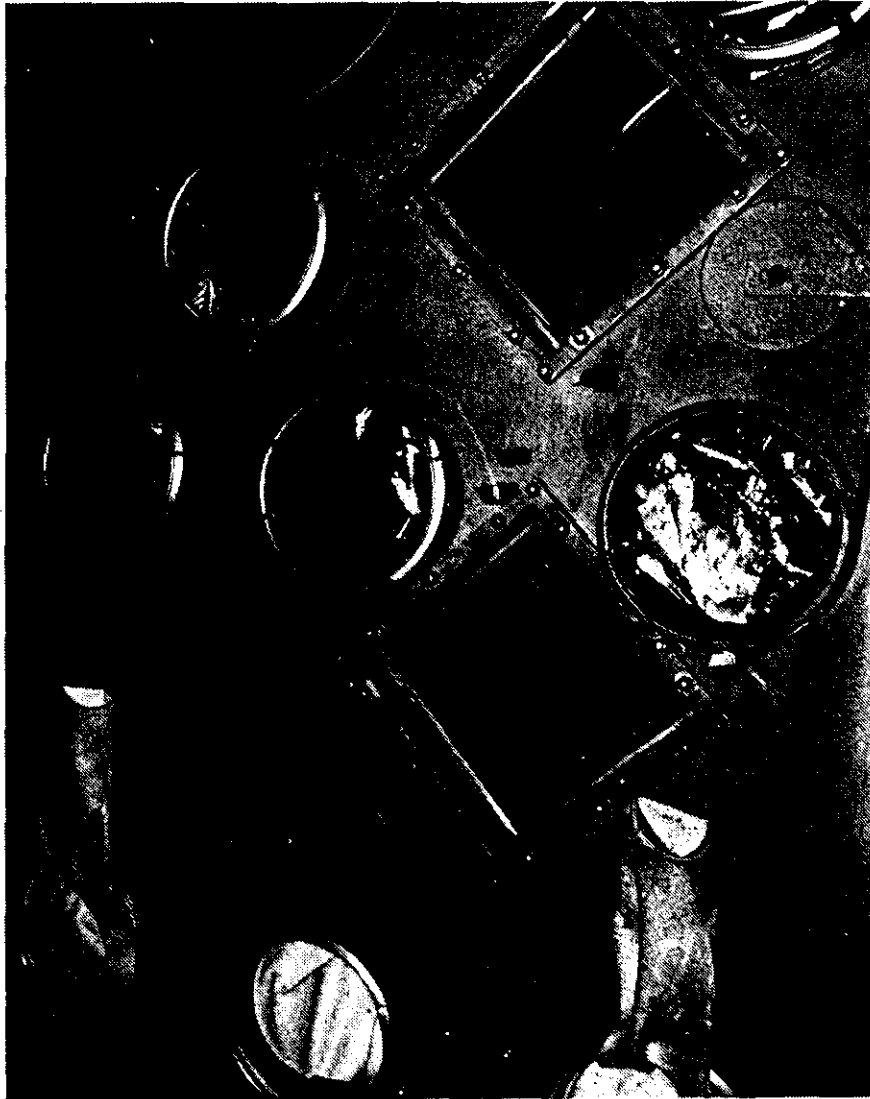
On April 30, 1976, virtually all processing stopped at the Hanford Site when the Hanford Atomic Metal Trades Council (HAMTC) went on strike. In the process of restarting operations in the americium recovery facility on August 30, 1976, an explosion occurred in glove box WT2, cation exchange W14A column, which contained about 100 grams of Am-241 that had accumulated on the resin before shutdown. The chemical operator who was standing in front of the column was grossly contaminated, and suffered facial cuts, burns, eye damage, and some Am-241 deposition. The probable cause of the explosion, according to an ERDA investigation, was an exothermic reaction between the 7 M (molar—a measure of acid concentration) nitric acid and the radiolytic degradation products from the resin in the column. An automatic pressure relief valve on the column had been removed from the equipment in 1974 because of leakage, and the pressure relief system present in 1976 was not adequate. The ERDA report also noted "the failure of management systems to recognize the hazard of...excessive radiolytic degradation of cation resin in an ion-exchange column." Recommendations for improvements were made in the areas of training, better glove box design, more thorough safety and operating procedures, updating of as-built drawings for process equipment and systems, improved understanding of the chemistry, reaction rates and activation energies of americium recovery processes, more intensive quality assurance (QA) involvement in operations, and rigorous implementation of formal conduct of operations compliance. Following the accident, the 242-Z facility closed permanently. The accident also had a far-reaching effect on operations throughout the PFP complex, because it prompted a series of evaluations that led to the decision in 1978 to D&D most of the PFP facilities (see Section 3.5).⁴⁴⁶

During early 1977, partial cleanout of the columns in the 242-Z facility took place, in preparation for column burial. However, in January 1978, RHO reported that "the cleanup effort in Glove Box WT2 of the 242-Z Building has been deferred until fiscal year (FY) 1979 due to insufficient funding."⁴⁴⁷ In 1980, a conceptual design report on the D&D of much of the PFP complex identified the 242-Z and 232-Z facilities as the first places for terminal cleanout work to begin. Such work was begun in 1982, but the campaign to restart the RMC Line and the PRF during 1983 through 1985 (see Sections 3.6, 6.5, and 12.4) consumed plant resources and little was accomplished in 242-Z cleanout.⁴⁴⁸ (See Figures 11-3 and 11-4.)

Figure 11-3. Hood Face Blown Out in Explosion, 242-Z Facility,
August 30, 1976.



Figure 11-4. Hood Panel Blown Out in Explosion, 242-Z Facility,
August 30, 1976.



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12.0 PLUTONIUM RECLAMATION FACILITY

12.1 NEED, CONSTRUCTION, DESCRIPTION OF THE PRF

During 1960, plutonium scrap recovery options were debated by the AEC. Essentially, the debate turned on whether the work should center at the Hanford Site or at the Rocky Flats Site. The volume of defense production occurring at the Hanford Site became a key factor in the decision. As G.E. Hanford Co. advised the AEC that year, shipment of HW's plutonium-bearing scrap to Rocky Flats was not recommended "because of safety hazards, accountability problems, and lack of economic incentives...A very severe problem involving relationships between AEC sites would rapidly develop if plutonium scrap material were processed at sites other than the one where they are generated." The use of "by-difference accounting" at the Hanford Site (in which "the amount charged to scrap accounts is the difference between measured input to a process step and measured output of useful product") would not always match measurements of actual materials at a distant point of receipt. According to G.E. Hanford Co., "constant haggling could be predicted." Advocating the construction of a multipurpose plutonium reclamation facility at HW, the contractor stated that an enlarged, safer, and more flexible version of RECUPLEX was needed, both to reduce plutonium discharges to cribs and to reap the economic benefits of plutonium recovery. That year, approval to begin design of the PRF was secured from the AEC.⁴⁴⁹

Construction of the PRF as Project CAC-880 began in June 1962 and concluded in December 1963. After initial test runs, hot processing began in May 1964. PRF differed from RECUPLEX in its use of a continuous organic treatment and recycle process, its remote operation, its use of geometrically favorable equipment (rather than administrative controls) to ensure nuclear safety, and, beginning in 1972, its capability for plutonium/uranium partitioning. It was originally justified "to (1) provide capacity to handle forecasted loads, (2) reduce personnel exposure to radiation under current and future plutonium processing conditions, (3) allow process work to be done in nuclearly-safe [sic] equipment (minimizing required administrative controls), (4) reduce loss of plutonium to the ground, and (5) allow future campaigned segregation of plutonium of different exposure levels." After April 1962 criticality closed the RECUPLEX facility permanently (see Section 9.8), the rapid completion of PRF became a virtual necessity for PFP operations.⁴⁵⁰ (See Figures 12-1 and 12-2.)

The 236-Z Building was a four-story, reinforced concrete structure, with a two-story penthouse over part of the main building. The main portion of the building was 79 feet wide by 71 feet long by 47.5 feet tall. The penthouse was 20 feet wide by 29 feet long by 22.5 feet tall. The 236-Z Building roof was open web steel joist framing, steel decking with rigid insulation consisting of light-weight concrete fill and gravel-covered, built-up roofing. The building had no basement. The main internal structural feature of the 236-Z Building was a single-process equipment cell (sometimes called the canyon) that was 32 feet wide by 54 feet long by 32 feet tall (extending into the penthouse to house 40- and 50-foot-tall ion exchange columns). A 2-foot-thick concrete cell wall surrounded process equipment and provided radiation shielding for personnel. Within the cell, a 10-inch-thick concrete wall shielded a decontamination and maintenance station from the remainder of the

Figure 12-1. PRF Construction, September 1962.

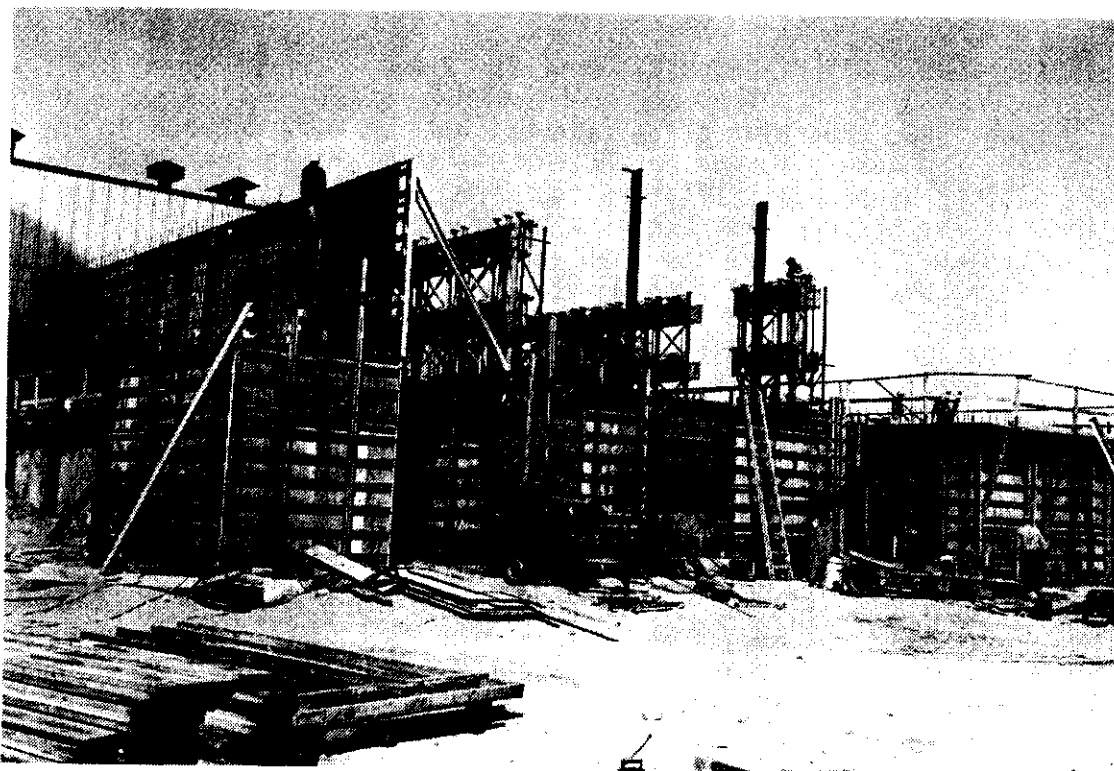


Figure 12-2. PRF Construction, October 1962.



process cell. According to the contractor, cell walls were designed such that feed with isotopic content as high as 20 percent Pu-240 and 10 percent Pu-241 could be handled "without creating a radiation exposure problem." For glove boxes, shielding was based on processing material "with a Pu-240 content of 12 percent and a Pu-241 content of 3.2 percent" on the theory that additional shielding could be "readily added at a later date." A concrete subfloor in the PRF was coated with permagileⁿⁿ sealant and a stainless steel tray covered this process cell floor.⁴⁵¹ The south wall of the process cell contained double entry doors. A large airlock structure was added outside the south wall in upgrades during the late 1970's to permit controlled movement of equipment into the cell.

Equipment in the process cell hung on the walls. A ceiling-mounted, stainless steel, remotely operated crane provided for equipment replacement in the cell. The crane was operated from viewing windows located around the cell on the second and third floors. Central control activities were carried out by operating personnel located on the fourth floor. PRF processes were conducted in stainless steel glove boxes containing glass viewing windows and hood gloves. Four main glove boxes were located on both sides of the process cell on the first two floors. They totalled 240 feet long and were approximately 8 feet high. These glove boxes serviced the connections from process cell equipment and housed control valves, pumps, flow meters, interconnecting piping, and other equipment.⁴⁵²

A cluster of five smaller glove boxes in Room 41 contained miscellaneous treatment (MT) processes. The MT (also sometimes called the gallery) was a multipurpose facility capable of small-scale processing for plutonium recovery from scrap. Primary, original equipment in Room 41 included dissolver pots, hot plates, condensers, and furnaces. Capabilities included receiving and inspection (glove box MT-1), dissolving (glove box MT-2), acid leaching and dissolution (glove box MT-5), electrolytic dissolution (glove box MT-3), and distillation and burning of plutonium-bearing organics (glove box MT-4). The MT-6 glovebox, added later, contained pumps used for solution clarification and solids removal.

Ventilation air was supplied to the 236-Z Building via a 520-foot-long, 60-inch-diameter steel duct mounted on the roof of the 234-5Z Building. At the 236-Z Building, this duct divided into distribution mains and submains for distribution throughout the building. Like other radiochemical facilities, the PRF operated with an air pressure differential that caused air from uncontaminated areas to flow to contaminated areas, then out a filtered exhaust system. Exhaust air from glove boxes and the canyon (E-4 area) was passed through three stages of HEPA filters. The first two stages were contained in filter boxes located near the sources; the third stage filters were located in Room 26 (second floor). Filtered air from these areas was combined with room air (E-3 area) that had been passed through a single HEPA filtration stage, routed through an underground, concrete duct to the 291-Z Stack Building, and passed out of the building through the 291-Z-1 stack.⁴⁵³ (See Figures 12-3 and 12-4.)

ⁿⁿ Permagile is a trademark of the Morhan Crucible Company PLC.

Figure 12-3. Construction of PRF's Ventilation Tie-In to the PFP Building, November 1962.

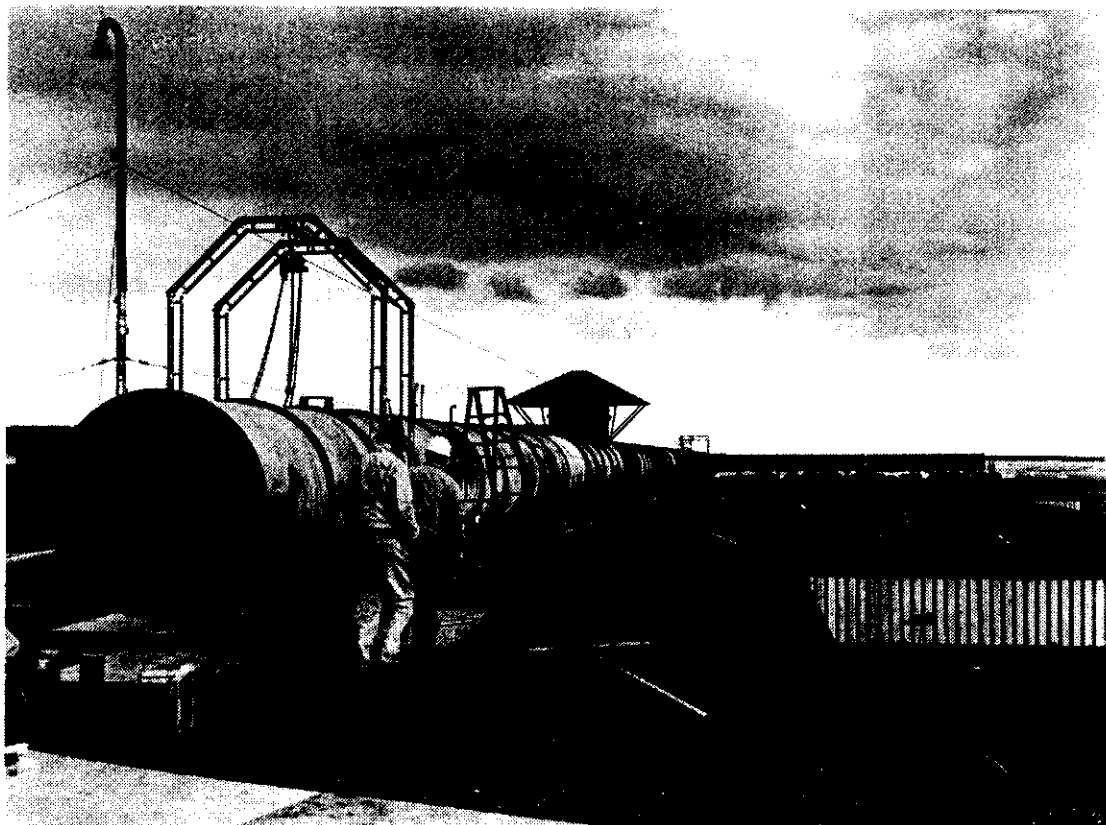


Figure 12-4. PRF Internal Construction, Room 44, August 1963.



The PRF underwent several design revisions during its scoping and construction period. Some were based on cost reductions, some on lessons learned in the RECUPLEX accident report (see Section 9.8), and some on better definition of needs and products as the New Production Reactor (NPR, later shortened to N Reactor) was developed. Proposals to incorporate a uranium product partitioning capability in the facility were submitted in 1963, and refined over the following 2 years, but were not built into the PRF until 1972.⁴⁵⁴

As finally constructed, the PRF was unique. Other plutonium recovery systems in use at the Los Alamos Site, the Rocky Flats Site, and the Savannah River Site were based on single or adjoining glove boxes, operated manually through protective gloves. None of these other recovery installations incorporated a dedicated solvent extraction system capable of returning a plutonium nitrate product to the feed stream of a plutonium metal-making line. Plutonium reclamation was conducted via ion exchange at the Rocky Flats and Los Alamos Sites, and via solvent extraction at the Savannah River Site, albeit not with a heavy organic extractant such as TBP-CCl₄ capable of producing concentrated plutonium nitrate. Recovery equipment at these other sites furnished products that still needed much additional processing before being ready as feed for plutonium metal production. The PRF used a continuous solvent extraction process to convert various plutonium-bearing scrap materials into a concentrated plutonium nitrate product suitable for feed back into the RMA and RMC Lines.⁴⁵⁵

12.2 THE PRF PROCESS

Operations with hot feed began in the PRF on May 6, 1964. The PRF process began with the MT system, located on the fourth floor of the facility. Dissolution or leaching of plutonium-bearing scrap took place in an MT glove box under reflux in aqueous solutions of HF acid, nitric acid, ANN and sodium fluoride. Plutonium-bearing scrap that already existed in aqueous solution bypassed the MT system and entered the next phase of PRF processing (solvent extraction [SX]) from a transfer station located in Room 19 of the 236-Z Building. (Upgrades completed in 1983 emplaced equipment for the transfer of plutonium-bearing scrap already in aqueous solution in a glove box located in Room 227 of the 234-5 Building.) Also, beginning in 1967, a solids removal step, accomplished through centrifugation, was added before material entered the solvent extraction columns.⁴⁵⁶

Solvent extraction in the PRF took place in the canyon, and was accomplished by countercurrently contacting the aqueous phase with a TBP/CCl₄ organic phase. Extraction occurred with plutonium remaining in the organic phase and the aqueous phase retaining the metal nitrates and other waste. Parallel pipelines brought PRF (aqueous) process waste to cribs south of the facility (see Section 15.1).⁴⁵⁷

After the aqueous waste was removed in the PRF process, the organic phase containing the plutonium was contacted with a nitric acid-hydroxylamine nitrate (HN) solution that stripped out the product. This aqueous phase was concentrated as plutonium nitrate, while the stripped organic was sent to a cleanup and recycle treatment. In a variation to the standard PRF processes, added in early 1972 (see Section 12.3), uranium could be extracted from the

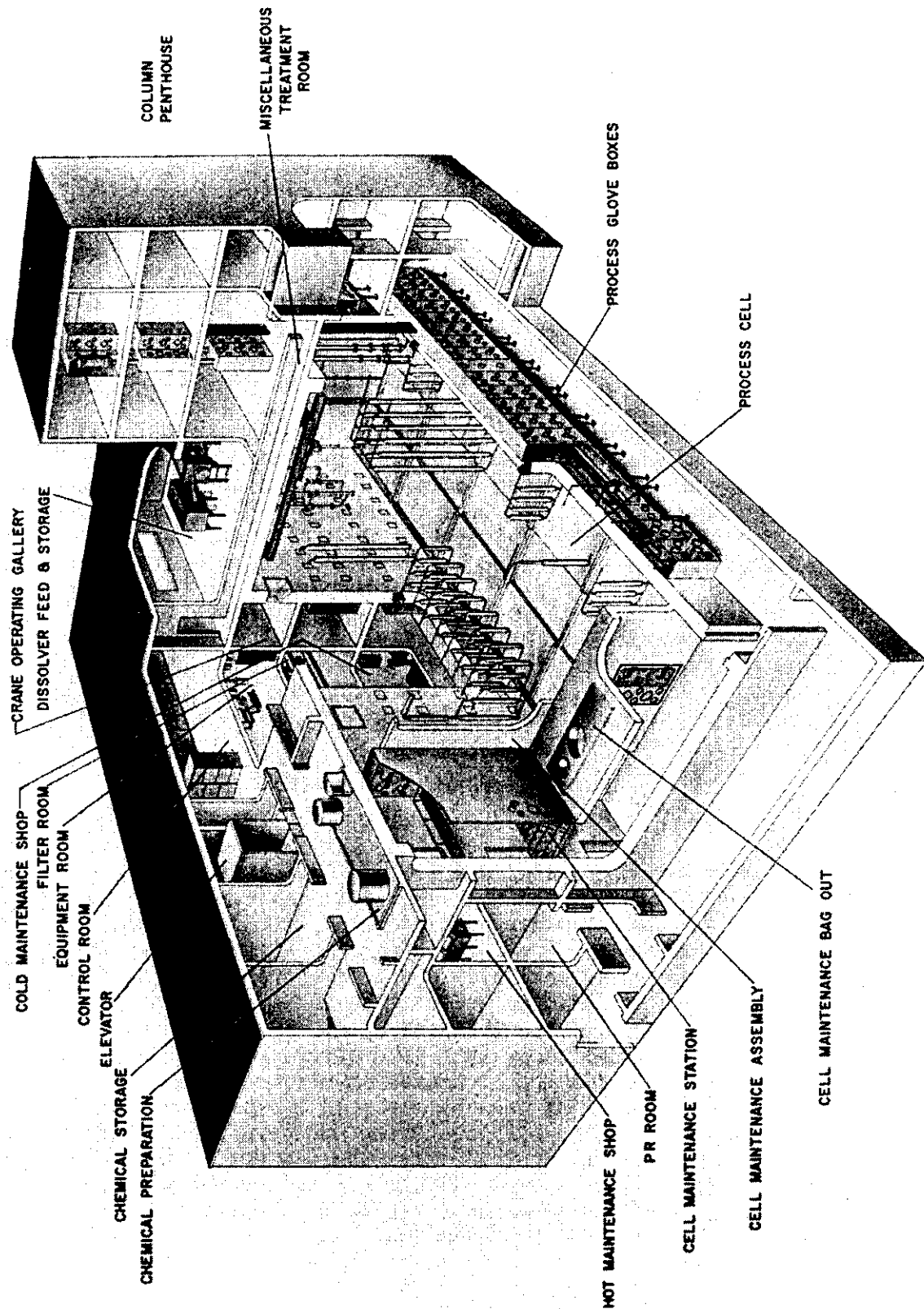
aqueous solutions that were produced by dissolving contaminated scraps. At the point where the plutonium in the organic phase contacted the HNO_3 -HN solution and was stripped into the aqueous phase, the uranium stayed with the organic. Just as in the standard process, this organic was sent to the cleanup and treatment system, where the uranium was stripped from it along with nitric acid. This uranium product could be processed in Hanford's Uranium Trioxide (UO_3) Plant.⁴⁵⁸ (See Figure 12-5.)

12.3 PRF BUSY IN LATE 1960's, EARLY 1970's: CSMO MISSION ARRIVES

Early performance in the PRF was generally satisfactory, but accompanied by some problems that would stay with the facility for many years. Sometimes known as the "880 Facility" in the early years, because it was built as Project CAC-880, the PRF initially contained two dissolvers known as Mark I and Mark II. During 1965, amounts ranging from 45 to 121 kilograms of plutonium nitrate would be returned to the RMC Line as feed as a result of PRF processing. A Mark III dissolver was added in 1966, and the PRF began to set records described by the contractor as "particularly impressive." In May 1966, 1,856 cans of feed were processed through the PRF, although the yield was relatively low (49 kilograms of plutonium) because of the low concentration characteristics of the feed. A record 1,856 cans were processed through the PRF in May 1967, yielding 34 kilograms of plutonium nitrate. At the same time, the facility was featured in *Chemical Engineering* magazine as a "truly unique plant," and a high-resolution, closed-circuit television system was procured for viewing inside the canyon. However, frequent pump failures occurred caused by corrosion from the HF acids, the ANN, and the TBP- CCL_4 mixtures. The dissolvers often were out of service for maintenance, and particular problems were associated with the propylene pall rings in the column used to strip plutonium from the extractant. These rings were replaced with Teflon and Kynar rings in late 1966.⁴⁵⁹

Perhaps the most significant difficulty in early PRF operations soon became the MUF (material unaccounted for) issue. The amount of special nuclear material that should have been in the facility and/or discharged in waste forms differed from the amount placed into the facility as feed. In April 1967, the contractor reported that "new data indicate that small but significant amounts of plutonium may be associated with solid particles (less than 12 microns in diameter) in the wastes from the Plutonium Reclamation Facility. The solids...are not soluble in nitric-hydrofluoric acid mixtures. The losses have not been detected before because the current analytical procedures are not designed to cope with the chemical inertness and small size of the particles." PRF engineers by this time estimated that "approximately 20 percent of the plutonium [in the MT dissolver product solutions was]...associated with the solids and not measured by the standards method of analysis." By July, the PFP sample laboratory had developed a better measurement technique (see Section 7.7). Its use led to the tentative conclusion that plutonium losses from PRF CWW (CW column waste) were "a factor of 3 or more greater than that previously reported." Waste from the CA and CX columns likewise contained undesirable solids. In September, equipment for the filtration of column interface solids was installed in the PRF's CA column, and testing was in progress. The following month, a CAW centrifuge was installed to remove the solids to discharge less process organic to the 216-Z-1A crib that served the PRF. At the same time, the discharge point for

Figure 12-5. Schematic of the PRF Process, 1984.



the 216-Z-1A crib was moved 75 feet south. However, the centrifuge experienced multiple problems to the point that it was inoperable most of the time by year's end.⁴⁶⁰

Throughout 1968, the situation with the centrifuge remained a problem, but somewhat improved. In July, facility engineers reported that centrifuge operation "was not good. The bowl dropped twice at times when the centrifuge was unattended, allowing CAW to spew out of the centrifuge." During much of the summer, it operated only 50 percent of the time. In December, however, it operated 81 percent of the time, in part because a frequent preventive maintenance schedule and flushing program was initiated in the autumn. Also, a solids filter emplaced on the CA column reduced the burden on the centrifuge and contributed to improved operations. At year's end, the AEC plant appraisal still noted a problem area for the PRF in "the quantity of plutonium discarded...[particularly] the solids problem."⁴⁶¹ The solids issue at the PRF remained difficult until a new, more sophisticated, prototype solids handling facility was emplaced in 1972 to separate and cement non-leachable solids with scrap materials. The solids handling facility was crucial to meeting product purity specifications in the PRF, and to limiting crib discharges of plutonium. Emplaced as Hood 6 in the MT, the prototype equipment consisted primarily of centrifuges and a vacuum pump. It was ready for testing in January 1973.⁴⁶²

Late in 1967, a large new mission was explored for the PRF when a study was completed, finding that "multi-kilogram quantities of mixed plutonium-uranium scrap...[were] stored at various sites throughout the AEC complex." In 1968, laboratory demonstrations and Process Test PRF 68-1, Plutonium-Uranium Partitioning, were performed successfully, showing that mixed plutonium-uranium (MOX) scrap could be processed in the PRF and separated to a plutonium product stream and a uranium product stream. These demonstrations led to Project HCE-651, Plutonium-Uranium Partitioning, which was completed in early 1972.⁴⁶³ In April 1967, the PRF began Process Test PRF-67-2, to pilot test methods of dissolving plutonium-bearing ash in the S&C dissolvers. Ash dissolving continued throughout 1967 and into late 1968, with some equipment problems and plugging. In late September, Process Test PRF-68-2 was begun, in which ash was reburned through the 232-Z Incinerator before being dissolved for plutonium recovery in the PRF. The reburned ash seemed to filter faster and did not result in the product bottles being coated with film. In November 1968, according to facility engineers, "an explosion or implosion occurred in...a routine ash dissolution in the No. 5 glass dissolver (Hood 5)...which caused it to shatter...Inspection of the off-gas and vent system showed a restriction on the vent pipe."⁴⁶⁴ Incinerator ash burning was discontinued in the PRF by AEC order on January 9, 1969, but resumed again that June.⁴⁶⁵

Other operations at the PRF during 1968 included Process Test PRF-67-4 to dissolve plutonium-aluminum turnings from a Hanford Site production experiment (see Section 5.12), and a very short campaign in Hood 227 to burn polystyrene cubes from other Site experimental work (see Section 7.7). In February, a piping modification was completed to permit concentration of aqueous solution that had accumulated on the PRF canyon floor in the filtrate concentrator (Tank 21) for subsequent processing through the solvent extraction columns. Approximately 1,100 liters of floor solution were processed in the first 2 weeks. Processing of plutonium fabrication oil and

the troublesome chloride wastes from this activity and other processes resumed in the summer. According to ARHCO, chloride processing had terminated the previous March "due to priority assignments" in the PRF. In early August, the filtrate concentrator at PRF failed and needed repair for the first time since start-up in May 1964. When it was dismantled and flushed, 800 to 900 grams of plutonium were removed from the components. In mid-September, a pressurization event occurred during an acid addition in a chemical make-up tank. ARHCO reported that the hydroxylamine nitric acid solution "foamed, causing the small make-up tank to...blow solution upward through the dry chemical addition port." In December 1968, in response to a new AEC directive, the PRF began a campaign to identify, sort and repackage various scrap liquids and oxides from polyethylene and other containers of short-term reliability into metal containers. In just 1 month, 221 cartons of scraps were repackaged. Throughout the year, equipment breakdowns requiring maintenance outages plagued the PRF.⁴⁶⁶

By 1969, according to ARHCO, the PRF was processing approximately 4,000 scrap items per month, "representing several tons of solids which contain only a few kilograms of plutonium." An International Business Machines (IBM) 7090 computer was being used to keep track of plutonium-bearing scrap inventory located in quonset huts to the west of the PFP. Ash dissolution activities from the 232-Z Incinerator, solids dissolution (plutonium metal and plutonium oxides), solvent extraction, and "unique processes" (for materials "not adaptable for direct input to other processing" operations were performed routinely.⁴⁶⁷ In January 1969, Process Test PRF-68-3 was begun to dissolve plutonium-aluminum turnings in higher concentrations than had been dissolved previously. Hood 60 remained in operation throughout 1969, processing chloride scraps. The burning of polystyrene cubes resumed in Hood 227 on March 18, after nearly a year of down time. During June and July 1969, Process Test PRF-69-1, Dissolution of Magnesium Oxide Crucibles with PV Lids in the S&C Dissolvers was run with good results. After that time, such dissolution became routine at PRF. Maintenance of equipment remained an ongoing burden in the 236-Z Building, because of the high corrosivity of the process solutions. The CAW centrifuge and the solids filter demonstrated very good performance, with the centrifuge operating usually above 90 percent of column time.⁴⁶⁸

PRF operations continued in a routine manner throughout 1970, but by the end of the year, equipment maintenance problems were such that replacements and upgrades had to be planned. During 1971-1972, several upgrades were made to PRF equipment, instrumentation, and alarm systems. Liquid level alarms with an annunciator panel, new process furnaces, many new valves, a continuous gas analyzer, and other items were emplaced, and hazards reviews were conducted.⁴⁶⁹ Also in 1972, automatic wet-pipe fire sprinkler systems, with attendant electrical detection and alarm components, were added to all areas of the PRF not already equipped, except for Cell 12 and the process hoods.⁴⁷⁰

As a combined result of the advantages offered by the success of Project HCE-651 at PRF, the emplacement of the solids handling and fire safety equipment, other upgrades at the PRF, the addition of continuous Am-241 recovery equipment at the 242-Z facility (see Section 11.2), and other advantages present in the PFP complex, the AEC/RL was assigned national responsibility for plutonium-bearing scrap management activities (except for

Pu-238 scrap) in 1972. The CSMO was established at AEC/RL, with its first goal being the reduction of backlog scrap to a 6-month inventory (i.e., plutonium scrap received during the last 6 months). This goal was considered important because of the problems associated with the buildup of Am-241 (an intensely radioactive alpha emitter) in aged plutonium scrap. Over the preceding years, the different goal of reducing the quantity of plutonium within scrap had "resulted in the processing of easily-processed scrap rich in plutonium and storage of lean, difficult-to-process scrap." As a result of these policies, noted the CSMO program plan in 1972, "essentially all of the stored plutonium will require americium removal before it can be utilized." The CSMO plan outlined an ambitious, complex, and interlocking project for scrap processing that used virtually all aspects of PFP equipment and operations, and that eventually would recover plutonium from current PFP waste streams and even from soil containing discarded plutonium. "Environmental restoration offers a real future for this new facility [CSMO]," wrote ARHCO in late 1972.⁴⁷¹

Throughout the years of burgeoning non-defense production work in the PFP (mid-1960's through early 1970's) (see Sections 13.2 and 13.3), fuel-grade scrap receipts from off the Hanford Site arrived at the PRF in growing quantities. The CSMO mission quickly increased the scrap receipts. These materials were processed in the PRF along with onsite scraps for plutonium recovery, with the added advantage that the plutonium/uranium partitioning facilities were available after March 1972.⁴⁷²

Between May and early July 1973, the PRF stood down for a review of all PFP complex interfaces with the environment (see Section 15.3). Restart was followed by a period of "accelerated schedule" work to dissolve a backlog of scrap. During the remainder of the year, PRF operated normally to process both defense and non-defense scrap and reject metal, making plutonium nitrate that served as feed for the FFTF oxides being produced in the A-Line (see Section 5.13) and for other PFP uses.⁴⁷³ At nearly the same time, two electrolytic dissolvers were emplaced in MT Hood 3 to directly dissolve reject plutonium metal in nitric acid by application of an electric current. The new dissolvers were more efficient than the old methods involving burning plutonium metal to produce oxides, then pulverization and lengthy dissolution of the oxide, to produce the desired plutonium nitrate product. A new flowsheet for "semicontinuous dissolution" of plutonium dioxide was developed for the PRF to solve the problem of excessive heels being built up in equipment caused by the incomplete dissolution of the oxides. An engineering study to replace the PRF's product evaporator also was performed, but the equipment was not replaced at that time. Once again, multiple equipment repairs and replacements were necessary.⁴⁷⁴

Throughout 1972 to 1976, in concert with other efforts at the PFP complex to reduce effluents disposal and find better waste management practices (see Section 15.3), trials were made in substituting less damaging solvents in the PRF (see Section 7.8). However, a computer program known as SEPHIS (Solvent Extraction Process Having Interacting Solutes) demonstrated that the TBP/CCl₄ system had the most sound technical basis for accomplishing the PRF mission, and this system was still in place in 1976.⁴⁷⁵ During this period, several operating cost studies also were performed at the PRF. The metal portion of the ventilation duct from the 236-Z Building to the 291-Z Stack also was replaced.⁴⁷⁶ Hood 4 in Room 41 was fitted with

improved equipment to burn polystyrene cubes imbedded with PuO_2 for plutonium recovery. The new process was demonstrated in a successful 10-day run in October 1972, and then started up full scale in January 1973. The polystyrene burning work continued through mid-1976. A violation of criticality prevention specifications occurred in February 1976 when an incompletely distilled cube was moved into the furnace section, accumulating too many full boats of material in one place.⁴⁷⁷ Ash burning continued throughout 1975, as did dissolution of plutonium-aluminum turnings, non-defense scrap receipts from off the Hanford Site, and plutonium/uranium partitioning activities.⁴⁷⁸ In April 1975, a criticality prevention specification was exceeded in Hood 6 of the PRF, when 1,165 grams of plutonium accumulated in the centrifuge.⁴⁷⁹

Throughout 1974 and 1975, the PRF continued to experience multiple equipment problems, requiring maintenance outages and replacements. In August 1975, ARHCO reported that the PRF "operated only about 25 percent of the time...due to corroded pumps, valves and lines failing and being replaced...Longer operating times were prevented by frequent failure of system components. A procedure departure notice was written to operate the dissolvers bypassing the failed interlock system."⁴⁸⁰

In November 1975, the fiscal year 1976 technology planning document for the PFP complex was produced. It identified a long list of upgrades for the PRF, reflective of the aging and corrosion of equipment, the need for processing flexibility and efficiency, and the mandate to continue to improve waste management practices (see Sections 15.3 and 15.4). Among the salient needs were improved methods for processing "slow recovery"-type scrap (small batches with unusual contents) and low-plutonium scrap, development of flow sheets for plutonium recovery from "graphite scarfings," improvements in techniques for crushing and burning polystyrene cubes for plutonium recovery, and the use of induction heating for the dissolver pots. Improving waste management practices also led to the eventual installation and use of continuous dissolvers (with a prototype continuous dissolver hood scheduled to be installed in Room 42 in late 1976), contingency planning and staging for various scrap campaigns, replacement of vacuum transfer lines in Hoods 5 and 6 in Room 41, replacement of Tank 39, replacement of the conductivity probes in Tank 17, better metering and control of the CAW stream neutralization, and general upgrading of instrumentation. As in previous years, the need to develop alternative organic extractants both to preserve equipment and to upgrade waste management practices, was identified. That year, PRF operating specifications, standards, and procedures were revised, emphasizing "process control points." In December 1975, procurement was undertaken for a new remote monitoring system for the PRF, consisting of an in-canyon counter, a new closed-circuit television, and the necessary protective housing for this equipment. However, funding for this system was withdrawn by ERDA in March 1976.⁴⁸¹

12.4 MID-1970's THROUGH LATE 1980's BRINGS SHUTDOWNS, CLEANOUTS, RESTARTS TO THE PRF

The PRF was shut down from late December 1975 through March 15, 1976, for maintenance upgrades and reviews of criticality prevention specifications and procedures. After restart, it had operated only about 2 weeks, when it was shut down again after a release of contamination above limits to the

216-Z-19 ditch.⁴⁸² After another brief restart, all Hanford Site production operations were shut down on April 30, 1976 because of a strike by HAMTC. When the strike ended in late August, PFP operations resumed, but were soon shut down again because of the explosion in the 242-Z facility (see Section 11.3). The resulting accident investigation kept all PFP operations in standby until late 1976. PRF operations then continued in shutdown status for 19 months, while hazards reviews and planning for upgrades took place. According to the contractor, "leaking piping and equipment...prevented successful operation. Examination of the plant revealed severe corrosion in the process lines." Replacement of many equipment pieces was recommended, including a new plutonium product concentrator, a new feed measurement tank for material accountability, several other tanks, and an organic removal system for aqueous waste treatment. During this stand down period, the PRF flowsheets also were studied and revised, the canyon airlock was added, and a sound barrier was installed in the control room. In some cases, hood leaks were repaired with coats of Devcon^{oo}, an industrial sealant. In January 1978, according to RHO, "all irradiated, nitrated resin" at the facility was buried, "thus completing a major...milestone."⁴⁸³

One salient, unresolved area of concern at the PRF was the integrity of the liner of the canyon floor. It was covered with a contaminated sludge resulting from glove box and piping leaks. The floor could not be examined thoroughly because of the accumulation of these plutonium-bearing solutions and solids. Also, the process hoods needed to be cleaned out to assess their integrity. Physical techniques and process chemistry for a cleanup campaign were developed and/or validated by the PFP's developmental laboratory and engineering development laboratory (see Section 7.8). A batch-operated "slurp system" was used, basically consisting of a slurp head, two glass tanks, a pump, two filters, and related piping. Floor materials were slurried with nitric acid, settled, filtered, and mixed with CCl_4 to remove soluble and entrained organics. The resulting material was transferred to the PRF's solvent extraction system for plutonium recovery. The PRF cleanup campaign took place from April 1978 to February 1979.⁴⁸⁴

In early 1978, the DOE mandated planning for the D&D of the PFP complex. A key role in scrap processing, as part of terminal cleanout operations, was identified for the PRF, with some scenarios forecasting a longer term role in scrap recovery. Such planning prompted assessments of the operability and viability of the PRF. One assessment report issued in April 1979, stated that the 236-Z facility was deficient in meeting then-current design criteria for plutonium facilities in terms of seismic, tornado and fire requirements. However, the report concluded that, "due to demonstrated sound safety management practices, the remote location of the plant and its many years of accident-free operations, the level of risk to...employees and the general populace is determined low enough to justify continued operation."⁴⁸⁵

A 2-year standby period (1980-1981) ensued, during which planning went forward for the processing of reactive scrap. Hoods 60, 5, and 6 would be used to prepare feed for the PRF's main solvent extraction systems, Hood HC-227-S would conduct solution blending, the filtrate evaporator would concentrate wash solutions, and the PRF's plutonium nitrate product would go

^{oo} Devcon is a trademark of the Illinois Tool Works Company.

to the RMA Line for calcination into oxide form. At the same time, alternative planning took place that might have emplaced a plutonium scrap processing facility in PUREX's N Cell. This facility was not constructed. While it was decided not to operate the RMA Line (see Section 5.13), an intensive period of upgrades and modifications went forward at PRF during 1982 to 1984. Improvements to the PRF during this period included new neutron monitoring equipment, 5 new centrifuges, 50-liter and 200-liter bank tanks. Process and operating specifications, as well as flow sheets, were rewritten for most PRF processes.⁴⁸⁶

The PRF restarted on January 1, 1984, and operated until November 18, 1984. The next campaigns were from December 17, 1984, through May 31, 1985; then December 23, 1985, through March 31, 1986; then July 1, 1987, through December 18, 1987. During the last RMC Line campaign at the PFP (July 1988 through June 1989), the filtrate evaporator and some storage tanks at the PRF were utilized to support the C-Line mission. During the 1984 campaign, the distillation and burning of polystyrene cubes for plutonium recovery was conducted in the MT area, but was not resumed in the subsequent campaigns because of persistent problems with the process. During the 1987 campaign, potential personnel exposure to carbon tetrachloride vapors occurred during transfer of the chemical between a drum and a vessel in late August.⁴⁸⁷ (See Figures 12-6 and 12-7.)

Upgrades continued at the PRF before each of the three 1980's campaigns, and into the early 1990's in preparation for yet another restart. Upgrades included new instrument air dryers, centrifuge repairs and parts replacements, new valves and jumpers inside glove boxes, and many other improvements. Protective shields were fabricated for glass tanks, welds were inspected and sometimes redone, civil and as-built drawings were verified and corrected, and procedures and flow sheets were reworked.⁴⁸⁸ During the mid-1980's, the PRF was considered a pilot plant to verify a process known as TRUEX (transuranic extraction) that would have separated the high-level and low-level fractions from the Hanford Site's tank farms waste before its final processing into solid forms for long-term storage. However, the TRUEX process was abandoned in the early 1990's.⁴⁸⁹

Beginning in 1989, the PRF was swept into larger safety and political concerns that enveloped the entire PFP (see Sections 16.1 and 16.2). As the Hanford Site's mission turned from production to waste cleanup with the signing of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement), the PFP complex began planning for terminal cleanout and stabilization of reactive, plutonium-bearing solutions. The PRF was to receive upgrades then function to conduct much of the required stabilization. A prototype air-pulsed liquid-liquid extractor was developed to test methods to optimize operation of the extraction columns in the PRF. A training run was conducted as a demonstration of operator proficiency in the PRF during mid-1994. However, agreements with Hanford Site regulators prevented full restart, and the PRF did not operate again.⁴⁹⁰

Figure 12-6. Operator Works at the PRF Access Glove Box, Second Floor East, 1980's.



: Figure 12-7. PRF Control Room During Last Campaign, 1988.



12.5 PRF DEACTIVATION PLANNED

In 1996, a deactivation plan for the PRF was submitted by the contractor, outlining phased activities beginning with more thorough characterization and definition of the hazards within the 236-Z Building. Together, DOE and contractor organizations responsible for both deactivation and eventual full D&D for the facility will define end-point criteria for the PRF's condition at the time it is turned over to the D&D group for long-term surveillance. Public shareholder involvement will be sought in this attempt to exercise "right to left" planning. To keep deactivation actions cost effective, their end points must be defined and agreed to before physical work begins. Following deactivation actions pioneered at the Hanford Site's PUREX Plant, 236-Z Building systems and spaces will be placed in categories based on the goals for each area. The possible categories are isolate and contain, monitor and control, refurbish or install, or document and label. Once deactivation objectives are clearly defined, safety authorization bases will be developed for the activities, regulatory partnering will be pursued, work plans and engineering plans developed, schedules defined and controlled, and work teams formed.⁴⁹¹

13.0 NON-DEFENSE WORK IN THE PFP

13.1 NON-DEFENSE WORK INTRODUCED TO THE PFP

Even before weapons fabrication work in the 234-5 Building began to shrink in the 1960's, new initiatives were undertaken to interface with the burgeoning commercial nuclear industry. With the impetus of the first U.S. commercial nuclear power plant at Shippingport, Pennsylvania completed in 1958 as a joint venture with the AEC, the commercial nuclear power industry was growing exponentially. In late 1962, the AEC asked the G.E. Hanford Company to investigate the feasibility and costs associated with receiving, storing, and disbursing power reactor-grade ("fuels grade") plutonium. The AEC wished to "buy back" plutonium produced by power reactors that operated on uranium fuel supplied by the Commission. The economically valuable plutonium would later be sold for use in research programs or for fueling plutonium recycle reactors. (The plutonium recycle concept was being tried at the Plutonium Recycle Test Reactor in the Hanford Site's 309 Building.) The following year, the Rocky Flats Site engaged in a demonstration project to pilot the "shipper-receiver procedures and techniques" for handling plutonium nitrate. In early 1964, the AEC designated Hanford as the site for full-scale implementation of this program. Plutonium would be separated from spent fuels and purified at Nuclear Fuels Services (NFS) facilities in West Valley, New York, and shipped to the Hanford Site as plutonium nitrate.⁴⁹²

During 1965-66, receiving, repackaging, and storage facilities were built into Room 227 of the 234-5 Building as Project CGC-180, Plutonium Buy-Back Facility. The project was completed in May 1966. Meanwhile, production of specially blended, non-defense plutonium oxide for EURATOM (European Atomic Energy Community—a consortium of the governments of France, West Germany, Italy, the Netherlands, Belgium, and Luxembourg) for commercial nuclear power development was begun in the PFP in September 1964. Also in 1964, the 234-5 Building began supplying non-defense plutonium (also known as "unclassified Pu") to Hanford's 209-E Critical Mass Laboratory for experimental purposes, and to NUMEC ((Nuclear Materials and Equipment Corporation), for fuel development tests for the SEFOR (Southeast Experimental Fast Oxide Reactor). SEFOR, located in Cove Creek Township, Arkansas, was a sodium-cooled reactor that was used for early research on fast breeder reactors. During occasional periods in 1964 and 1965, non-defense plutonium production constituted the majority of production at PFP.⁴⁹³

On the basis of "projected increases in plutonium requirements and the wide variation in compound forms being requested, a "special plutonium preparation facility" was proposed for the developmental laboratory in the 234-5 Building as Project CAC-138. The facility would prepare "special plutonium compounds," mostly oxide blends and metals with unique isotopic blends for commercial and experimental customers. According to the contractor, the facility was justified on the grounds that it would "minimize interference with routine production and with critical research and development activities." However, with the downturn in defense production beginning in 1965, this facility was not constructed.⁴⁹⁴

When the AEC announced its decision to withdraw defense plutonium fabrication work from the PFP in late 1965, a diversification study was undertaken for the building. The study stated that encouragement should be given "to the growth of a competitive commercial capability in the field of plutonium processing and fabrication...comprehensive plutonium fabrication service [should be made available] to industry and government." The PFP complex, the study also noted, "could serve industry needs for storage and accountability, scrap handling and reclamation, quality control, and analytical support." Aside for plutonium-related work, the diversification study also looked to processing work with "other promising alpha-emitters" such as polonium 210, neptunium 237, uranium 233, americium 241, curium 242, and Pu-238 (generally used for non-defense purposes). Small, specialized work in precious-metal recovery, formulating krypton- or tritium-bearing materials, manufacture of specialty ceramic products, and "limited production of high-purity metals" also were listed as future 234-5 Building activities with high potential.⁴⁹⁵

13.2 RAPID EXPANSION OF NON-DEFENSE WORK DURING 1966-1969 AT PFP

Large-scale interaction with the commercial nuclear industry, nuclear research customers and foreign nuclear customers became a reality at PFP in 1966. Although the RMC Button Line operated to produce weapons-grade plutonium buttons during the early months of the year, it was "cleaned and inventoried" in late April and began "the processing of plutonium from N Reactor" containing approximately 12-percent Pu-240—a non-defense isotope (see Section 6.3). For the remainder of the year, both defense and non-defense shipments were made from the PFP. Among the non-defense customers for plutonium nitrate, oxides, and metal were Battelle Northwest (BNW), the Hanford Site's research and development contractor, United Nuclear Corporation, Inc. (UNC), EURATOM, Parkwell Laboratories, Argonne National Laboratory (ANL), Oak Ridge National Laboratory (ORNL), General Electric Vallecitos Inc., Monsanto Chemical Corporation, and Babcox and Wilcox, Inc. Non-defense plutonium also was received at the 234-5 Building as scrap from BNW, from the Rocky Flats Site, and from NUMEC, and either processed and blended into a different form or stored. Late in the year, Isochem, Inc. bid to fabricate 40 percent of the plutonium ingot fuel elements for the Zero Power Plutonium Research Reactor (ZPPR), then being built by ANL at the National Reactor Testing Station (NTRS), now known as the Idaho National Engineering Laboratory (INEL). Isochem Inc. also bid to begin a Pu-238 scrap recovery program in the 234-5 Building.⁴⁹⁶

Throughout 1967, non-defense work continued as an important part of 234-5 Building activities. The RMC Line operated to fill orders for non-defense materials approximately 36 percent of the time. The contract to blend and cast ZPPR ingots was secured, and well over 1,000 kilograms of this material were produced. Materials were assembled in HC-21A and HC-21AX, cast and broken out in hoods HC-19 A1 and A2, stored in Hood HC-45S, and machined and inspected in hoods HC-24B and HA-19. Aside from the use of Hood HA-19 in the A-Line, the ZPPR work was performed in the C-Line. Most of the ZPPR ingots were shipped to the Rocky Flats Site for fabrication, but some were shipped to NUMEC for sampling and test activities. Other non-defense work consisted of receiving and processing fuels-grade plutonium scrap from NFS and NUMEC, high-exposure plutonium (24-percent Pu-240) from the Shippingport

reactor, and Pu-238 from a special production test at the Hanford Site's N Reactor. Non-defense shipments were made to the same customers as in 1966, plus Battelle Memorial Institute in Ohio (BMI or Battelle-Ohio), some classified customers, and an NFS facility in Erwin, Tennessee.⁴⁹⁷

As the commercial nuclear industry continued to expand, non-defense work went forward as a part of PFP activities in 1968, occupying about 30 percent of the facility's time and effort. According to the Hanford Site operating contractor, anticipation of further non-defense work in the facility was definite in mid-1968. "Plutonium oxide or mixtures of plutonium-uranium oxides for reactor programs will probably be supplied in large quantities" from the 234-5 Building.⁴⁹⁸ In support of the expanded work scope, the oxalate precipitation and oxide portions of the RMA Line were cleaned out and reactivated (see Section 5.13). At the same time, specialized equipment to evaluate and perform QA testing on plutonium oxides and mixed oxides, prepared for commercial and experimental reactor use, was emplaced in the PFP analytical laboratory (see Section 7.7).⁴⁹⁹

Throughout 1968, the ZPPR ingoting program continued in the PFP, with over 1,000 kilograms produced. A year-end appraisal of 234-5 Building operations particularly commended "the excellent success and the punctual supply of specification ingot plutonium to the ZPPR Program." Other non-defense work in 1968 included shipments to many of the same customers as in 1966 and 1967. Additional customers were W.R. Grace Corporation, United Nuclear Inc. of Pawling, New York, New Brunswick Laboratory, and Atomics International. Two special orders for non-defense, plutonium oxide blends were filled for BNW, which was renamed Pacific Northwest Laboratory (PNL) late in the year. One order was for experiments in the Plutonium Recycle Critical Facility (PRCF) in the Hanford Site's 309 Building, and the other was for "pre-qualification test material for potential fuel fabricators" for the FFTF, the nation's prototype "breeder reactor" that would be built at the Hanford Site. The FFTF order involved 59 kilograms of oxide material blended from NFS and PUREX feed. Non-defense scrap shipments were received at the 234-5 Building from NFS, NUMEC, ORNL, BMI, Westinghouse Electric Corporation, Carborundum Corporation, and the SRP.⁵⁰⁰

During 1969, non-defense work in support of commercial nuclear fuel development became a greater part of PFP activities. Melting, ingoting, and casting of the very-high-exposure (26 to 27-percent Pu-240) metal for ZPPR ingots continued, as did the blending of 11- to 12-percent Pu-240 oxides for FFTF development. Shipments of non-defense material to many of the same offsite customers continued, plus shipments to SRP and the Brookhaven National Laboratory (BNL) as fuels-grade customers. That year, 106,499 grams of fuel-grade metal in the 234-5 Building were placed under control of the IAEA in September, and 7,770 grams in the 224-T Building were placed under IAEA control in December (see Section 14.2). The receipt, identification, sorting, and repackaging of non-defense grade scrap increased in the PRF (see Section 12.3).⁵⁰¹

13.3 FFTF SUPPORT AND OTHER NON-DEFENSE WORK AUGMENTED AT THE PFP IN 1970-1973

The processing of non-defense metals and oxides in the 234-5 Building increased again in 1970. In July, processing was begun on a large order of plutonium oxide (dioxide) for use by the new FFTF development contractor, the Hanford Engineering Development Laboratory (HEDL), a Hanford Site contractor and subsidiary of Westinghouse Electric Corp. The RMA Line in the PFP operated to convert plutonium nitrate to plutonium oxide, which in turn was used by FFTF contractors to fabricate pellet fuel for Cores 1 and 2 of the test reactor. Other new PFP customers for non-defense plutonium that year included Union Carbide Corporation, Kerr-McGee Corporation, Idaho Nuclear, and National Nuclear Corporation. The DuPont Corporation at SRP also became a PFP customer when a special order of high Pu-240 metal was needed for a "Deep Burn Californium" experiment. Additional fuel-grade material in the 234-5 Building was transferred to IAEA control during 1970, and in September the first "utility-grade" plutonium in the buy-back program arrived at PFP from NFS.⁵⁰²

In 1971, non-defense work, especially in support of FFTF development, remained important in the 234-5 Building. With this work expected to increase, Project HCE-658, Plutonium Oxide Handling Facilities, was installed to provide special shielding and modifications to the discharge system in Hood H-9A, and to the second-stage calciner and powder storage facilities in the A-Line. The project was justified on the basis that "personnel receive[d] excessive radiation exposure while handling the oxide." Also in 1971, a specific glove box for analyzing plutonium oxide was emplaced in the PFP's developmental laboratory (see Section 7.8), and quality verification plans were written to cover all oxide testing procedures. Non-defense shipments were received from previous shippers, as well as from General Nuclear Corporation, the United Kingdom, ANL, Monsanto Chemical Laboratory, Kerr-McGee Corporation, Babcock and Wilcox Corporation, Atomics International, Los Alamos Scientific Laboratory (LASL), and the Donald W. Douglas Laboratories.⁵⁰³

Throughout 1972, non-defense work continued as a salient function in the 234-5 Building, with the production of plutonium oxides for FFTF development a key activity. The LASL was added as a new customer for fuel-grade oxides from PFP, and fuel-grade scrap receipts arrived from the previous shippers as well as from Allied Chemical Corporation, Gulf-United Nuclear, Monsanto Chemical Corporation, HEDL, and the Rocky Flats Site.⁵⁰⁴ Also in 1972, a study was conducted by the Hanford Site's operating contractor to examine a role for the 234-5 Building in Operation Plowshare, a national AEC program to use nuclear explosives for large land excavations and oil and gas exploration. Part of the "peaceful atom" programs of the AEC, Plowshare would have used some defense-grade and some non-defense grade plutonium to fashion specific nuclear explosives tailored to individual excavation jobs. The Hanford study concluded that the PFP complex facilities offered a "powerful system" in support of Plowshare programs. This work, which would have greatly expanded the 234-5 Building's non-defense role, never came to the facility because the program lost its funding at the national level shortly after the 1972 study was completed.⁵⁰⁵

During 1973, work on production of oxides for FFTF Cores 1 and 2 continued at PFP. One lot, produced in April, included excessive cadmium contamination and needed to be reworked. Looking ahead that year to anticipated increases in non-defense work, ARHCO began design studies for a new, high-exposure plutonium processing facility to be constructed in the 200 East Area, near the PUREX Plant, to produce oxides for FFTF's Core 5 beginning in 1978. The aging A-Line was not to be considered for this work. New shippers of non-defense, plutonium-bearing scrap to the PFP complex in 1973 included Schlumberger Wells Services Inc., Dresser Industries, McCullough Services (Baroid Division of the National Lead Company), Seismograph Services Corporation, the University of California at Berkeley, Lockheed-Georgia Company, Halliburton Company Welox Division, Case Western Reserve University, and General Motors Corporation. Many of the industrial shippers had used radioactive sources as neutron sources, tracers, and tools in industrial processes.⁵⁰⁶

In general, the RMA Line program to produce oxides for Cores 1 and 2 for the FFTF was successful, and it continued until April 1975. However, laboratory verification tests of the oxide product in mid-1974 at both PFP and Los Alamos Site laboratories showed high amounts of calcium and carbon impurities. Some other oxide lots produced in early 1975 also tested out of density specifications. Additional non-defense customers and shippers to PFP in 1974 included Johns Hopkins University and the University of Dayton. Plutonium-beryllium sources used in experiments were a major form of the scrap shipped by universities.⁵⁰⁷ New shippers in 1975 included the University of Wisconsin, the Laboratory for Electronics, Inc., Teledyne Isotopes Company, the Industrial Reactor Laboratory, Louisiana State University, Rockwell International, EON Corporation, Aerojet Nuclear Inc., and an unidentified Australian shipper. During mid-1975, the A-Line produced a small order of experimental plutonium oxide with a high Pu-240 content for the Westinghouse (Company) Advanced Reactor Department. The autumn was spent updating procedures and quality verification plans for the RMA Line, and submitting samples, for the expected startup of oxide production for FFTF Cores 3 and 4.⁵⁰⁸

In January 1975, a personnel contamination incident and spread of radioactive contamination occurred in Room 166 of the 234-5 Building as plutonium nitrate feed for non-defense oxide production was being sampled out of the feed blending tanks. Later that year, a personnel exposure review of the processing of PuO_2 in the RMA Line was completed, revealing an ongoing lack of adequate shielding for gamma radiation (Hoods 7A and 9A). The study covered plutonium dioxide processing from August 1973 through February 1975. The isotopic content of the non-defense plutonium required the additional shielding.⁵⁰⁹

13.4 END OF NON-DEFENSE WORK AT THE PFP

During the first half of 1976, the RMA Line continued preparation for the production of non-defense oxides for FFTF Cores 3 and 4 (see Section 5.13). Shipments of non-defense, plutonium-bearing scraps to the PFP continued from many of the usual customers, as well as from new shippers including the National Bureau of Standards.⁵¹⁰ After the 1976 accident at the 242-Z facility in the PFP complex (see Section 11.3), the ERDA began a

long evaluation of the continued viability of the PFP facilities. In 1977, the contract to produce oxides for FFTF Cores 3 and 4 was given to SRP, with subsequent shipment of these oxides to the Hanford Site for sampling in the HC-21A glove box, part of the inactive fabrication equipment in the RMC Line. Blending and repackaging of the SRP-produced oxides also took place at the PFP. This campaign to produce ceramic-grade plutonium dioxide for FFTF fuel cores 3 and 4 at SRP continued through 1978. Final analysis and blending of the FFTF oxides was completed in the 234-5 Building as of January 31, 1979.⁵¹¹

In January 1978, the DOE ordered studies to begin for the D&D of most of the complex (see Section 3.5), signaling an end to the 234-5 Building's role in commercial-grade plutonium production. The PRF closed for upgrades and modifications in 1976, and remained closed for 7 years (see Section 12.4). In 1977, the CSMO mission terminated at the Hanford Site (see Section 8.6), virtually ending defense-grade scrap shipments to the Hanford Site. The stabilization of reactive scrap items was pursued as a major mission at the PFP throughout the late 1970's and early 1980's, using various 234-5 Building glove boxes until the PRF restarted in January 1984. However, the legacy of non-defense grade scrap at the PFP still totalled thousands of items when a comprehensive count was made publicly available in 1996. Some of this reactive scrap had to be repackaged over the years, because of the buildup of hydrogen gases in storage containers (see Sections 14.4 and 14.5), resulting in operator exposures from normal and off-normal repackaging operations in some cases. In one example in 1966, during removal of a pressure vessel flange lid from an L-10 (10-liter) shipping container, an operator, and one corridor in the 234-5 Building were contaminated with plutonium. The L-10 containers were polybottles inside of stainless steel sleeves, containing plutonium and uranium in solution with various acids.⁵¹² Issues associated with the final stabilization of the many scrap items resulting from the PFP's non-defense work of the 1960's and 1970's are discussed in Sections 16.1 and 16.2.

14.0 PLUTONIUM FINISHING PLANT

14.1 EARLIEST PLUTONIUM STORAGE FACILITIES

Plans for the original 234-5 Building included a large storage vault, but to meet the need for speed and expediency, these plans were deleted from the project in October 1947 (see Section 2.2).⁵¹³ When the facility opened in 1949, Rooms 166, 173, 174, and 175 on the first floor were designated as vault rooms for plutonium storage and were equipped with automatic electrical protective and annunciation devices. Doors to process areas and the rooms used as vaults were constructed of steel with safe-type combination locks.⁵¹⁴ These rooms, along with other rooms designated for storage; the 711 Waste Storage Hut constructed in 1952; and storage facilities in the 221-U, 221-B, 271-T, and 224-T Buildings; contained the various plutonium-bearing materials processed through the 234-5 Building during the first 13 years of PFP operations (see Sections 2.8 and 10.3). Abandoned ammunition "igloos" from the former Camp Hanford (an Army anti-aircraft installation) west of the 200 West Area were also used for storage during the 1960's. (see Section 10.3).⁵¹⁵

By 1962, plutonium processing at PFP was at record levels (see Section 3.2), and attention was given to building improved, dedicated plutonium storage facilities. In October, Project CGC-968, Additional Plutonium Storage Facilities, was authorized. It provided for the addition of storage facilities for plutonium ingots, materials needing rework, castings, feed material, and finished components in the 234-5 Building. This project, completed in late 1963, also afforded improved facilities for loading out finished components.⁵¹⁶ In 1963, a fire occurred in a waste carton being stored in the 711 Waste Storage Hut in the PFP complex. The fire spread contamination throughout hut. The following year, as a result of the fire, the hut was equipped with a new fire detection and alarm system.⁵¹⁷ That year, the decision was made to store plutonium at the PFP in all-metal containers after pyrophoric hydrides were found to be forming as a result of plutonium corrosion in plastic-lined containers.⁵¹⁸

14.2 MISSION CHANGES AT PFP BRING NEED FOR IMPROVED STORAGE FACILITIES

After weapons-shaping work was removed from the PFP in December 1965 (see Section 3.3) and non-defense work began to increase in the facility (see Section 13.2), new missions were considered for the 234-5 Building. One of these missions focused on the recovery of plutonium from multiple types of plutonium-bearing scrap (see Section 12.3), including scrap from other government and commercial research and production facilities. Another new plan for the PFP envisioned a role in international agreements for safeguarding plutonium. Both missions depended on having larger, more reliable storage facilities. In 1967, a study conducted for the AEC found that up to 5 years' production of weapons-grade plutonium could be stored in the west end of the 234-5 Building either as metal or as oxide. Additional plutonium could be stored in the REDOX canyon, which had closed earlier in 1967; in the U-Plant galleries, idle except for storage missions since 1958; and potentially in the 2101-M Shop facility and temporary sheet metal buildings.⁵¹⁹

During 1968, the PFP began participation in an "International Safeguards Experiment" in which some of the plutonium nitrate in the 234-5 Building (and some stored in the 224-T Building) was accessed and inspected by the IAEA, a multinational, nonproliferation group headquartered in Vienna, Austria. Safety reviews of the 10-liter polyethylene bottles used to ship and store plutonium nitrate were conducted. At the same time, equipment modifications in the PRF allowed more flexibility in scrap recovery operations there, and the PRF's mission in processing offsite, plutonium-bearing scrap expanded (see Section 12.3). Concurrently, the 1968 year-end appraisal for plutonium finishing operations by the AEC noted a problem area in "the quantity of plutonium discarded...[particularly] the solids problem."⁵²⁰ Together, these developments reinforced the need for more extensive, secure, and reliable plutonium storage facilities for the PFP.

In 1969, IAEA cooperation expanded, as 106,499 grams of fuel-grade metal in the 234-5 Building were placed in the International Safeguards program in September, and 7,770 grams in the 224-T Building were placed under IAEA control in December. That year, Rooms 192-A, 192-B, and 192-C, the three rooms that had been built to house and service the MEV X-ray machine in Project CG-811 during 1960 to 1962 (see Section 3.1), were converted to plutonium storage facilities. With their 48-inch-thick, reinforced-concrete walls, airlock entry, and labyrinth of passageways, these rooms met many of the then-current federal criteria for plutonium storage vaults. At the same time, scrap receiving, identification, sorting, and repackaging activities increased and, as a concomitant, intensive studies were conducted of the needs and requirements for safe storage and improved containment processes. A Value Engineering Study entitled "Canning Plutonium Metal for Long-Term Storage" was held in the summer, with the result that new "canning" (storage in cans) procedures were adopted for both new and recanned plutonium buttons. According to ARHCO, the old method had been to "bag the button in a plastic bag, place the bagged button in a tuna can, and roll-top seal the can. These packages normally were not required to withstand long-term storage (greater than 6 months)." However, in the new containment method, the aluminum can holding the button (primary containment) was purged with argon, roll-top sealed, then bagged in polyvinyl chloride bagging, then sealed in steel food-pack cans. "This triple-barrier sealing method," stated a contractor report, "is expected to provide a greatly improved containment barrier while protecting the plutonium from oxidizing influences."⁵²¹

14.3 CONSTRUCTION, DESCRIPTION AND STARTUP OF THE 2736-Z PLUTONIUM STORAGE VAULTS

Questions surrounding the safe storage of increasing amounts of weapons-grade plutonium and plutonium scrap from across the AEC complex continued to command great interest and attention at the 234-5 Building throughout 1969 and 1970. In July 1969, a can containing plutonium metal that oxidized sufficiently to breach its container. Again in October 1970, a storage container ruptured inside Vault Room 192-C, resulting in the spread of contamination inside the vault. In addition, three violations of criticality prevention specifications involving plutonium storage containers occurred in September and October of 1970. Plutonium scraps continued to be stored in the quonset huts west of the PFP complex, and inventory information remained the responsibility of the waste generator and shipper.⁵²²

As a result of concerns over these situations, radiation safety and shielding issues, and fire safety and safeguards and security concerns, the recommendation to build a separate, new, concrete vault building within the PFP complex was made by ARHCO to AEC management. Construction of the vault building became Project HAP-642, Plutonium Storage Vault, and was authorized by the Commission in April 1970. By that time, plutonium product material was being stored in Rooms 169, 170, 172, 173, 175, 179, 192, 192A, 192B, 192C, 192D, 194, 196, 221, and 232 of the 234-5 Building, and plutonium scrap was being stored on the second and third floors of the 224-T Building, the 711 Waste Hut, and in the old ammunition igloos west of the 200 West Area. Also, modifications were under way to allow additional plutonium scrap to be stored on the third floor of the 271-U Building, but these modifications were halted when construction of the actual vault storage building was authorized. While the 2736-Z Vault facility was constructed and first upgraded (1970 to 1973), the 224-T Building was upgraded for plutonium scrap and liquid storage. Additional seismic upgrades were added to the 224-T facility at the same time that they were added to the 2736-Z Building.⁵²³

Construction of the 3,705-square-foot, reinforced-concrete storage facility, the 2736-Z Building, was completed in early 1971. A 638-square-foot annex (2736-ZA) devoted to the ventilation equipment needed to maintain pressure gradients and frequent air changes was completed a few years later.⁵²⁴ In March 1971, when the first storage areas in the 2736-Z Vaults became available, the plutonium inventory in Rooms 192-C and 194 in the 234-5 Building was transferred to the new facility. Other inventory was transferred soon afterwards, but many plutonium-bearing scrap materials continued to be stored in existing vault rooms in the 234-5 Building and elsewhere. In November 1975, a container of hood sweepings ruptured in Room 173 of the PFP (an original storage room that had been converted to pedestal storage and material staging) and spread contamination throughout the room. An early violation of criticality prevention specifications occurred in the 2736-Z Vaults in December 1971 when plutonium containers were arranged in arrays too closely spaced in Room 2. In April 1975, the last inventory of plutonium-bearing fabrication oil scrap was removed from the 711 Waste Hut and transferred to the 271-U Building. At the end of that year, all used fabrication oil was removed from the 234-5 Building's service tunnels. In 1976, additional stored plutonium was removed from the PFP's pipe tunnel and Room 308, and from the 221-B Building, but storage in Rooms 166, 172, 173, 174, 192-B, 192-C, 194, and 225 of the PFP, and in the 224-T and 271-U facilities, continued.⁵²⁵

The 2736-Z Building is a 65-foot-long, 56-foot-wide, 14-foot-high, reinforced poured-concrete rectangle. The exterior walls are 8 inches thick, supported by cast-in-place concrete columns. The roof is a cast-in-place concrete slab, 6.5 inches thick, and contains vibration sensors. The building consists of four rooms for the storage of SNM, and is divided by a corridor that runs the length of the building. Each storage room is approximately 28 feet by 28 feet.⁵²⁶

Originally, Rooms 3 and 4 were equipped with shielded cubicles constructed of precast concrete panels 8 inches thick. These rooms are so equipped today. Each cubicle has a cross-sectional area 1 foot by 2 feet, and is 8 feet tall. Each room has 68 cubicles, all of which have pedestal storage rings for fixed array storage. The maximum number of storage rings per

cubicle is 28 (14 rings for each of two pedestals), and each pedestal stores a single canister containing plutonium. The storage rings are made of steel; each ring is 12 inches from the ring above or below it. Each storage ring also is 7-3/8 inches from the nearest storage ring to each side. Each cubicle has two doors, one hinged and the other unhinged, constructed of precast concrete 8 inches thick at the thickest part. The doors, when closed, leave an 8-inch gap to allow for air circulation via natural convection. Ventilation is aided further by a 6-inch gap between the bottom of each door and the floor. Ventilation for these rooms is provided by supply and exhaust ducts mounted near the ceiling on the west and east walls, respectively.⁵²⁷ (See Figures 14-1 and 14-2.)

Room 2 originally was equipped with a limited amount of steel shelving, and Room 1 originally contained no cubicles or shelving. The 2736-Z Facility was equipped with smoke detectors, fire sensors, and alarm bells in several locations, including all vault rooms. Fire suppression sprinkler were located in the corridor, but not in the vaults themselves because of the extremely low fire loading and concerns for criticality safety.

The 2736-ZA facility is a 40-foot by 22-foot rectangle, 13 feet high, constructed of reinforced, poured concrete. It is located 5 feet west of the 2736-Z Primary Plutonium Storage Facility and has no windows. It contains two rooms that house exhaust fans and filters and backup diesel-powered electricity-generating equipment to power them for the 2736-Z facility.

14.4 NEW MISSIONS AND SAFETY REVIEWS BRING MODIFICATIONS TO THE 2736-Z VAULTS AND TO PLUTONIUM STORAGE PRACTICES AT THE HANFORD SITE

In 1972, as a combined result of the advantages offered by the construction of the 2736-Z facility, the upgrading of the 224-T facility for plutonium storage, and other factors, the CSMO was established at AEC/RL (see Section 12.3). Mainly because of difficulties in storage and handling of aged plutonium-bearing scrap in the PFP complex and the 224-T Building, CSMO's first goal was to reduce the amount of backlog scrap to a 6-month inventory (i.e., plutonium scrap received within the previous 6 months). "Radiation levels produced by the americium [Am-241]" were causing operator exposure problems and safety issues within the new vaults.⁵²⁸

Soon after completion of the 2736-Z Building, Project HCP-676, Modifications to 2736-Z Plutonium Storage Vault, was undertaken during 1973 and 1974 to upgrade seismic support for the fire sprinkler system and strengthen tornado resistance. Another project to emplace intrusion detection monitors and alarms (Project HCP-680) was funded and begun during 1973-1974, but was not completed. In 1978, after standards changed, this project was canceled.⁵²⁹

During late 1975 and early 1976, a series of reviews of the rooms in the 234-5 Building that still stored plutonium was undertaken to verify compliance with requirements of the new ERDA. It was learned that Vault Rooms 192-A, 192-B, and 192-C, upgraded in 1975 with additional concrete between the rooms, were the most compliant. However, even these rooms did not meet ERDA criteria for physical protection (SAS) barriers, totally noncombustible construction,

Figure 14-1. 2736-Z and ZA Facilities Schematic, 1973.

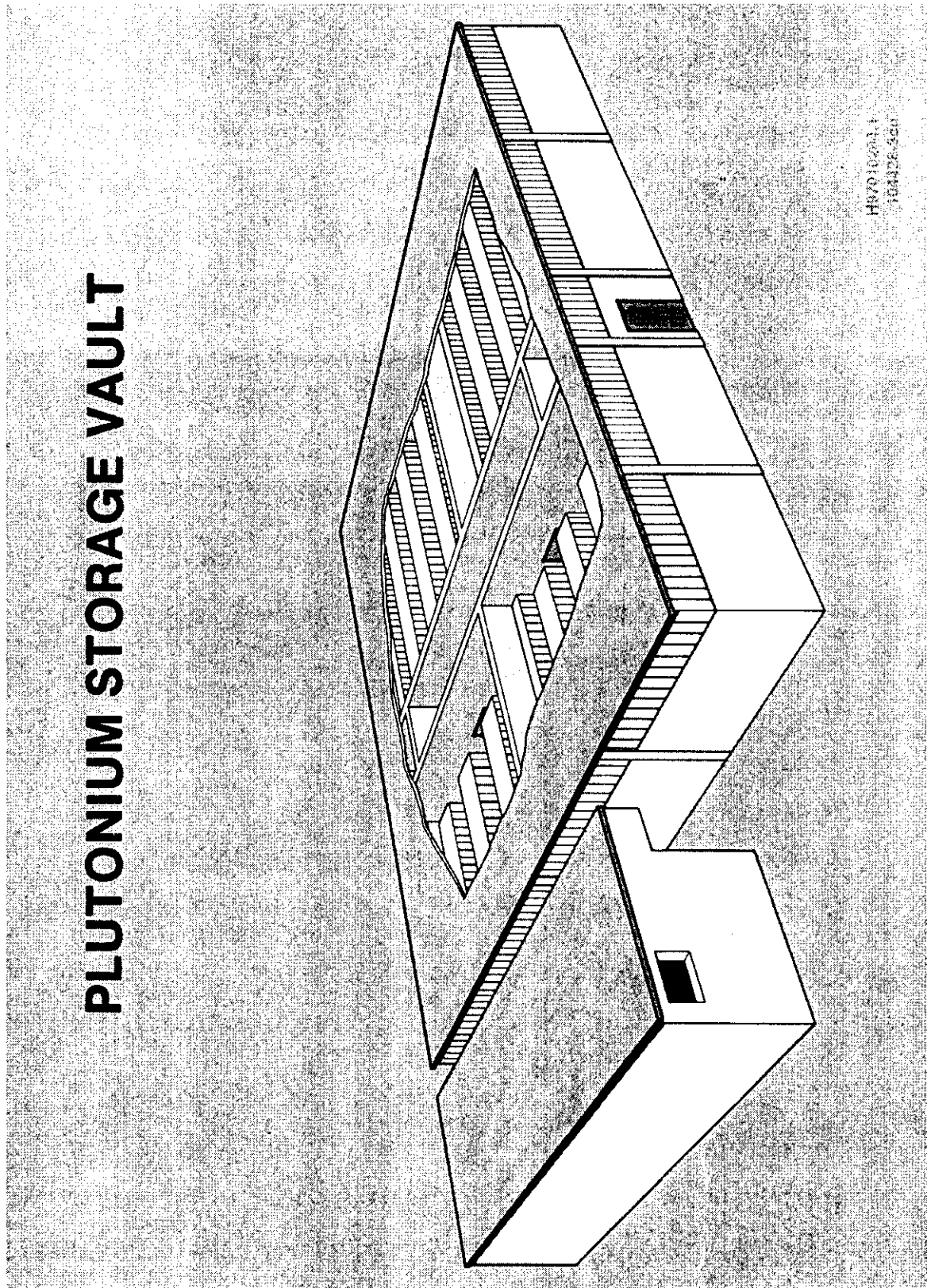


Figure 14-2. Plutonium Storage Vaults in the 2736-Z Facility, 1973.



containment features after a postulated nuclear excursion, provisions for the collection of spent fire extinguishing agents, ventilation systems (including the need to filter noble gases), earthquake and tornado resistance, container corrosion criteria, ability to detect and prevent self-heating of plutonium storage containers, and adequacy of criticality alarming systems. Rooms 139, 145, 174, 175, 190, 194, and 225 met even fewer of the ERDA criteria. Upgraded locks, requiring no fewer than two persons at a time to enter plutonium storage vaults, were installed on some of these rooms in 1978.⁵³⁰

During 1974 and 1975, compliance reviews were conducted for some of the types of plutonium storage containers then in use at the PFP complex. However, when a metal food pack can containing plutonium oxalate bulged and leaked in Room 2 of the 2736-Z Vaults in June 1976, a full review of the various plutonium storage containers was undertaken.⁵³¹

Some of the containers were found to be fully compliant with ERDA standards, including the 30- and 55-gallon drum assemblies used for plastic-bagged waste storage, and 10-liter containers for plutonium nitrate storage. Aluminum "birdcage" assemblies containing 50-pound slip-lid, steel cans for holding plutonium-contaminated dry materials (usually waste) met the criteria, but the slip-lid cans alone did not. Food-pack cans used for holding plutonium metal, dry plutonium compounds, and contaminated mixtures were not in compliance with corrosivity resistance and sealing requirements. Three-liter containers used to enclose neutron sources and some dry plutonium compounds were not in compliance, although they could meet compliance criteria when enclosed in concrete and vented inside 30-gallon carbon steel drums. As a result of these evaluations, a vented food pack can was proposed during 1976-1977, but was not developed at that time. Also, a new set of process specifications for plutonium storage was issued in January 1978. When plutonium-uranium scrap material inside a slip-lid can and encased in two layers of plastic spontaneously ignited during a repackaging operation in Room 230-C in the 234-5 Building on October 9, 1980, procedures for the storage of reactive scrap were tightened further. The granular and pellet material involved in the ignition incident had been received at the Hanford Site from the Carborundum Corp. in 1965 as part of the early effort to build a non-defense plutonium business at the PFP (see Section 13.1). The event confirmed the need to verify chemical stability in long-term storage and repackaging of reactive scrap.⁵³²

During 1978-79, internal physical changes were made to the 2736-Z Building, to be able to move more plutonium out of the 224-T and 234-5 Buildings and into more reliable vault storage. Room 1 in the 2736-Z Building was equipped with 68 cubicles constructed of precast concrete panels 8 inches thick. Like the cubicles in Rooms 3 and 4, each cubicle had a cross-sectional area 1 foot by 2 feet, and was 8 feet tall. Sixty-six of the cubicles had pedestal storage rings for fixed-array storage, and two had shelves so that storage container locations could be rearranged. The pedestal rings and the shelves were made of steel. The fixed-array cubicles had a maximum of 45 storage rings; nine for each of five pedestals. Each storage ring was 10 inches from the storage ring above or below, and was 6 inches from the nearest storage ring to the side. Each shelved-storage cubicle had 15 shelves. All cubicles in this room had two interlocking doors made of precast concrete, 8 inches thick. The doors of the cubicles were flush with the top of the cubicles and each had a 2-inch gap between the bottom and the floor. A ventilation duct attached to the top of each cubicle provided a continuous air flow through each cubicle. Thermocouples located in the top of each cubicle were emplaced for air temperature monitoring. These arrangements and equipment are still in place in the facility today.⁵³³

At the same time that Room 1 was modified, Room 2 received additional steel shelving for shelved storage space for 700 items of SNM. Each cubicle measured 9 inches wide, by 12 inches high, by 12 inches deep. Containers were maintained on the shelves by means of a restraining wire on the front and a 2-inch lip at the bottom of each shelf. Also, this room had about 588 square feet of open floor space for the storage of fissile material in shipping and storage container arrays up to the limit allowed by criticality prevention specifications. Ventilation for Room 2 was provided by supply and exhaust ducts mounted near the ceiling on the east and west walls, respectively. Today, Room 2 is still so equipped and arranged. At the same time, a separate

project emplaced additional intrusion detection and alarming capabilities in several locations in the PFP complex, including vault areas, and in the 224-T Building where plutonium continued to be stored. Motion detectors and a closed circuit television system were provided for the 2736-Z Vaults.⁵³⁴

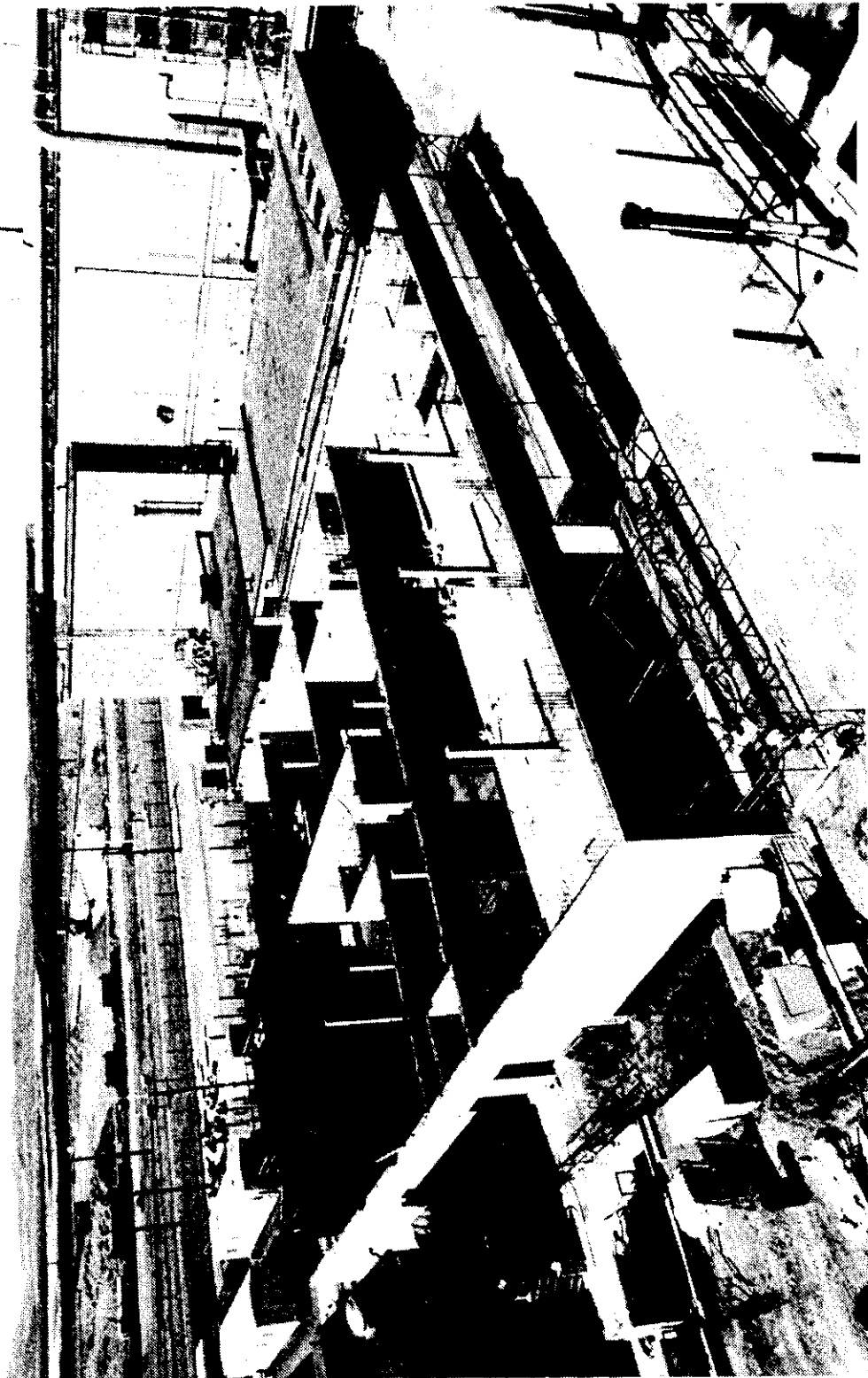
From 1981 through 1983, the 2736-ZB Support Building was built adjacent to the 2736-Z Building in Project B-246. The new facility contained additional ventilation and exhausting capacity for the 2736-Z vaults; provided an area for assaying and enclosed glove box equipment for repackaging plutonium-bearing materials; and offered office space, change, and locker rooms, and additional security protection for the 2736-Z vault room. The primary purpose of the 2736-ZB facility was to allow the 2736-Z/ZA Buildings to achieve "stand alone" capability because plans were being made to decommission the PFP itself. The 2736-ZB building is a 132-foot by 90-foot, reinforced-concrete rectangle 14 feet high. It is located immediately south of the 2736-Z facility. It contains an NDA laboratory, a mechanical room with a computer terminal, a repackaging area, a staging area for the temporary storage of 100 shipping containers the size of 55-gallon drums, a long corridor, several offices, and change and locker rooms. The building also has an enclosed external metal loading dock of 1,700 square feet, 15 feet high.⁵³⁵ (See Figures 14-3 and 14-4.)

14.5 VAULT SAFETY AND INVENTORY SYSTEM AND OTHER RECENT UPGRADES

During 1984 through 1987, the 2736-Z Facility was upgraded with the installation of the Vault Safety and Inventory System (VSIS), a state-of-the-art detection, measurement, annunciating, and alarm system for plutonium inventory protection. The VSIS emplaced a combined storage capacity of 6,868 canister monitoring units (CMUs) in Rooms 1, 3, and 4. Attached to the bottom of each canister is a label that is specially designed to provide electronic capacitance identification data because each canister has a unique electronic signature. This label is capacitively coupled to the CMU. Specifically, label identification, canister bulge, canister temperature, presence, and ambient air temperature next to the canister are the data read by the VSIS equipment. Canister bulge data is gathered by a pressure switch, another pressure switch confirms canister presence, and two thermistors gather temperature data for both the canister and the air next to the canister.⁵³⁶ (See Figure 14-5.)

The VSIS data processing equipment provided the data logging and processing of information received from the container monitors. Any anomalies identified by the system were annunciated. The plutonium stored in the 2736-Z Facility also was protected by the physical safeguards and barriers of the PFP protected area.⁵³⁷ Also during 1986-1987, upgrades were made in the motion detectors protecting the 2736-Z Vaults, some calibration equipment was replaced, two new sprinklers were added to a new enclosure built in Room 641 of the 2736-ZB facility, and other improvements were made.⁵³⁸ Process and operating specifications for plutonium storage in the PFP complex were rewritten in 1981 and 1984.⁵³⁹ By 1988, the 2736-Z Facility was holding several metric tons of stabilized plutonium, protected by the VSIS technology and other safeguards systems.⁵⁴⁰

Figure 14-3. Construction of the 2736-ZB Support Facility, 1982.



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Figure 14-4. Ventilation Equipment in the 2736-ZB Support Facility, New, 1983.

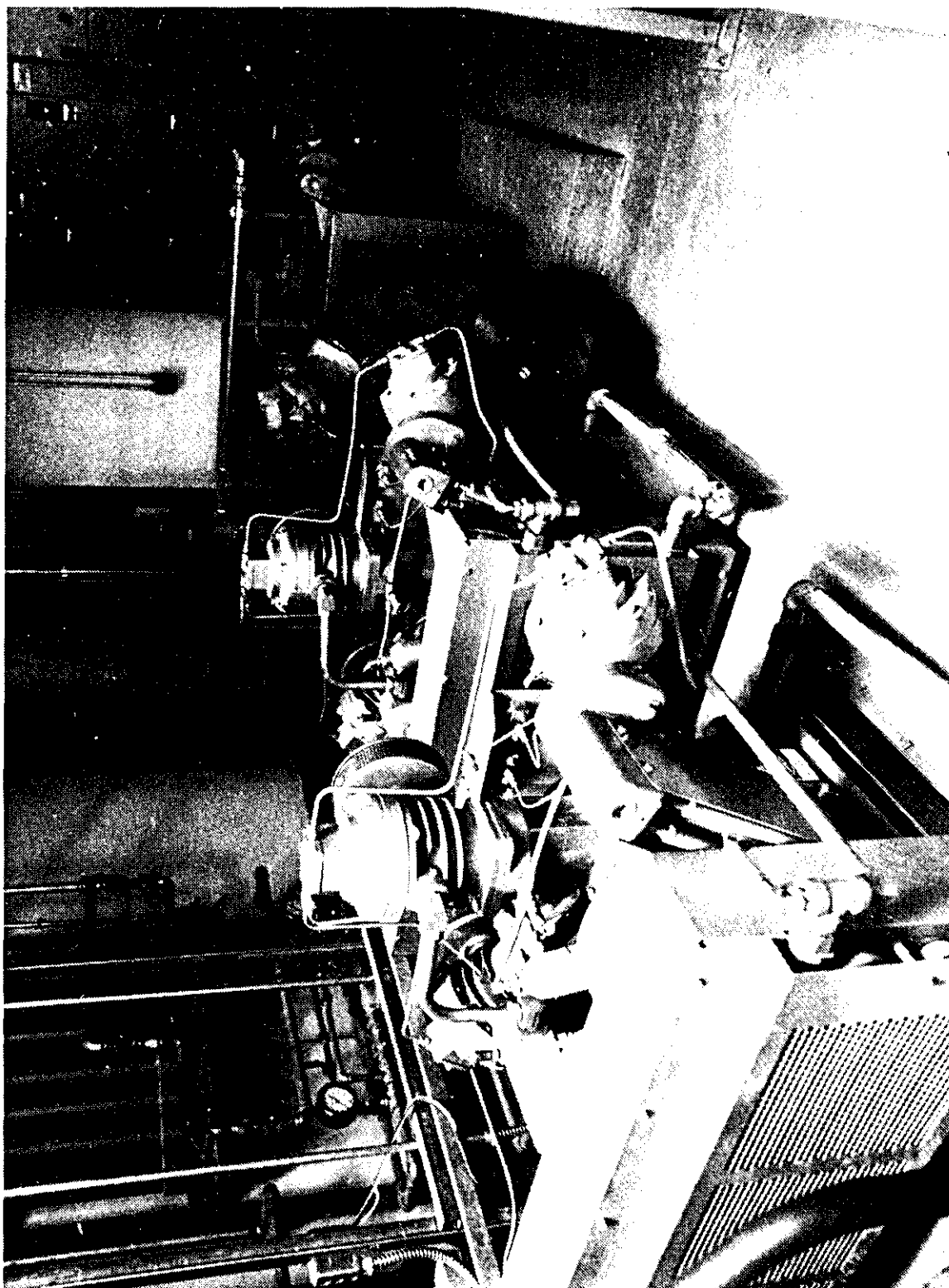
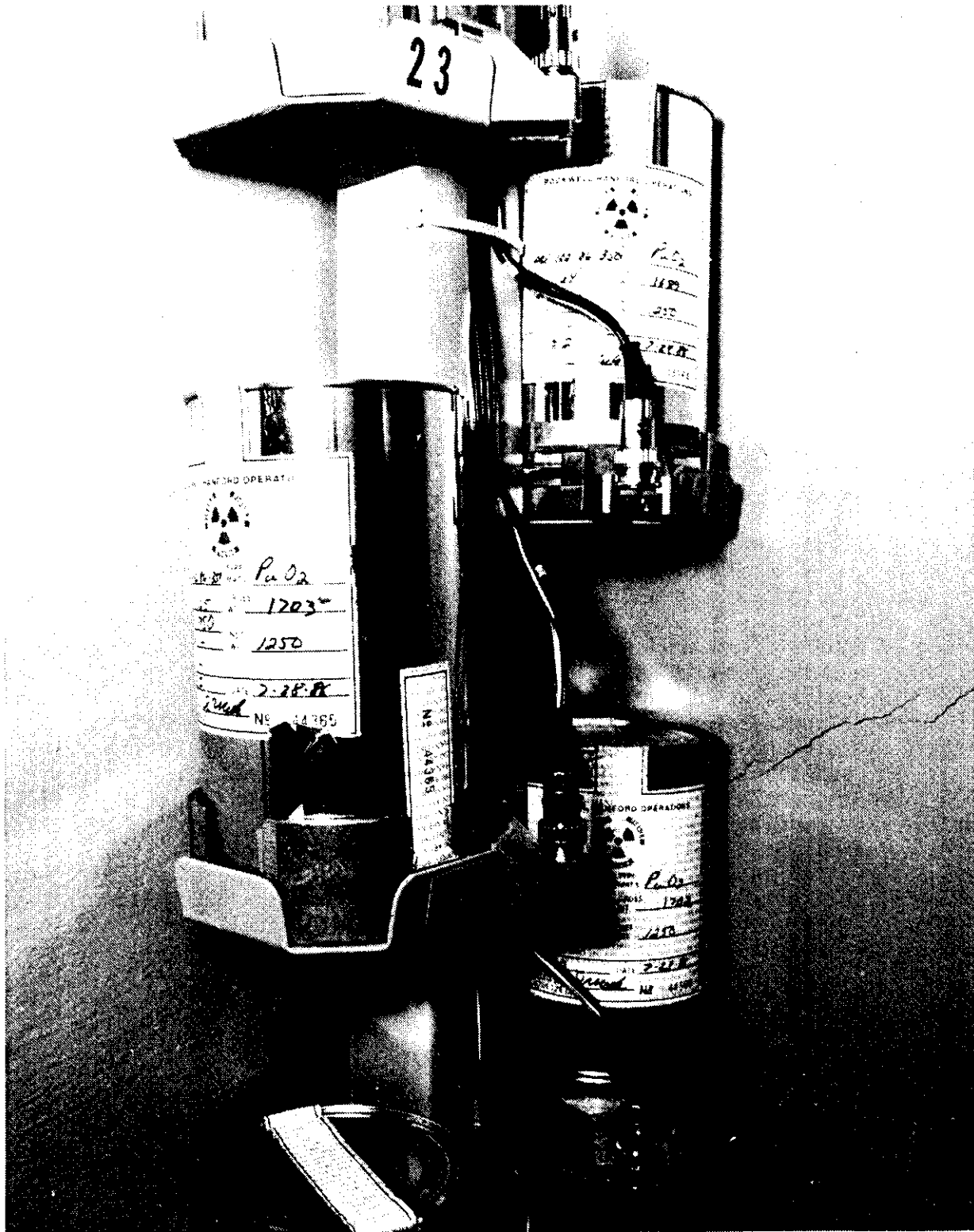


Figure 14-5. VSIS Equipment Monitors Can Containing Plutonium in 2736-Z Vaults, 1988.



In January 1993, just before leaving office, U.S. President George Bush signed the second Strategic Arms Reduction Treaty (START II) with Russian President Boris Yeltsin. The following April, the new President William Clinton held discussions with Russian President Boris Yeltsin regarding safeguarding and accountability procedures and systems for SNM. Five months later, speaking before the United Nations, Clinton offered to declare a large amount of SNM that once constituted warheads or warheads materials as "excess" to U.S. defense needs. Hoping to prolong the existing nuclear Nonproliferation Treaty as a 1995 conference on its extension approached, and to support global controls on fissile materials, Clinton further issued Presidential Decision Directive 13, offering to place excess American defense materials under the safeguards (control and inspection) of the IAEA, headquartered in Vienna, Austria.^{PP} In November 1993, the U.S. Nuclear Weapons Council recommended specific quantities (within categories) of excess materials to the National Security Council.

In 1994, largely because of the capabilities of the VSIS equipment and the physical integrity of the 2736-Z Building (along with the 2736-ZA and ZB Buildings), the Hanford Site was chosen to be part of a new International Safeguards Program coordinated by the IAEA. On a stifling day in July, history was made once again at the Hanford Site when 10 high-ranking representatives of the Ministry of Atomic Energy (MINATOM) in Moscow and of various scientific and nuclear institutes in Russia toured the PFP complex, even entering the tightly guarded 2736-Z storage vaults. During that visit, two cold warriors who had been adversaries in the national security business for about three decades, shook hands in the PFP's CAS and promised to work together as a team to dismantle the fearful SNM they were inspecting. Nikolai Egorov, deputy minister of MINATOM, and Jack Keliher, then director of DOE's Office of Nonproliferation and National Security, discussed ways to improve physical security methods for plutonium and highly enriched uranium (HEU), and expressed hope for peace and a new world order. Just two days later, the IAEA began inspections of the 2736-Z vaults, as part of an overall effort to inspect SNM storage facilities throughout the United States.^{QQ} During 1994-1995, additional upgrades and SAS measures were taken at the 2736-Z Vaults, including the installation by the IAEA of inventory monitoring cameras and new fiber-optic seals on containers. Other upgrades and measures in response to DOE Standard 3013 cannot be discussed because of nonproliferation concerns. By mid-1995 over 1,000 items of excess plutonium was under IAEA safeguards in 2736-Z Vault Room 3. In late 1996, a remote monitoring test to broadcast inventory information via satellite to IAEA headquarters was under way.⁵⁴¹ (See Figures 14-6, 14-7, and 14-8.)

^{PP} At the 1995 NPT conference, the treaty was extended for an indefinite period of time.

^{QQ} Other DOE Sites including the Rocky Flats Site in Colorado, the Oak Ridge Site in Tennessee, and others also placed excess SNM under IAEA safeguards during 1994-1995.

14.6 SIGNIFICANCE AND FUTURE OF THE 2736-Z VAULTS

The activities and missions carried out in and because of the 2736-Z Primary Plutonium Storage Facility are associated with events that are extremely significant and important in American history. Foremost, the decision to construct the 2736-Z vaults represented a growing awareness of, and concern with, safety and environmental issues at the Hanford Site and in the national nuclear defense complex in the late 1960's and early 1970's. Further, the scrap management mission that came to the Hanford Site largely because of the existence of the 2736-Z Facility resulted in larger and more diverse inventories of plutonium scrap and stabilized plutonium to Washington State than otherwise would have been in the region. The presence of this plutonium has brought safety concerns, environmental concerns, and programs to address those concerns that would not have existed had the Hanford Site been required to process and store only its own plutonium materials. Therefore, the Cold War waste legacy that resides at the Hanford Site has national connections and implications.

In turn, the presence of the plutonium inventory in the 2736-Z Building justified the funding for the emplacement of the VSIS technology, which then attracted an international mission. The IAEA involvement at the Hanford Site represents a milestone in American and worldwide attempts to deal with the legacy of the Cold War. At present, there are no plans to deactivate or demolish the 2736-Z facilities when the rest of the PFP complex is dismantled and decommissioned.⁵⁴² (See Figure 14-9.)

Figure 14-6. First Russian Delegation to Visit PFP, July 1994.



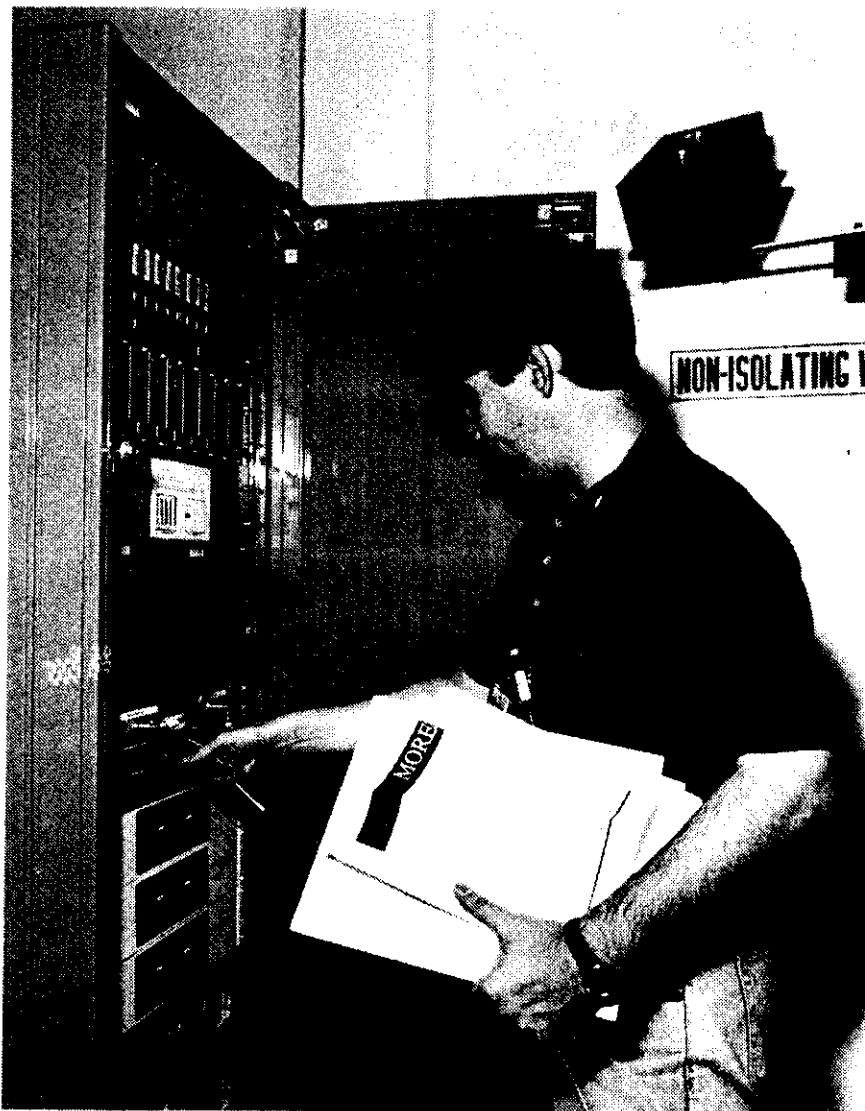
Figure 14-7. DOE's Jack Keliher Escorts Russians Through the 2736-Z Vaults, July 1994.



Figure 14-8. Nikolai Egorov at the PFP, July 1994.



Figure 14-9. IAEA Inspector Verifies Inventory Using Computerized Camera Link with 2736-Z Vaults, 1996.



15.0 PFP EFFLUENTS, EFFLUENT CONTROL

15.1 DESCRIPTION OF ORIGINAL 231-Z AND PFP WASTE SYSTEMS, AND LATER CRIBS

The cribs that served the PFP are described in Table 15-1.

Table 15-1. Cribs Serving the Plutonium Finishing Plant Complex.
(2 sheets)

Number	Years of Service	Facilities Served
216-Z-1 Ditch (also called 2904-Z Ditch)	1944-1959	231-Z and 234-5 Buildings, 291-Z Stack
216-Z-1 Crib	1949-1952 and 1968-1969	234-5Z Laboratories (1949-1952) 236-Z (uranium wastes, 1968-1969)
216-Z-1A Tile Field (also encompasses 216-Z-1AA, 1-AB, and 1-AC Tile Fields)	1949-1959 and 1964-1969	234-5 Building Process Lines and Laboratories (1949-1959) 242-Z and 236-Z Buildings (1964-1969)
216-Z-2	1949-1952 and 1966	234-5 Building Process Lines and Laboratories (1949-1952) 242-Z and 236-Z Wastes (1966)
216-Z-3	1952-1959	234-5 Building Process Lines and Laboratories
216-Z-4	1945	231-Z Building
216-Z-5	1945-1947	231-Z Building
216-Z-6	1945	231-Z Building
216-Z-7	1947-1967	231-Z Building, 300 Area Laboratories via 340 Building
216-Z-8	1955-1962 (a French drain)	RECUPLEX Facility in 234-5 Building (overflow)
216-Z-9	1955-1962	RECUPLEX Facility CAW and aqueous and organic wastes
216-Z-10	1945 (a reverse well)	231-Z Building
216-Z-11	1959-1971	Multiple PFP complex facilities
216-Z-12	1959-1973	234-5 Building Process Lines and Laboratories
216-Z-13	1949-1979 (a French drain)	291-Z Stack Floor Drainage

Table 15-1. Cribs Serving the Plutonium Finishing Plant Complex.
(2 sheets)

Number	Years of Service	Facilities Served
216-Z-14	1949-1979 (a French drain)	291-Z Stack Exhaust Fan Turbine
216-Z-15	1949-1979 (a French drain)	291-Z Stack Evaporator Cooler Drainage
216-Z-16	1968-1977	231-Z Building
216-Z-17	1967-1968	231-Z Building
216-Z-18	1969-1973	242-Z and 236-Z Buildings
216-Z-19	1971-1981	231-Z, 234-5, and 236-Z Buildings
216-Z-20	1981-1995	231-Z, 234-5Z, 232-Z, and 236-Z Buildings ⁵⁴⁴

CAW current acid waste
PFP Plutonium Finishing Plant
RECUPLEX recovery of uranium and plutonium by extraction

Table 15-1 summarizes the soil disposal facilities, including cribs, ditches, tile fields, reverse wells, and French drains that received liquid waste from the PFP complex during its operating and cleanout lifetime.^{rr} During the early years of plutonium isolation and finishing activities at the Hanford Site, all waste not designated for recycle and plutonium recovery went to the soil column. In 1973, a series of effluent upgrades rerouted many such wastes to the 242-T evaporator and to the Hanford Site's high-level waste tank farms (see Section 15.3). In 1995, all discharges to the soil from the PFP complex were stopped when the PFP facilities were tied into the Hanford Site's 200 Area Treated Effluent Disposal Facility (TEDF) (see Section 15.5).⁵⁴⁵

The PFP soil disposal facilities received wastes fed through the 241-Z Facility, a system of holding and sampling tanks and associated piping and auxiliary facilities. The 241-Z Sump contained five underground, 4,600-gallon, single-shelled, 3/8-inch thick holding and sampling tanks designated D4, D5, D6, D7, D8. Each tank had an operating volume of 15,000 liters, weighed 6 tons when empty, and operated within a concrete cell. The cells had removable cover blocks for the replacement of large equipment.

^{rr} A holding basin for cold (nonradioactive) liquid wastes also existed for many years at the 207-Z facility. It was renamed as the 216-Z-21 Basin in 1988. See Pfluger, "Meeting Minutes, Plutonium Finishing Plant Cold Waste Pond Informal Readiness Review".

Each cover block weighed about one ton. There was no enclosure over the cover blocks. Tank samplers were located in unventilated plywood boxes. The 241-Z tanks had temperature, density, and liquid level indicating instrumentation, and were equipped with agitators to keep precipitated solids in suspension. Tank and cell ventilation system was not HEPA filtered. When one of the "D" tanks was full, it was sampled, the solution was neutralized, and it was discharged to the 241-Z-361 tank. The latter tank was a 13-foot-wide, 26-foot-long, 18-foot-deep, reinforced concrete structure with a steel liner and a sloping bottom. In 1972, tank D9 was added to the 241-Z facility, to store wastes from the PRF's plutonium/uranium partitioning work before such waste could be trucked to the PUREX Plant for disposal to underground tank farms (see Section 15.3). In March 1972, tank D6 failed after a number of previous repairs had failed to refurbish it. It was taken out of service. Drain lines leading to it were rerouted to tank D4.⁵⁴⁵

Throughout the operating years at the PFP complex, cribs were replaced when plutonium breakthrough occurred beyond limits defined as acceptable at the time. For example, in 1958, work was undertaken to replace crib 216-Z-3, which had received plutonium-contaminated waste from the main 234-5 Building processes and from the facility laboratories since 1951. When samples from the soil from the bottom of the deepest test well monitoring the crib (about 50 feet above the water table) indicated that "low concentration of plutonium" had reached this depth, replacement of the crib was requested at the "earliest practical date." According to G.E. Hanford Company, although plutonium movement below the point 50 feet above the water table could "only be estimated...the soil zones possessing the greatest ion exchange capacity have been penetrated and faster plutonium penetration can be expected in the underlying sand and gravel." Crib 216-Z-3 was replaced by crib 216-Z-12 as of March 11, 1959. The same project, CAC-798, Crib and Test Wells for 234-5 Building Wastes, also drilled test wells for the RECUPLEX waste facility, crib 216-Z-9, to a depth lower than the 100 feet penetrated and sampled by the original test wells.⁵⁴⁶ (See Figures 15.1 through 15.4.)

When the PRF was constructed, separate, parallel pipelines to bring the PRF process (aqueous) waste to the 216-Z-1A tile field were built in 1963 in Project CAC-118, Process Waste Disposal - Plutonium Reclamation Facility. Also built in this project were two test wells at the tile field, and a plastic barrier and earth cover over the tile field. In 1966, construction of new cribs (216-Z-16 and 216-Z-17) was authorized when the 216-Z-7 crib for 231-Z Building waste reached its limits. Also in 1966, in response to growing evidence that discharges to the 216-Z-9 crib had been greater than recorded (see Section 15.2), G.E. Hanford Co. identified the 216-Z-1A and 216-Z-12 cribs as being "of concern." A new crib system, 216-Z-18, was constructed to replace the 216-Z-1A tile field in 1968, in Project HAP-620, Plutonium Reclamation - Salt Waste Crib 216-Z-18. Later upgrades to the effluent disposal system neutralized this aqueous waste, centrifuged it to remove solids, and routed it to the D-5 waste handling system that served the 234-5 Building. Waste too high in plutonium content to be disposed of, but too low in plutonium content to be used as feed for solvent extraction, were concentrated in a filtrate concentrator.⁵⁴⁷ However, at the end of 1968, the AEC appraisal for the PFP facility noted a problem in "the quantity of plutonium discarded...[particularly] the solids problem..."⁵⁴⁸

In 1973, a sampling and monitoring facility as part of a large series of waste management upgrades at the PFP complex (see Section 15.3). The sampling and monitoring facility was to be located at the outfall to the 216-Z-19 crib. The alpha monitoring equipment was emplaced the following year, at the same time that a 12-foot-square metal building (2904-ZA) was erected to house it.⁵⁴⁹ Also during 1973 through 1974, boreholes were drilled and neutron pulse measurements were taken to determine the plutonium content of both the 216-Z-9 crib (see Section 15.2) and the 216-Z-1A tile field. These actions were part of multiple undertakings in waste management improvements. Drilling of 5 boreholes in the 216-Z-1A tile field took place throughout 1974, with the plutonium content estimated at 57 kg. In March 1977, ARHCO reported that the 216-Z-19 ditch monitor had "not been found to be reliable and maintainable...there is serious lack of control of contamination release in the aqueous effluent from Z Plant." Meanwhile, samples of crib 216-Z-12, also taken out of service in 1973 in the PFP's waste management upgrades, revealed a load of 25.1 kilograms of plutonium.⁵⁵⁰ In 1981, when closure and backfill of the 216-U-10 Pond was planned, the 216-Z-19 facility, which fed this pond, was taken out of service and the 216-Z-20 crib was constructed.⁵⁵¹

Figure 15-1. Construction of the 216-Z-9 Crib, March 1954.

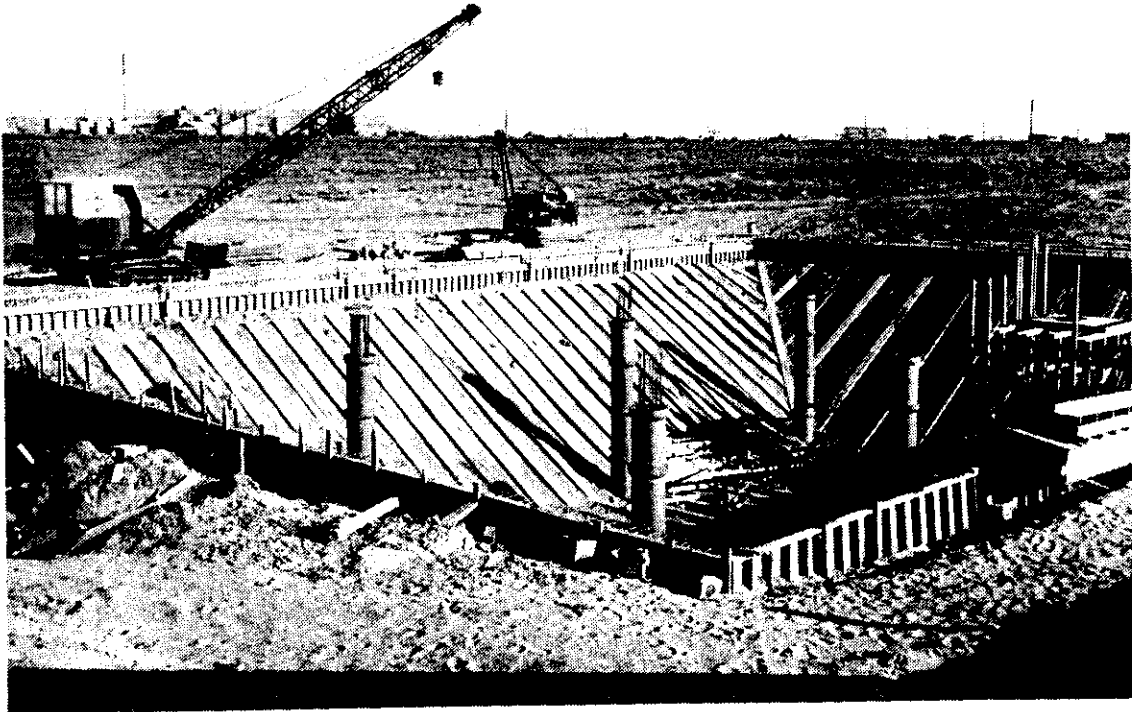


Figure 15-2. Construction of the 216-Z-9 Crib, October 1958.

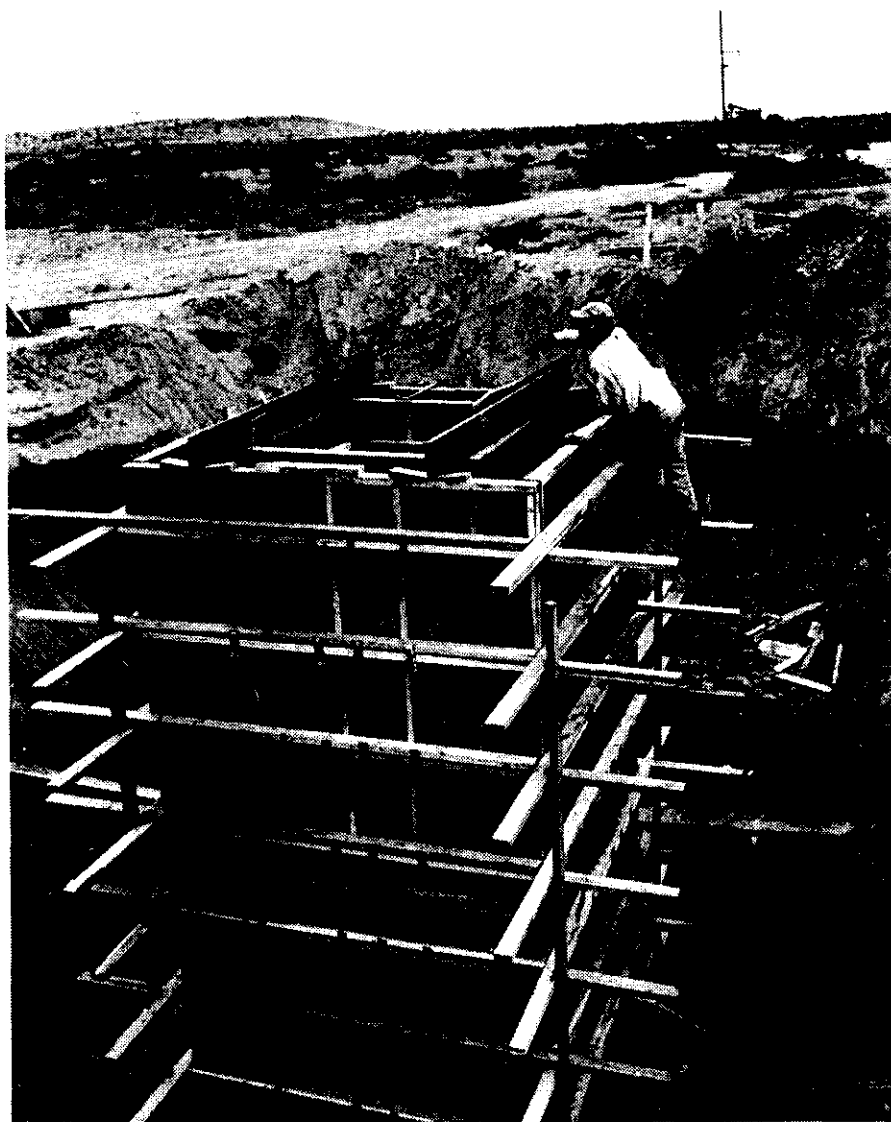


Figure 15-3. Project CA-798, Crib and Test Wells for the PFP, 45 Percent Complete, December 1958.



Figure 15-4. Construction of the 216-7-18 Crib, looking North, August 1968.



Mishaps sometimes occurred in the 241-Z piping, tank, and crib system. Examples include a 1966 incident in which particulate contamination was released to the atmosphere and on a localized ground area during a change of the 241-Z vent pit filters. Forty thousand disintegrations per minute^{ss} were measured on the nearby ground.⁵⁵³ In another example in February 1969, the waste pipeline from the 234-5 and 236-Z Building to the 241-Z Sump failed and severe cracking occurred in the concrete pipe trench, resulting release to the soil of 30,000 gallons of waste.⁵⁵⁴ In April 1971, the 216-Z-18 crib line from the PRF broke approximately 6 feet south and 12 feet west of the southwest corner of the 236-Z Building. An excavation 25 feet long by 6 feet wide by 7 feet deep uncovered gross alpha contamination in the soil to levels greater than 6 million disintegrations per minute per 100 square centimeters of surface. A soil removal project was undertaken, and approximately 100 55-gallon barrels of contaminated soil were placed in a marked, plutonium "storage-for-recovery" burial ground. Six feet of clean soil were placed over the contaminated soil area just southwest of the PRF.⁵⁵⁵

15.2 Z-9 CRIB MINING

The 216-Z-9 crib was a 21-foot-deep underground soil disposal facility with an enclosed "cavern" (a wooden void space) at the head end, located just southeast of the 234-5 Building. It was covered by a 9-inch-thick concrete slab measuring 90 feet by 120 feet, but the crib sloped inward toward its bottom and was only 30 feet by 60 feet at the floor. The crib was built during 1954 to serve the RECUPLEX facility (see Section 9.0), and received the CAW stream of both aqueous and organic waste, as well as unwashed fabrication oil, from RECUPLEX operations from 1955 to 1962. As early as 1959, Hanford Site operators became concerned that the Z-9 crib might be reaching its criticality limitation for plutonium per cubic centimeter. At that time, the total criticality limit for the crib stood at 25 kilograms of plutonium. Four core samples of Z-9 crib soil were taken in August 1959, with one core showing concentrations as high as 1.5 milligrams of plutonium per cubic centimeter. However, Site scientists concluded that gelatinous precipitates formed when RECUPLEX waste contacted calcareous soils, thereby holding up the plutonium in upper soil layers and preventing downward migration toward the water table. They also cited the theory that ion exchange reactions with the soil would hold up additional plutonium, and render continued discharge to the crib acceptable.⁵⁵⁶

Other samples of the crib were taken in 1961, resulting in the February 1962 recommendation that the total plutonium limit could safely be increased to 50 kilograms. However, the RECUPLEX criticality accident terminated RECUPLEX operations and discharges to the crib 2 months later (see Section 9.8). Further soil samples taken in 1963 caused Hanford Site scientists to conclude in August of that year that the Z-9 crib "contains sufficient plutonium to pose a critical mass problem if the crib were used for additional Pu-bearing wastes." This conclusion prompted the decision that year to build the 216-Z-1A tile field for PRF effluents (see Section

^{ss} Disintegrations per minute (dpm) is a rate of radioactive decay and is a measure of the number of radioactive atoms converted each minute into stable atoms. It is used as a measure of radiation intensity.

15.1).⁵⁵⁶ Subsequent contractor measurements taken during 1964 and 1965 at the Z-9 crib found that the crib was a "potential criticality hazard." At that time, it was believed that the crib contained approximately 25 kilograms of plutonium, but that "this figure may be low." A soil mining and leaching plan was developed as early as 1966. Essentially, the plan called for the use of modified mining equipment to remove the top 1-foot layer of crib soil (1,800 cubic feet), and to leach out the plutonium by dissolving the soil in mixtures of nitric-hydrofluoric acids. Leaching would be performed on 1-gallon batches. The leaching facilities would be located in the MT area of the PRF (see Section 12.1). S&C dissolver solutions within PRF would provide salts to mix with the acids. The leached soil would be packaged into plastic-lined 50-gallon-drum loads and buried in specified Site solid waste burial grounds.⁵⁵⁷

By 1967, estimates of the plutonium content of the Z-9 crib had been revised upward to range from 27.5 to 196 kilograms. Accountability records showed the lower figure, but widely varying soil sample results caused Site scientists to allow for much higher possible totals. This uncertainty factor, combined with the stoppage of plutonium fabrication activities (which in turn cut the volume of available S&C material considerably), resulted in many revisions to project proposals for the mining activity and to the chemical flow sheets being developed in the PFP developmental laboratory (see Section 7.7). These changes, as well as the changeover in the Hanford Site chemical processing contract to ARHCO in 1967 (see Section 3.3), caused further delays in the soil mining project. A new set of project proposals was generated by the operations contractor during 1970-1971. Meanwhile, further soil sampling went forward, and safety analysis documentation of the procedures was written.⁵⁵⁸

In 1972, the CSMO mission came to the Hanford Site (see Section 14.4). Among its goals, the CSMO program plan envisioned the eventual recovery of plutonium from current PFP waste streams and from the soil in the 216-Z-9 crib for its economic value. "Environmental restoration offers a real future for this new facility [CSMO]," wrote ARHCO in late 1972.⁵⁵⁹ That year, a cold test of the prototype mining equipment to be used in the Z-9 crib recovery operation was conducted. The equipment consisted of a clamshell assembly attached to a boom, allowing for both horizontal and vertical movement. The boom rotated around a center point, capable of scooping an area with a radius of 19 feet. Power to open and close the clamshell jaws and move other equipment parts was supplied by hydraulic cylinders. The equipment operator was positioned 30 to 60 feet away, and could use a television camera with a zoom lens. The equipment was mounted on two 42-inch risers that were sunk into and secured to the trench top. (During the cold test, the equipment was mounted on a simulated riser 18 feet above the level of clean test ground.) A system of floodlights on poles also was emplaced around the work area.⁵⁶⁰

Another delay was encountered in late 1972, when it was realized that less than 250 cubic centimeters remained from previous samples of the top layer of Z-9 crib soil. As an ARHCO memorandum pointed out, "the top layer has been visually characterized as a 'grey, pasty, and sticky layer,' [but] no cation, anion, or organic residue analyses have been run." Actual Z-9 crib mining operations were postponed so that additional testing could be performed on the disengagement/separation factors of PRF organic combined with Z-9 leach solutions. In the spring of 1973, the AEC brought consultants from the Los

Alamos and Savannah River Sites to Hanford to study the situation, and additional pulsed neutron surveys of the crib were undertaken. The 1973 neutron pulsing measurement indicated higher values than those obtained in 1963 and 1969. According to ARHCO, the new tests "indicated that the reactivity of the system was increasing...this trend was recognized as indicating an undesirable change." The offsite consultants also expressed "concern...[over] the large inconsistency between the conditions in this trench as indicated by the sample analyses which have been obtained, and by the results of the pulsed neutron reactivity measurements." As a result of these concerns, an isodose map of the Z-9 crib floor was produced, to determine the relative distribution of Pu-239 for future sampling. Also, the decision was made to add cadmium nitrate (a neutron absorber, also known as a neutron "poison") to the crib soil through test holes, before beginning mining operations. The poison additions, in the form of a 10-percent cadmium nitrate solution, were begun in August 1973⁵⁶¹

Meanwhile, in the summer of 1973, the AEC authorized Project HCP-687, Contaminated Soil Removal Facility, 216-Z-9 Enclosed Trench. By late 1973, the contractor reported that the "best estimate [of Z-9 crib content] is that the plutonium content in the top 30 centimeters is about 40 kilograms."⁵⁶² Additional characterization studies, project revisions, safety reviews, and flowsheet changes continued during 1974 and 1975.⁵⁶³ Further safety reviews, acceptance test procedures, the establishment of critical mass specifications for the packaged soil drums, and decisions about the NDA methods to be used consumed the first several months of 1976. A specialized, new SGSAS gamma measurement system was used in the PFP analytical laboratory. A more immediate, soil assay monitor system (SAMS) based on sodium iodide gamma detection was used at the Z-9 location (see Section 7.8).⁵⁶⁴ (See Figures 15-5 and 15-6.)

On August 17, 1976, the first removal of contaminated soil from the Z-9 crib began. Nine days later, the operation was shut down to resolve differences in the SAMS and SGSAS NDA methods being used. On January 11, 1977, mining operations resumed, with the top 1 foot of the soil from the north half of the crib removed. This soil, the richest area of yield, produced 28.5 kilograms of plutonium. Mining of the south half, yielding 29.5 kilograms of plutonium, was completed July 14, 1978. Approximately 86.8 percent of the soil mined was classified as waste,

Figure 15-5. Drill Rig Used in the 216-Z-9 Crib Excavation, 1976.

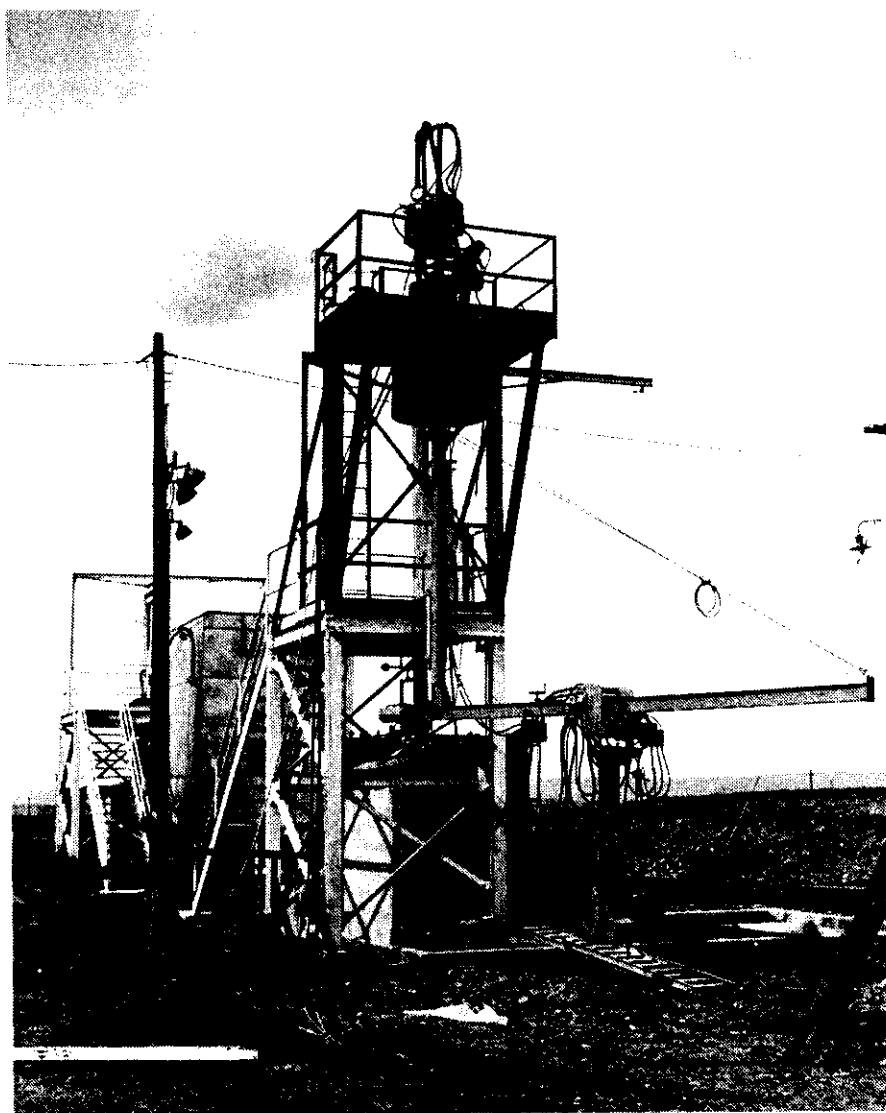
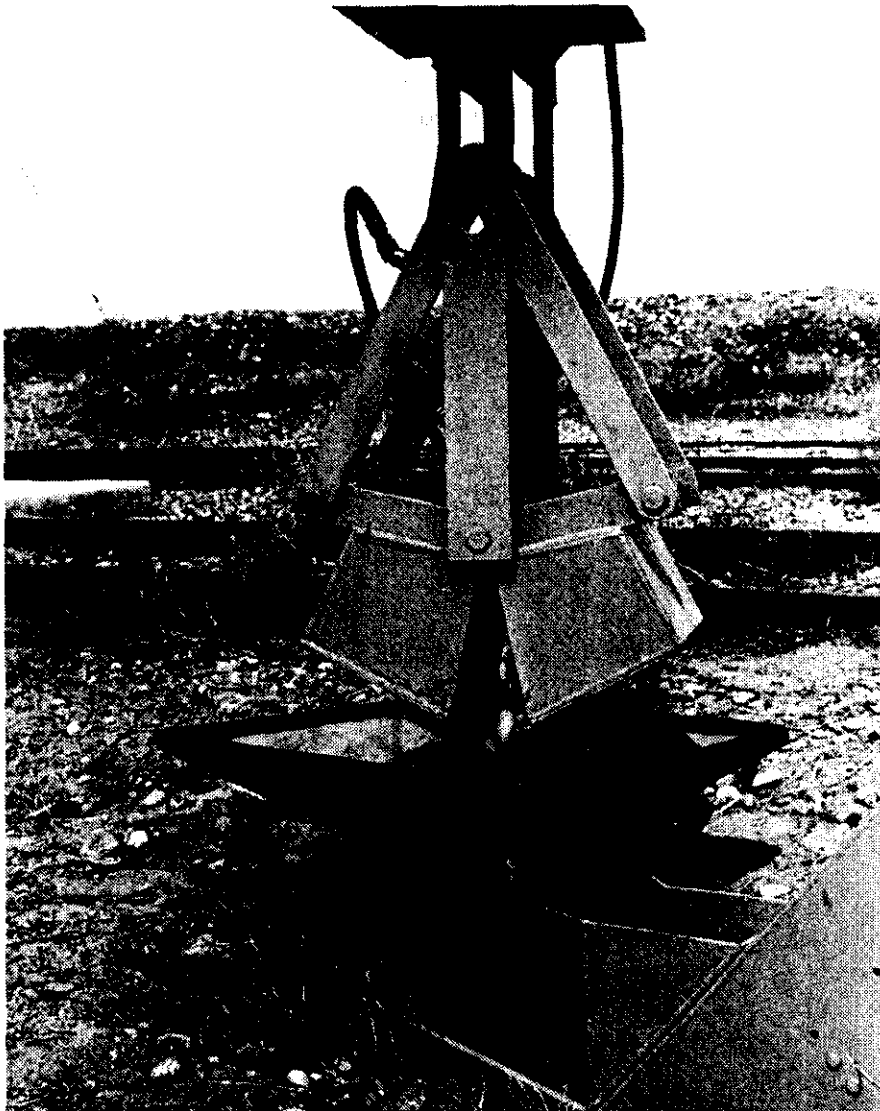


Figure 15-6. "Clamshell" Tool for Mining of the 216-Z-9 Crib, 1976.



12.6 percent was classified as potentially recoverable, and only 0.6 percent was high enough in plutonium content to be classified as "Pu-bearing scrap." During the operations, corrosion of the metal canisters holding the small lots (2.8 gallons each) of soil awaiting leaching became a problem, and thick polyethylene liners were added to these canisters. Another problem concerned radiolytic buildup of hydrogen gases within the canisters. To resolve this issue, the space between the polyethylene liner and the metal canister was filled with vermiculite, and the canisters were vented. During 1978, all canisters, as well as the waste drums containing the leached soil were retrofitted with vented lids and antiexplosive catalysts.⁵⁶⁵

15.3 OTHER PLUTONIUM EFFLUENTS CLEANUP PROPOSALS/PROJECTS DOMINATE 1970'S

In February 1967, Isochem, Inc., the Hanford Site chemical processing contractor, was directed by the AEC to "reevaluate the waste management program in view of current needs and technologies, and to recommend" program upgrades. At that time, the estimated volume of radioactivity discharged to the ground in aqueous waste streams was 16,000 curies of fission products and 8,400 grams of plutonium, with about 7,000 grams of plutonium coming from the PFP (mostly PRF discharges to the 216-Z-1A crib, with discharges from the 242-Z facility, the 234-5 Building laboratories, and the fluorinator off-gas scrubbers in the A-Line and C-Line). Late that year, Isochem produced an ambitious plan that stated that, for a cost of \$6 million, such discharges could be reduced to approximately 400 grams of fission products and less than 10 grams of plutonium. A key part of the proposed upgrades would have built facilities to collect and reroute 500,000 gallons per year of PRF high-salt waste to either the 242-T Evaporator in 200 West Area, or to an in-tank solidification (ITS) unit then operating in the BY tank farm.⁵⁶⁷

During 1968, the amount of plutonium discharged to the soil from PFP facilities increased to 9,385 grams. At the end of that year, the AEC's evaluation for the PFP complex noted a "problem area" in waste discard. The improved operation of a centrifuge in the PRF to remove non-leachable solids from PRF waste caused this amount to drop to 6,126 grams in 1969. However, seeking further improvements, Isochem's replacement, ARHCO, prepared a flowsheet in 1969 for routing Z Plant high-salt waste to the ITS facility. The plan involved accumulating the waste in a bank tank for pH adjustment and ANN addition for corrosion control and salting strength, processing of the treated waste in a solvent extraction system, centrifuging the waste from the solvent extraction system for organic removal, neutralizing the waste, and trucking it to the ITS facility. Separate processes were developed for low-salt and organic waste. In mid-1969, ARHCO proposed a new building to house the Z Plant waste treatment facilities. The proposed metal structure would be 24 feet by 52 feet, and all tanks and processing equipment would be located in large underground cells.⁵⁶⁸

During 1970, plutonium discharges to the soil from PFP facilities hovered near the 1969 levels. ARHCO reported the discharge of 5,721 grams in 1970, and 6,771 grams in 1971. During the first quarter of 1972 alone, 2,633 grams were discharged. Meanwhile, experiments went forward in the PFP developmental laboratory in a waste liquid calciner (see Section 7.8). When these experiments proved less than successful, the AEC authorized Project HCP-669, Plutonium Effluent Cleanup, in March 1972. This project was designed to "provide facilities and modifications to discontinue discharging plutonium-bearing liquid waste from the [PFP]...into the Hanford soil where plutonium is sorbed." The project consisted of three components: conversion of the high-salt aqueous waste "into a salt cake, using the 242-T Evaporator" (a change from earlier plans), recovery of CCl_4 from spent organic extractant at the PRF, and storage of the degraded organic phosphate residue from the extractant in existing tanks. According to ARHCO, recovery of the contaminated organic would be accomplished by feeding the waste through a steam distillation column "to [e]ffect a separation of the low boiling point organics from the higher boiling point organics." Plans to construct an organic waste incinerator at the Hanford Site to burn the high-boiling-point fraction (the residue) from

the Z Plant distillation process, as well as stored organic wastes from the REDOX facility and the 241-C tank farm, were postponed.⁵⁶⁸

At the same time, plans went forward to process low-salt aqueous waste through an ion exchange column for plutonium recovery, and evaporate the remaining waste and release the condensate to the soils. The concentrate remaining from this process would be routed to the high-salt-waste collections.⁵⁶⁹ Concurrently, plans were made to modify the fluorinator off-gas water jet system in the C-Line by installing a recycling jet scrubber system in glove box HA-46.⁵⁷⁰ Yet another upgrade in waste management practices during 1972 involved installation of a waste concentrator in the PFP analytical laboratory (see Section 7.8). An additional new practice that year collected the waste from the PRF's plutonium-uranium partitioning operations, and trucked it to the 212-A Loadout Facility at the PUREX Plant for transfer through PUREX piping to underground storage in Hanford Site tank farms.⁵⁷¹ Another upgrade in waste management emplaced a waste compactor for dry, solid contaminated waste in Room 234 of the PFP in 1972. This machinery, which had been piloted in the T Plant facility, pressed the waste into 55-gallon drums for burial.⁵⁷²

Throughout late 1972 and 1973, preparations for Project HCP-669 went forward with the safety analyses, hazards reviews, construction specifications and acceptance test procedures being written, and alternatives for organic storage being evaluated.⁵⁷³ In April 1973, a task force was established within ARHCO to evaluate Z Plant waste management practices, and to recommend improvements. The following month, all of the ARHCO 200 Areas chemical processing facilities stood down for a "review of procedures and facility systems...in order to avoid unacceptable risks to the environs." On May 15, the major objectives of Project HCP-669 were achieved when, according to ARHCO, "all intentional organic discards [from the PFP complex] were discontinued. Contaminated discards to ground were terminated and contaminated aqueous streams were discarded to the 242-T Waste Evaporator...via the D-5 tank." However, ARHCO continued, "heavy organic was noted in the outfall to the 216-Z-19 ditch as late as July 1973." During the second week of July, the PFP facilities and the 242-T Evaporator were allowed to restart.⁵⁷⁴

Throughout most of 1973, other ARHCO facilities remained in stand down status, partially caused by a very large investigation prompted by the discovery in June of the largest underground storage tank leak in Hanford Site history. Tank 241-T-106 had been leaking throughout the spring, with the total loss approximately 115,000 gallons. The Washington State Department of Ecology (Ecology) requested an investigation, but was not satisfied with the AEC's internal probe. Ecology then requested an investigation with offsite participants. Eventually, a panel was formed with members from regional universities, newspapers, and other public agencies, and public scrutiny of Hanford's waste management practices began.⁵⁷⁵

Almost immediately after the May 15 beginning of transfers of Z Plant waste to the 242-T Evaporator, planning began at the PFP complex to construct recirculating process cooling systems in the 236-Z, 242-Z, and 234-5 Buildings. This alternative was preferred to sending ongoing large volumes of liquid waste to the 242-T Evaporator, because, according to ARHCO, "the waste evaporator system...is not capable of handling the very large

volumes handled by the 216-Z-19 ditch."⁵⁷⁶ By mid-1974, it was clear that the processing of PFP complex wastes in the 242-T Evaporator was not going well. A contractor assessment written in June reported "plutonium-ameridium contamination control problems in the 242-T Waste Evaporator and associated bottom tanks, developing since Z Plant liquid wastes have been routed to this facility. Tedious control measures have been necessary during the frequent filter changes, valve repairs, and other maintenance activities." In early 1975, ARHCO reiterated to the AEC that "the experience of processing Z Plant waste at the 242-T Evaporator has been marginally satisfactory, with the spread of plutonium contamination in the system causing operating inconvenience and expense." As a result, Project B-105, Z Plant Waste Neutralization and Crystallization, an undertaking that would have routed similar PFP complex waste to the 242-S Evaporator Crystallizer after the 242-T facility's scheduled closure in 1976, was rejected.⁵⁷⁷

During mid-1974, ARHCO produced a "waste management master plan" for the AEC, aimed at establishing "assurance that radionuclides resulting from past, present or future activities will not be a hazard in the ecosystem during their radioactive life." Later that year, an ARHCO engineering study submitted eight specific proposals to ensure environmental protection in the PFP complex. These projects were to install "closed-circuit cooling" (recirculating cooling water) in the 236-Z, 232-Z, and 234-5 Buildings; install recirculating seal water (operating water) in the 26-inch mercury vacuum system serving the 234-5 Building; improve the ventilation in the 236-Z Building; construct a structure over the sump pit at the 241-Z facility; emplace a surveillance system for underground drain lines and waste piping by building a series of caissons for entry and visual inspection approximately 40 feet apart along such piping leading to the 241-Z facilities; and to provide for effluent retention and monitoring at Z Plant facilities by building three transfer pump stations to sample waste before it reached the 241-Z facility.⁵⁷⁸

In 1975, engineering plans for Z Plant environmental protection were scoped downward by eliminating the proposal to build a series of caissons along the pipelines leading to the 241-Z facility. Plans to construct a weather enclosure above the 241-Z sump pit were weighed against an alternative proposal to build an entirely new 241-Z sump pit structure. The existing, 27-year-old 241-Z sump facility was described by ARHCO as being "in extremely poor condition...the grating and piping in some of the cells have corroded away, and the concrete walls of the cells are cracked. The facility does not provide adequate containment of wastes outside of the tanks." Planning for the other six components of the 1974 environmental protection proposals went forward in more detail. Also in 1975, liquid level detection system modifications and alarms were installed in the 241-Z tanks. At the same time, the leaking 241-Z-361 tank was taken out of service and a large part of its contents was emptied into one of the Hanford Site's underground tank farms "in order to prevent an accidental release of the contaminated liquid to the soil." However, plutonium-bearing solids remain in the tank's "heel" (a hardened residue clinging to the tank's bottom). A violation of upgraded contaminated solid waste burial practices at the Hanford Site occurred in October 1975, when a drum of plutonium-bearing waste from the PFP, containing more than 200 grams of plutonium, was inadvertently buried. However, the ERDA gave permission for the drum to stay in place, rather than incur the operator exposure associated with moving it.⁵⁷⁹

Throughout 1976, plans continued for the proposals, including the recirculating process water system in the 232-Z facility. However, this portion of the work was eliminated when the decision was made in early 1977 not to restart the incinerator facility. ARHCO reported in July 1976 that over 1 million gallons of Z Plant waste had been routed through the 242-T Evaporator by that time. Soon afterward, evaporator operations closed. However, waste transfers from the PFP to this facility continued into 1977, for purposes of neutralization and routing to tank farms only.⁵⁸¹

During 1978-1979, the environmental upgrade endeavors at the PFP complex coalesced into three projects. Project B-183 relocated the 26-inch mercury vacuum system lines in the 234-5 Building (see Section 3.5), and was scheduled to provide a closed-circuit cooling-water system that would serve both the 236-Z and 234-5 Buildings. However, RHO reported in January 1980 that the project had been downsized "due to a lack of funds." The closed-circuit cooling system's portion of this project was not emplaced until the 1990's (see Section 15.6). Project B-183a, installed in 1979, provided for a new 26-inch vacuum pump system for PFP's process and laboratory needs. The old 26-inch mercury vacuum system had operated in the building since initial construction, with various upgrades over the years (see Sections 2.8, 3.1, and 3.5). According to the contractor, the old vacuum pumps, located in the 291-Z Building, had "developed inefficiencies due to corrosion and wear." The replacement project was funded as a waste effluents upgrade because the new pumps, which would be located in Room 308 of the 234-5 Building, would have a recirculating sealed water system and improved filtration of exhaust air. The recirculating sealed water system, an upgrade from the existing once-through water system, would be discharged periodically to the 241-Z sumps via the D-6 header, after monitoring and heat removal. The existing HEPA filters on the pump system were described by the contractor as being "of an old design and the filters are difficult to replace and do not have a bag-out capability for contamination control during filter replacement." The new filter system would have an additional stage of HEPA filtration, as well as bag-out capabilities.⁵⁸²

The third waste effluent upgrade effort planned during 1978-1979 was Project B-137, 241-Z Sump Improvements. According to a contractor assessment in 1978, the existing 241-Z Sump Facility had "cracks in the floors and walls of its cells. The secondary confinement provided by the vault is not an adequate barrier against contamination spread to the environment in the event of a sump tank or line failure inside the vault...The cover blocks, the grating and piping in some of the cells are in disrepair...sampling of the wastes in three of the four tanks is done without a confinement barrier, and the fourth tank is sampled in a poorly ventilated glove box...The sump facility is enclosed...The existing cell and tank ventilation systems use vitreous clay pipe as exhaust ducts [and] vitreous clay is not a currently accepted material of construction for exhaust ducts."⁵⁸³

The 241-Z Sump Improvements project would have provided the facility with a enclosure to permit all-weather maintenance of the sump, new grating with structural supports over the sump area, a ventilated change area of 200 square feet equipped with electrical outlets for the use of survey instrumentation, two stages of HEPA filtration with bag-out capability on the 296-Z-3 release point, a new ventilation system based on the negative pressure system, and in-line sampling capability for the existing tanks. The sampling

equipment itself was located in an unused, ventilated glove box in the 241-ZA Building. The enclosure was a prefabricated metal building 92 feet long by 26 feet wide by 24 feet high, with an airlock for personnel entry and exit.⁵⁸³ However, only project B-183a was completed at that time. Ventilation upgrades and pressurization changes for airborne contamination control went forward in the 291-Z and 234-5 Buildings (see Section 3.5).

15.4 Z PLANT AQUEOUS WASTE SOLIDIFICATION PROJECT

As soon as engineers at the PFP and the 242-T Evaporator realized in 1974 that the plutonium-bearing waste being routed to the evaporator was causing numerous operating difficulties in the facility, the recommendation was made not to jeopardize the much newer 242-S Evaporator-Crystallizer by sending this waste to it (see Section 15.4). With the 242-T facility scheduled to shut down in 1976, engineering studies commenced in early 1975 to find alternative means for long-term packaging and storage of Z Plant's high-salt, aqueous wastes. At that time, a plan was adopted to build solidification facilities in Room 221 of the 234-5 Building. According to ARHCO, the facility would be "compact," would operate continuously, and would first concentrate the waste then denitrate them with either formic acid, formaldehyde, sugar, or direct evaporation. It would compact the treated waste and package it in 55-gallon drums for burial as retrievable TRU waste. Waste could be transferred to Room 221 from the D-5 tank in the 241-Z Sump via existing pipelines, and existing PFP counting equipment could be used for plutonium accountability purposes. In early 1975, experiments began in the PFP developmental laboratory to test the various drying agents and technologies in small-scale, glass equipment (see Section 7.8).⁵⁸⁴

In the spring of 1975, ARHCO requested that the AEC approve a project to fully design and construct the waste solidification facility. The benefits of such a facility were listed as "avoiding an alpha contamination problem at the 111-U tank pump pit and at the valve pits" (the route the Z Plant aqueous waste would follow if it were sent to the 242-S facility), "eliminating the need to upgrade the 242-S Evaporator-Crystallize to handle higher levels of plutonium...eliminating the need for one and possibly two future double-shell tank bottoms...[and] improving the product form of Z Plant waste for improved storage and reliability." In October of that year, the AEC approved design work on Project B-121, Z Plant Aqueous Salt Waste Solidification Facility. By early 1976, an environmental assessment, quality assurance program plan, and conceptual design reports had been written.⁵⁸⁵

As laboratory studies began to define the drying methods and equipment for the aqueous waste solidification (see Section 7.8), PFP engineers spent the spring of 1976 designing a twin-drum drier, the processing vessels, product load-out station, shielding requirements and materials, and the other components of the Room 221 facility.⁵⁸⁶ Procurement specifications for the salt drum drier and other equipment were issued in the summer, tie-ins to the 241-Z tanks were designed, and plutonium detection instrumentation was selected.⁵⁸⁷ A safety analysis was nearly finished when multiple concerns about project criteria were raised in October by ARHCO. The concerns included worries about laboratory studies in potentially explosive mixtures of red oil in the drying process (see Section 7.8), the inadequacy of volume capacities, the potential inadequacy of Room 221 itself, construction cost overruns, and

the lack of redundant facilities if the waste solidification facility should break down.⁵⁸⁹

In early November, ERDA stopped work on Project B-121, but stated that "the programmatic needs to be satisfied by this project are still valid and an early project restart is important." However, by March 1977, laboratory efforts still showed corrosion pitting on the prototype drum drier and other process difficulties. That month, ARHCO recommended the cancellation of the project to ERDA, citing "the current philosophy regarding the continued operation of Z Plant" (see Sections 3.4 and 3.5). Although some studies continued on certain aspects of engineering for the waste solidification facility in the spring of 1977, the project was dropped soon afterward and it was never installed. Projects B-183, B-183a, and B-137 then went forward to deal with PFP's liquid waste (see Section 15.3)⁵⁹⁰

15.5 THE RADIOACTIVE ACID DIGESTION TEST UNIT FACILITY

Another attempt to upgrade waste disposal practices at the PFP came when the Radioactive Acid Digestion Test Unit (RADTU) was emplaced in Rooms 192-D and 196 and portions of Rooms 192, 197, and 235 of the 234-5 Building in 1978. RADTU was installed by the HEDL, in association with its work to operate 300 Area development laboratories associated with the FFTF. RADTU was planned as a demonstration facility that would begin with small, experimental operations, then expand testing, and become a production-scale facility at the same time that it would be taken over by the Hanford Site's chemical processing contractor in 1980.⁵⁹¹

The RADTU process operated within glove boxes. Its feed material consisted of combustible substances such as paper, wood, plexiglass, styrofoam, polyethylene, ion exchange resins, polyvinyl chloride (PVC), nylon^{tt}, Tygon, plastic tape, latex, neoprene, and Hypalon^{uu} contaminated with TRU waste. First, segregation from noncombustible waste took place in a sorting glove box. The combustible waste was shredded, and fed into a "digester" vessel where it was mixed with nitric and sulfuric acids. After dissolution, residual solids were separated and the solution was dried and packaged for disposal as solid waste. A volume reduction of approximately fiftyfold was achieved. However, a management oversight and risk tree (MORT) assessment of the RADTU facility conducted by the chemical processing contractor in 1979 identified daunting mechanical and flow problems; piping, drain, and temperature issues; accountability and assay difficulties; monitoring and alarming deficiencies; and ergonomic deficiencies. Soon after a small fire occurred in the digester glove box in July 1980, the decision was made not to convert RADTU to a production-scale operation. The facility closed in April 1981.⁵⁹² (See Figure 15-7.)

^{tt} Nylon is a trademark of E.I. DuPont de Nemours and Company.

^{uu} Hypalon is a trademark of the E.I. DuPont de Nemours and Company.

Figure 15-7. Stabilized (Calcined) Product Leaves Oven, 1996.



15.6 1980's AND 1990's EFFLUENTS AND WASTE MANAGEMENT UPGRADES AT THE PFP

Beginning during 1983-1984 when the PFP complex was upgraded in preparation for the resumption of defense production, several safety and other improvements were made to various PFP facilities (see Sections 3.6, 6.5, and 12.4). In terms of effluent controls, another monitoring, holding, and waste neutralization tank (D10) was added to the 241-Z facility in 1982 and tank D11 was added 2 years later to minimize the mixing of waste neutralization chemicals. Process specifications and operating specifications for the 241-Z facility were revised in 1981 and 1983, as were specifications for several waste-handling and packaging operations in the PFP complex. During 1982-1983, stack monitoring instrumentation was upgraded on the main stack serving the PFP complex (291-Z), the 296-Z-3 release point serving the 241-Z Sump, the 296-Z-6 release point serving the 2736-Z and ZA facilities,

and the 296-Z-9 release point serving the 216-Z-9 crib. In 1984, the crib monitoring equipment in the 2904-ZA Building was upgraded. In 1986, a steam blowdown vent line was added to 241-Z tank D9, modifications were made to the liquid level measurement system for the 216-Z-20 crib, and a new window was added to the glove box holding the 241-ZA transfer pump. A new alarm and annunciator was emplaced in the 241-Z Sump in 1987, along with new jets and dip tubes, and existing gauges were relocated to alleviate condensation problems. In 1987, civil structural plans and drawings were verified and corrected, new liquid level gauges were installed in the 241-Z facilities, and insulation was added to piping in the 241-ZA facility.⁵⁹²

Also in 1987, an investigation was conducted of a decreased drainage problem in the 216-Z-20 crib. The chemical composition and timing of wastes discharged were found to be forming particulates that clogged the crib bottom. RHO formulated plans to improve the drainage by "dissolution and/or dispersion of amphoteric layers of hydrated oxides of aluminum and iron" that had built up in crib sediments.⁵⁹³

In 1989, in response to the signing of the Tri-Party Agreement for the cleanup of the Hanford Site, a large Hanford Environmental Compliance (HEC) Project was conceived to address liquid discharges and tank systems across the Hanford Site. This umbrella project installed several effluents upgrades at the PFP complex. Most notable was the construction of the 243-Z Low Level Waste Treatment Facility, a system of influent sump tanks, pumps, particulate filters, and absorption treatment media. This facility, completed in 1994, used granulated activated carbon to remove organics, bone char to remove actinides, and ion exchange resin to remove various metal cations from the liquid effluents streams of the PFP complex having low levels of contamination. Other HEC projects at the PFP complex finally constructed a closed-loop cooling system for the 236-Z, 234-5, and 291-Z Buildings, installed new, double-contained waste piping from these buildings to the 241-Z facilities, replaced waste piping inside the 236-Z and 234-5 Buildings, and tied the PFP complex into the 200 West Area TEDF. In 1995, these upgrades culminated when all liquid waste discharges to the soil from the PFP complex ended via tie-in to the Hanford Site's 200 West Area TEDF.⁵⁹⁴

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16.0 1990's AT PFP: SHUTDOWNS, PUBLIC INVOLVEMENT, STABILIZATION AND DEACTIVATION

16.1 PFP STABILIZATION/DEACTIVATION ATTRACTS ATTENTION

After the 1987 shut down of the PRF (see Section 12.4) and the 1989 shut down of the RMC Line (see Sections 3.6 and 6.5), the PFP entered a waiting period while the world witnessed some of the most historic events of the twentieth century. In late 1991, the crumbling and dissolution of the former Soviet Union into 15 separate and independent republics began. That September, U.S. President George Bush announced the largest cuts in nuclear weapons ever undertaken since such weapons became part of the American stockpile. He also took the U.S. Strategic Air Command (SAC) bombers off of constant alert status for the first time in 42 years. He explained his conviction that the former U.S.S.R., Cold War adversary of the United States for decades, no longer posed a "realistic threat" of sudden attack on Western Europe. In January 1993, just before leaving office, Bush signed the second START II with Russian President Boris Yeltsin.

During the early 1990's, the DOE authorized a number of equipment, instrumentation, and containment upgrades in the PFP complex in preparation for a "stabilization run." With the core work to be performed in the PRF and the RMC Line, the stabilization would have converted and/or solidified most of the plutonium-bearing residues, sludges, liquids, and other materials into oxide powders or plutonium metal. However, as plans and upgrades moved forward, two safety incidents occurred during 1991 (in June and October) and two more occurred during March 1993. At that time, the plant was placed on administrative hold, pending safety reviews, by WHC.⁵⁹⁵

During this hold period, several interest groups, as well as the Yakima Indian Nation, sent a letter to Secretary of Energy Hazel O'Leary asking for detailed and lengthy documentation and information about the PFP, its history, inventory, and condition. Concerned stakeholders confronted DOE with the contention that the stabilization run was, or could be, viewed as a "back-door" way to continue plutonium production. Furthermore, stakeholders that identified themselves to DOE objected to spending money to upgrade key parts of the "production infrastructure" at PFP. Once facilities such as the C Line and the PRF were refurbished, stakeholders contended, DOE might use the modernized condition of these facilities to attract or accept new plutonium production missions for the Hanford Site. Such future missions, groups such as the Seattle-based Heart of America Northwest and others stated, were distinctly unwelcome. In mid-1993, stakeholders requested that DOE prepare an environmental impact statement (EIS) to address the impacts of cleaning up and restarting these major facilities. In January 1994, DOE agreed to do so, and placed the RMC and PRF upgrade campaigns on hold.⁵⁹⁶

Because the PFP complex by this time contained nearly 8,000 packages of plutonium-bearing materials in containers not designed for long-term storage, a search immediately was begun for alternative or interim methods to begin stabilization of some of the higher risk materials being stored. Most of the higher risk residues left over from PFP's own processing operations were stored in glove boxes. Other more stable items, some left over from the demise of the breeder reactor program and some from the years when the facility was

designated as the CSMO site for plutonium-bearing scraps for the entire AEC/ERDA, were stored in the PFP vaults. The higher risk reactive scrap produces gases that prevent those containers from being able to be sealed. The various packages had to be under a periodic surveillance program, resulting in ongoing worker exposure and potential environmental exposure from plutonium and americium.⁵⁹⁷

In the summer of 1994, several "interim stabilization" measures were developed at the PFP, and in November of that year two calciner ovens were turned on inside a glove box to begin the stabilization process. During 1995, other projects got under way to remove plutonium-contaminated duct work; stabilize certain plutonium-bearing process residues with cement; remediate nearby soils, trenches, and sumps; and institute many other measures. In the meanwhile, in May 1994, the DNFSB, an arm of Congress, issued DNFSB Recommendation 94-1, calling on the DOE to formulate a comprehensive, expedited plan to convert plutonium and irradiated fuel into conditions suitable for safe interim storage in the nation's defense nuclear facilities. That November, DOE issued the *Plutonium Working Group Report on Environmental, Safety, and Health Vulnerabilities Associated with the Department's Plutonium Storage*, the findings of a plutonium working group established to examine storage locations and conditions of plutonium in its nuclear facilities. In February 1995, DOE headquarters responded by issuing its 94-1 Implementation Plan, outlining corrective measures to be taken at all of its facilities, including both at the PFP (for plutonium) and at the 105-K Basins (Hanford Site storage pools holding spent nuclear fuel). An inventory of plutonium-bearing materials in the PFP complex was presented to the DNFSB in July 1996.⁵⁹⁸

16.2 FINAL STABILIZATION PLANS FORMULATED

In late 1995, a draft EIS for PFP stabilization was completed and sent out for review by stakeholders. In June 1996, a record of decision (ROD) on the final EIS was signed, which outlined the manner in which DOE was committed to complete stabilization of all of the plutonium-bearing residues at the plant and finish cleanup of the buildings and structures of the PFP. The programmatic target date for stabilization of the residues was placed at the year 2002, while the facilities cleanup was to be completed by 2005. Unlike many traditional EISs, the PFP document identified a "toolbox" of multiple stabilization and cleanup alternatives that can be used together, as needs arise during the various processes. The plutonium vaults in the PFP complex, located in separate buildings from the main plants, will not be removed in the agreements reached in the ROD.

Under way by late 1996 were some of the first steps in the PFP Deactivation Project, including cementation of some plutonium-bearing solids; thermal stabilization of some plutonium-bearing liquids; building duct removal; emplacement of a computerized distribution monitoring and control system for ventilation flows in the 234-5, 236-Z, 2736-Z, 243-Z, and other PFP complex buildings; cleanout activities at the 232-Z Incinerator (see Section 10.7); deactivation planning for the PRF (see Section 12.5); effluent upgrades (see Section 15.6); planning for the cleanout of the 231-Z Building (see Section 1.6); and many other measures.⁵⁹⁹

In October 1996, a new contractor consortium assumed the management of the PFP complex, pledging to accelerate the completion of stabilizing the plutonium-bearing residues.⁶⁰⁰ The consortium would be following DOE's new mandates of public involvement, openness, and international cooperation in the safe and intensively technological storage of plutonium. Thus, the facilities of the old complex that had done so much to build the nuclear defense stockpile of the United States entered the new world of the 1990's. (See Figures 16-1 through 16-9.)

Figure 16-1. The PFP Complex in 1992.

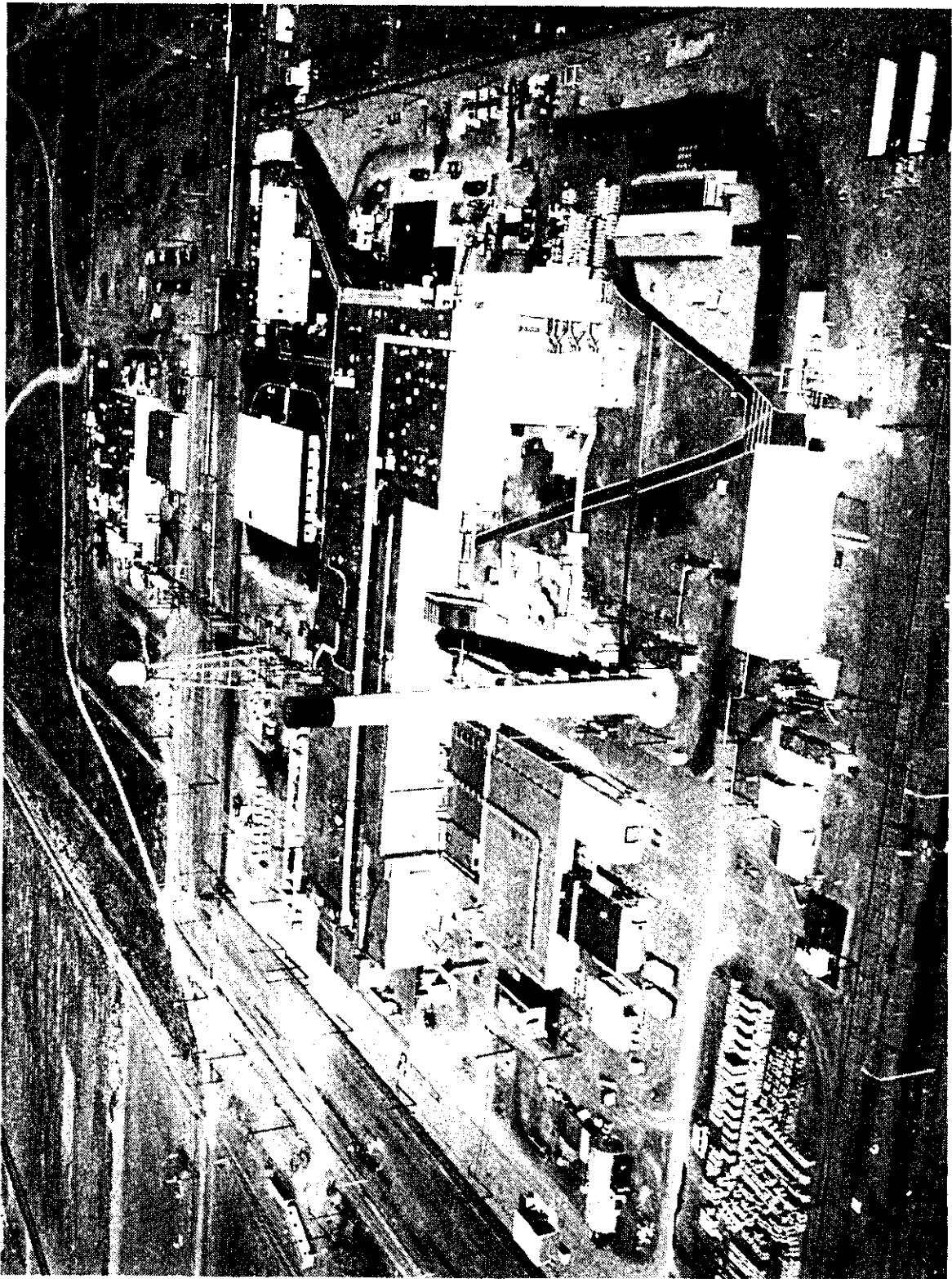


Figure 16-2. Cleanout of the 232-Z Incinerator, 1994.

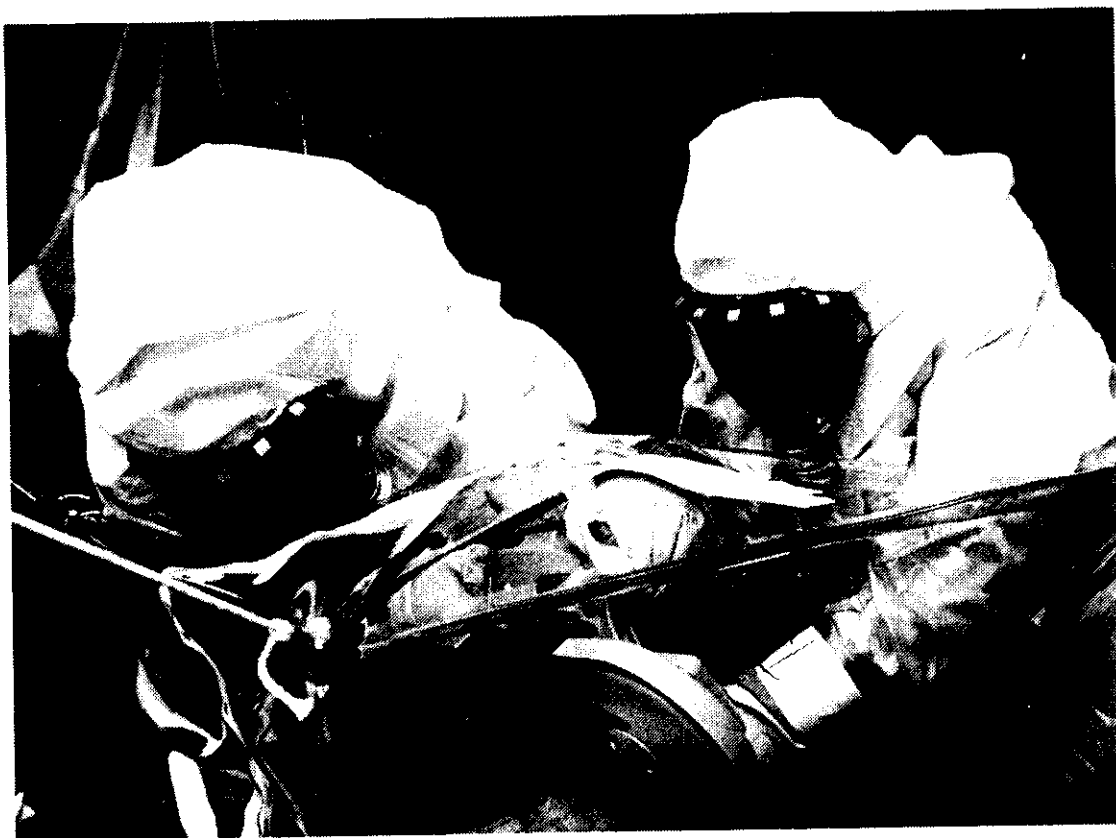


Figure 16-3. Operator Monitors the Earliest Interim Thermal Sludge Stabilization, 1994.

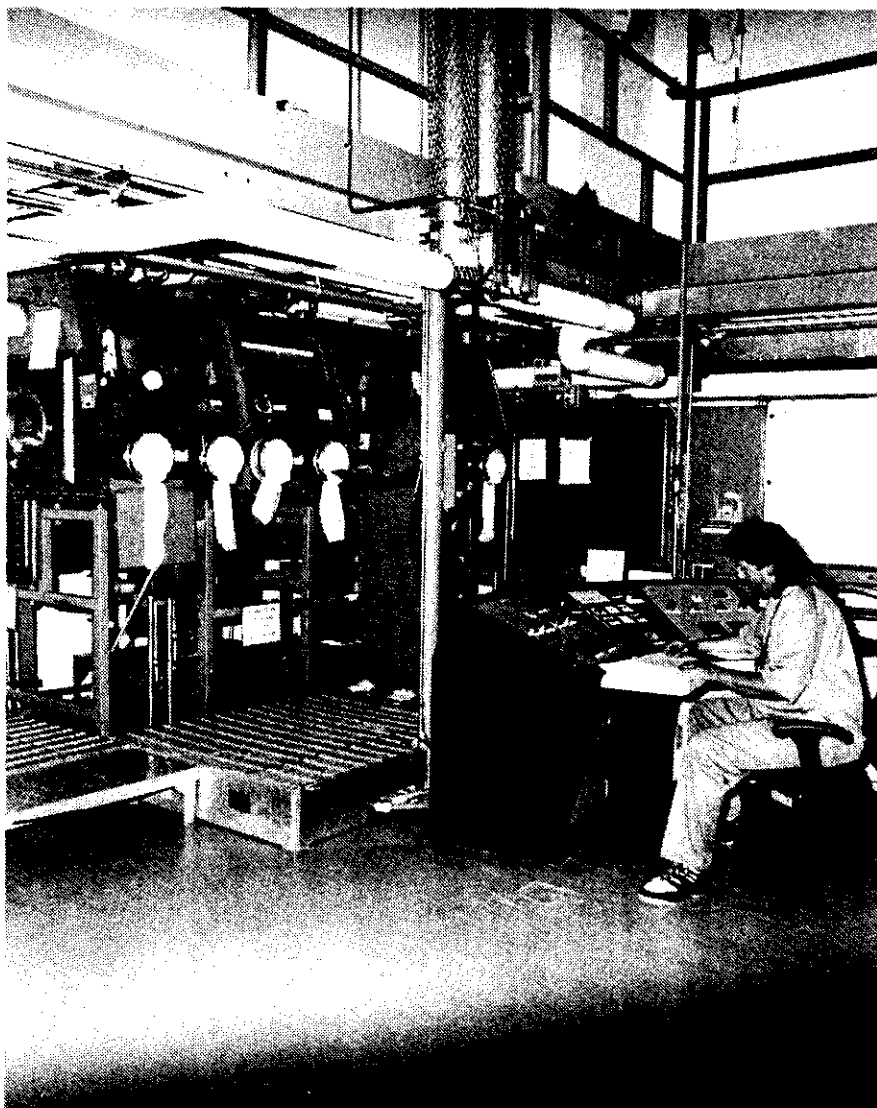


Figure 16-4. Operator Oversees Thermal Stabilization Campaign, 1995.



Figure 16-5. Operator Prepares to Open Sludge Container for Stabilization, 1995.



Figure 16-6. Operator Pours Sludge into Filter Boat for Calcination, 1995.



Figure 16-7. Stabilized (Calcined) Product Leaves Oven, 1996.



Figure 16-8. Duct Remediation in the 234 5 Building, 1996.

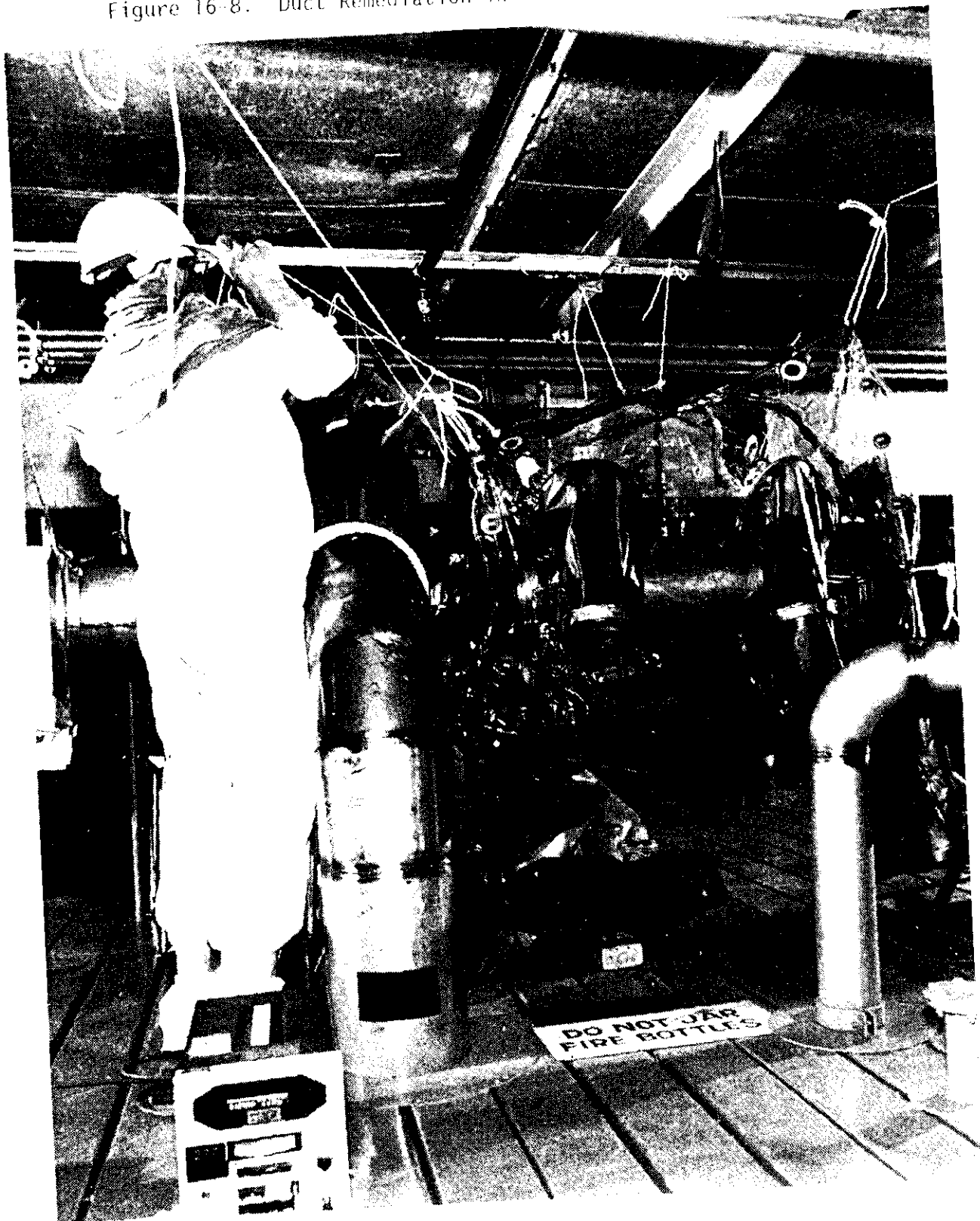
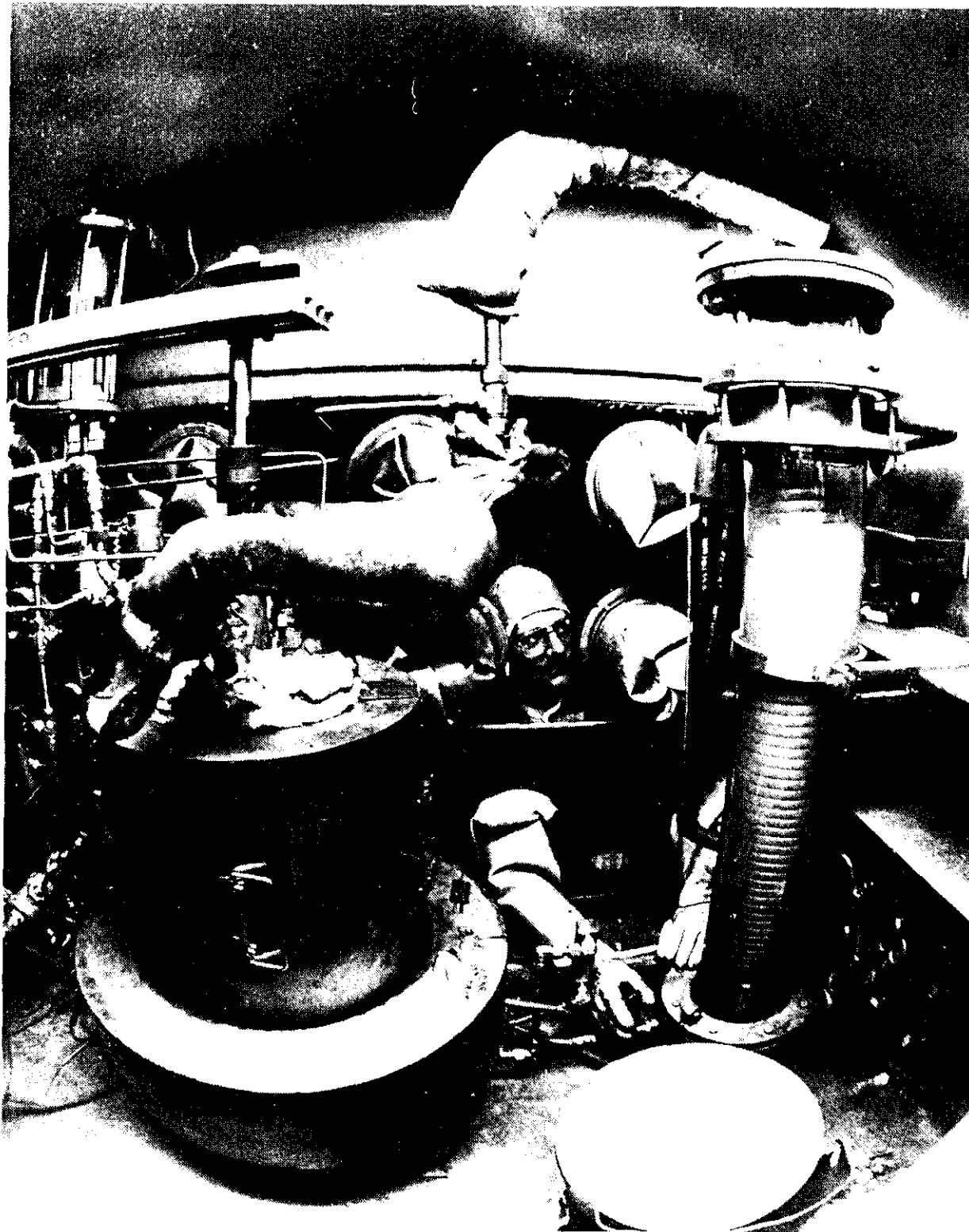


Figure 16-9. Calcining of Plutonium-Bearing Solutions out of 10-Liter Containers, 1996.



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17.0 ENDNOTES

1. DuPont, HAN-73214, Book 12; Hanford Engineer Works, HW-7-1293 DEL, p. 18.
2. DuPont Corporation, HAN-73214, Book 12, p. 117; Matthias, OUT-1642.
3. G.E. Hanford Co., HW-20438 DEL, p. 139; Kerr, HW-22333.
4. G.E. Hanford Co., HW-20438 DEL, p. 139; Kerr, HW-22333.
5. G.E. Hanford Co., HW-18473 DEL, p. 121, 126; G.E. Hanford Co., HW-19622 DEL, pp. 6, 48, 75, 132, 139-140; G.E. Hanford Co., HW-19842 DEL, pp. 6, 142, 133, 143.
6. G.E. Hanford Co., HW-23140 DEL, pp. 37, 90; G.E. Hanford Co., HW-26720-DEL
7. Packer, HW-30999.
8. G.E. Hanford Co., HW-20991 DEL, pp. 382-383; Bell, HW-21563 DEL; G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25.
9. G.E. Hanford Co., HW-18700 DEL, p. 111; G.E. Hanford Co., HW-23437 DEL, p. 105; G.E. Hanford Co., HW-23982 DEL, p. Fb-20; Isaacson, HW-25834; G.E. Hanford Co., HW-24377 DEL, p. Fb-28; G.E. Hanford Co., HW-24605 DEL, pp. Fb-27-28; G.E. Hanford Co., HW-24928 DEL, p. Fb-25.
10. G.E. Hanford Co., HW-18700 DEL; G.E. Hanford Co., HW-26047 DEL.
11. G.E. Hanford Co., HW-23437 DEL, p. 148; Carr, HW-24800-105, pp. 2-4; Gerber, WHC-MR-0437, pp. 1-2.
12. G.E. Hanford Co., HW-23982 DEL.
13. G.E. Hanford Co., HW-27624-DEL.
14. G.E. Hanford Co., HW-25227 DEL.
For other early process changes in the 231-Z Building, see: Gross, HW-26090; Maider, HW-32053; Smith, HW-32077; Helgeson, HW-41167.
15. G.E. Hanford Co., HW-28576 DEL; Smith, HW-36334; G.E. Hanford Co., HW-36440 DEL; G.E. Hanford Co., HW-38375 DEL, pp. F-2-3; G.E. Hanford Co., HW-38828 DEL, p. Fc-14; G.E. Hanford Co., HW-39751 DEL, pp. Ff-5-6; G.E. Hanford Co., HW-40182 DEL, pp. Ed-7, Fg-5, Fg-12; G.E. Hanford Co., HW-40692 DEL, pp. Fc-53, Ff-6, Ff-12, Fg-14; Poucher and Ingalls, HW-39871 RD.
16. G.E. Hanford Co., HW-39900 DEL, p. 19; G.E. Hanford Co., HW-34631 DEL, pp. F-2-3; G.E. Hanford Co., HW-35530 DEL, p. Fg-2; G.E. Hanford Co., HW-35891 DEL, p. Fg-2; G.E. Hanford Co., HW-36440 DEL, pp. Ed-16, Fc-16; G.E. Hanford Co., HW-36928 DEL, p. Fc-16; G.E. Hanford Co., HW-38375 DEL, pp. F-2-3; G.E. Hanford Co., HW-38828 DEL, p. Fc-14; Smith, HW-36334; Travis, Directive HW-361, and Modification #1; G.E. Hanford Co., HW-39751 DEL, pp. Ff-5-6; G.E. Hanford Co., HW-40182 DEL, pp. Ed-7, Fg-5, Fg-12; G.E. Hanford Co., HW-40692 DEL, pp. Fc-53, Ff-6, Ff-12, Fg-14.

17. Department Managers, HW-42219 DEL, pp. Ed-6, Fc-15, Fc-17, Ed-2; Department Managers, HW-42626 DEL, pp. Ed-5, F-1-2, Fc-16, Ed-5; Department Managers, HW-41205 DEL, pp. Ed-5-6; Browne, HW-44305; Department Managers, HW-43137 DEL, p. E-2; Department Managers, HW-43938 DEL, pp. Fc-16; Pugh, HW-45940; Bunch, HW-54559; Department Managers, HW-44580 DEL, p. Ed-5.
18. G.E. Hanford Co., HW-23437 DEL; Department Managers, HW-41205 DEL; Department Managers, HW-42219 DEL; Department Managers, HW-42626 DEL; Operation Managers, HW-48132 DEL; Operation Managers, HW-51802; Thomas, Directive No. HW-394, Modification #2.
19. Plock, "Property Record, Project C-198;" Bloom, BPF-1451; Work, HW-08254; Work, HW-08272; Shaw, Directive No. HW-107.
20. Finch, "Planning Meeting Minutes...", February 15, 1957; Mobley, "Status of Fire Protection Activities...", April 19, 1957; Palmer, "Cambridge Special "G" Type Space Filters...", September 9, 1957; Travis, Directive No., HW-438; Operation Managers, HW-48132 DEL, p. E-9; Operation Managers, HW-54319 DEL, p. E-9; Thomas, Directive No. HW-438, Modification #1; Schipper, Directive HW-526.
21. Schipper, Directive HW-505.
22. Department Managers, HW-41205 DEL; Department Managers, HW-42626; Travis, Directive No., HW-361, and Modification #1; Operation Managers, HW-48132 DEL; Thomas, Directive No. HW-424, and Modification #1; Wick, HW-70577 DEL; Wick, HW-72115 DEL; Wick, HW-73530 DEL.
23. Priode, Benoliel, Gilbert, McGrath, Tomlinson and Zuhr, HW-55767; Wick, HW-70577 DEL; Wick, HW-72115 DEL; 73530 DEL; Demiter, Duncan, Meeuwsen, Reddinger and Zvonar, WHC-IP-1791; Powers, BNWL-CC-1924; Wang, Dahlgren and Laegried, BNWL-SA-5244; Pawlewicz and Laegried, PNL-SA-6811; Pottmeyer, DeLorenzo, Weyns-Rollosson, Berkwitz, Vejvoda, and Duncan, WHC-EP-1659; Miller, BNWL-1769.
24. Ritchie, Directive No. HW-631; Smith, Directive HW-631, Modifications #1, #2; Williams, Directive No. AEC-290; Wheeler, RHO-CD-278; Westinghouse Hanford Co., DOE/RL-88-19; Maxfield, RHO-CD-673; Walters, BNWL-CC-2591 Rev. 1; Williams, Directive AEC-270, and Modifications #1, #2; Davenport, BNWL-CC-1924, Sup 4; Williams, Directive #AEC-332, and Modification #1; Williams, Directive AEC-336; Tumlinson, Directive AEC-332, Modifications #2, #3; Smith, Directive No. HW-631, and Modification #1.
25. King, Asmund, and Butts, BNWL-B-479; Williams, Directive No. AEC-270, and Modifications #1, #2; Ritchie, Directive No. HW-631; Gallant, RHO-CD-130; Smith, Directive No. HW-361, Modifications #1, #2; Williams, Directive No. AEC-336; King, PNL Occurrence Report PNL 83-4; U.S. DOE, DOE/EH-0415.
26. G.E. Hanford Co., HW-10475 C, p. 1108; DuPont Corporation, HAN-73214, Book 12, pp. 115-135, 148-151, 184-195; Swartout, HW-3-2801; Wahl, LA-75; Veltman and Burke, A-84-019, 32-3 Series; Christensen and Maraman, LA-3542, pp. 1-8; G.E. Company, HW-24800-36, p. 5; Streid, HM-253, p. 1-2; Bell, HW-23232, p. 1.
27. Hewlett and Duncan, WASH-1215; U.S. AEC, AEC-1140; Streid, HM-253.

28. Streid, HM-253, p. 2; G.E. Hanford Co., HW-24800-36, pp. 5, 13; G.E. Hanford Co., HW-7-6048 DEL, p. 143, 146; G.E. Hanford Co., HW-7-6184-DEL, p. 156; G.E. Hanford Co., HW-7-6391 DEL, p. 151; G.E. Hanford Co., HEW-7096 DEL, p. 157; G.E. Hanford Co., HEW-7283 DEL, p. 169; Bell, HW-23232, pp. 1-2.
29. Streid, HM-283, pp. 2-3; G.E. Hanford Co., HEW-7504 DEL, p. 164.
30. Bell, HW-23232, p. 3; Streid, HM-283, pp. 3-4; Streid, HM-24; G.E. Hanford Co., HW-07795 DEL, p. 179; G.E. Hanford Co., HW-07997 DEL, p. 183; Prudich, HW-08106; Knights, HW-08285; Work, HW-08323; Prudich, HW-08347; Work and Bell, HW-08355; G.E. Hanford Co., HW-08438 DEL, p. 197; Work, HW-11112; Shaw, Directive No. HW-12; Work, HW-11321.
31. Bell, HW-23232, p. 3; Streid, HM-283, pp. 3-4; Streid, HM-24; Streid, HM-118; G.E. Hanford Co., HW-07795 DEL, p. 179; G.E. Hanford Co., HW-07997 DEL, p. 183; G.E. Hanford Co., HW-08438 DEL, p. 197; G.E. Hanford Co., HW-08931 DEL, pp. 214-215; G.E. Hanford Co., HW-08267 DEL, pp. 186-187; Shaw, Directive No. HW-12, Modification #1; G.E. Hanford Co., HW-09191 DEL, pp. 112-113; G.E. Hanford Co., HW-24800-36, p. 7.
32. Streid, HM-283, pp. 4-5; Work, HW-08252; G.E. Hanford Co., HW-10378 DEL, pp. 65, 76; G.E. Hanford Co., HW-10714 DEL, p. 202; G.E. Hanford Co., HW-10993 DEL, p. 216; G.E. Hanford Co., HW-11226 DEL, p. 39; G.E. Hanford Co., HW-11499 DEL, p. 50; G.E. Hanford Co., HW-11835 DEL, p. 53; G.E. Hanford Co., HW-12086 DEL, pp. 43, 127; Work, HW-10006; Knights, HW-10139; Haught, HW-10324; Shepard, HW-10595; Work, HW-10482; Haught, HW-10576; G.E. Hanford Co., HW-12391 DEL, p. 93.
33. Streid, HM-253, pp. 6-7; G.E. Hanford Co., HW-12666 DEL, pp. 4, 90; G.E. Hanford Co., HW-12937 DEL, pp. 90-91; G.E. Hanford Co., HW-13190 DEL, pp. 4, 41-42; G.E. Hanford Co., HW-13561 DEL, pp. 4, 43, 95; G.E. Hanford Co., HW-13793 DEL, pp. 4-5, 42, 45, 49, 55, 102; Shaw, Directive No. 12, Modifications #2, #4; Schlemmer, Directive No. 12, Modification #3.
34. Streid, HM-253, pp. 16-17; Work, HW-08140; G.E. Hanford Co., HW-14042 DEL, pp. 269-270.
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36. Plock, "Property Record, Project C-198;" Bloom, BPF-1451; Work, HW-08254; Work, HW-08272; Shaw, Directive No. HW-62, and Modification #1; Bell, HW-23232, pp. 6-9.
37. G.E. Hanford Co., HW-15550 DEL, pp. 145-146, 285-287;
38. G.E. Hanford Co., HW-14043 DEL, pp. 3-6, 21, 39, 52, 58, 74, 84, 132, 133; Lane, RL-SEP-855 DEL, p. 6; Bell, HW-15953, pp. 7-10; G.E. Hanford Co., HW-14338 DEL, pp. 108, 5.
39. Bell, HW-15953, pp. 6-17.

40. G.E. Hanford Co., HW-14338 DEL, pp. 138-139, 283; G.E. Hanford Co., HW-14596 DEL, pp. 137-138, 277; G.E. Hanford Co., HW-14916 DEL, pp. 143-145, 295-296; G.E. Hanford Co., HW-15267 DEL, pp. 141, 145-146, 290-292; Roesch and Watson, HW-27194, p. 1.
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42. G.E. Hanford Co., HW-15843 DEL, pp. 307-308, 310; Groswith, HW-15821; G.E. Hanford Co., HW-17410 DEL, pp. 335-336; G.E. Hanford Co., HW-17660 DEL, p. 348; G.E. Hanford Co., HW-17971 DEL, pp. 337-338; G.E. Hanford Co., HW-18221 DEL, pp. 345, 350, 362-363; G.E. Hanford Co., HW-24800-36, p. 11; G.E. Hanford Co., HW-18740 DEL, p. 372-373.
43. G.E. Hanford Co., HW-18221 DEL, pp. 4, 93; G.E. Hanford Co., HW- 19325 DEL.
44. G.E. Hanford Co., HW-19021 DEL, pp. 6, 99, 159; G.E. Hanford Co., HW-19325 DEL, pp. 6, 138, 128; G.E. Hanford Co., HW-18221 DEL, pp. 5, 123, 134; G.E. Hanford Co., HW-19622 DEL, pp. 7, 140; Members of the Technical Divisions, HW-19301 DEL, p. 9; Weidenbaum, HW-19758.
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46. G.E. Hanford Co., HW-15843 DEL, pp. 154-155; G.E. Hanford Co., HW-17410 DEL, pp. 155-156; G.E. Hanford Co., HW-17660 DEL, p. 165; G.E. Hanford Co., HW-17971 DEL, pp. 163-164; G.E. Hanford Co., HW-18221 DEL, pp. 167-168; G.E. Hanford Co., HW-18473 DEL, pp. 169-170; G.E. Hanford Co., HW-18740 DEL, pp. 178-179; G.E. Hanford Co., HW-19325 DEL, pp. 184-185; G.E. Hanford Co., HW-19622 DEL, pp. 184-185.
47. G.E. Hanford Co., HW-20161 DEL, pp. 74, 98-99, 363-65, 379, 381, 383-384; G.E. Hanford Co., HW-20438 DEL, pp. 407-409; Bell, HW-20506 DEL; Beaulieu, HW-20674; Bell, HW-21097 DEL; G.E. Hanford Co., HW-20671 DEL, pp. 399-401; G.E. Hanford Co., HW-20991 DEL, pp. 382-383; Bell, HW-21563 DEL; G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25.
48. G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25; G.E. Hanford Co., HW-21260 DEL, pp. 132, 389, 395, 397-398; Shaw, Directive No. HW-186, Modification #1; Travis, Directive No. HW-233; Shaw, Directive No. 239, and Modification #1; G.E. Hanford Co., HW-20506 DEL, p. 85; Bell, HW-21563 DEL; Wood, HW-55196, p. 2; Bell, HW-23232, pp. 4-8.
49. G.E. Hanford Co., HW-21802 DEL, pp. 273, 287; G.E. Hanford Co., HW-22075 DEL, pp. 42, 131-132, 125, 127; Anicetti, HW-21195; G.E. Hanford Co., HW-22304 DEL, pp. 42, 83, 130, 133, 135-136; G.E. Hanford Co., HW-24800-90, p. 24; G.E. Hanford Co., HW-22610 DEL, pp. 138, 148-149; G.E. Hanford Co., G.E. Hanford Co., HW-22875 DEL, pp. 90, 142, 146-147; Chapman, HW-23125 DEL; G.E. Hanford Co., HW-23140 DEL, pp. 91-93, 142, 147-148, 158; Shaw, Directive No. HW-280; G.E.

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50. G.E. Hanford Co., HW-20671 DEL, pp. 78, 395; Shaw, Directive No. HW-242, and Modification #1; G.E. Hanford Co., HW-21506 DEL, pp. 84-85, 87; G.E. Hanford Co., HW-21802 DEL, pp. 68, 72, 86; G.E. Hanford Co., HW-22875 DEL, pp. 122, 47, 89.

51. G.E. Hanford Co., HW-23982 DEL, pp. A-1, F-1, Fb-6; Stark, HW-24046; Quinn, HW-24084; Quinn, HW-24165; G.E. Hanford Co., HW-24800-90, pp. 13, 18.

52. G.E. Hanford Co., HW-23437 DEL, pp. 135, 145; G.E. Hanford Co., HW-23638 DEL, pp. 44-45, 145-146, 149; G.E. Hanford Co., HW-23882 DEL, pp. Ff-2, Ff-5; G.E. Hanford Co., HW-24337 DEL, pp. F-3-4, Ff-7; G.E. Hanford Co., HW-24605 DEL, pp. Ed-1, Ed-8, F-3, Ff-2.

53. G.E. Hanford Co., HW-23437 DEL, p. 107; G.E. Hanford Co., HW-23982 DEL, p. Fb-21; G.E. Hanford Co., HW-25533 DEL, p. Fc-10; G.E. Hanford Co., HW-26720 DEL, p. Fc-15; Hay, HW-26191; G.E. Hanford Co., HW-24605 DEL, p. Fb-30; Anicetti, HW-25651.

54. G.E. Hanford Co., HW-24605 DEL, pp. Fc-4, Ff-18; G.E. Hanford Co., HW-25227 DEL, p. Fd-14; G.E. Hanford Co., HW-25533 DEL, pp. Fd-8, Fg-13; G.E. Hanford Co., HW-25781 DEL, p. Fd-8; G.E. Hanford Co., HW-26047 DEL, p. Fd-7; G.E. Hanford Co., HW-26376 DEL, p. Fd-5; G.E. Hanford Co., HW-26720 DEL, pp. Fd-11-12.

55. G.E. Hanford Co., HW-23437 DEL, pp. 45, 241; G.E. Hanford Co., HW-23638 DEL, p. 147; G.E. Hanford Co., HW-23982 DEL, p. Ff-17; G.E. Hanford Co., HW-24337 DEL, pp. Ff-16-18; G.E. Hanford Co., HW-24605 DEL, pp. Ff-5, Ff-13, Ff-17; Sloat, HW-65616 Rev; G.E. Hanford Co., HW-24928 DEL, pp. Ff-8, Ff-13, Ff-18; G.E. Hanford Co., HW-35227 DEL, pp. Ff-9, Ff-12, Ff-17; G.E. Hanford Co., HW-25533 DEL, pp. Ed-10, Ff-8-9, Ff-12-13, Ff-18; G.E. Hanford Co., HE-25781 DEL, pp. Ff-10, Fg-6, Fg-12-14, Fg-18; G.E. Hanford Co., HW-26047 DEL, pp. Ff-10, Fg-6, Fg-18; G.E. Hanford Co., HW-26376 DEL, pp. Fg-7, Fg-13, Fg-15, Fg-19-20; G.E. Hanford Co., HW-26720 DEL, pp. Ed-11, Fg-7, Fg-12, Fg-19.

56. G.E. Hanford Co., HW-25227 DEL, p. Fg-17; G.E. Hanford Co., HW-25781 DEL, p. Ff-10.

Note: This laboratory addition or annex to the 234-5 Building was not built.

57. G.E. Hanford Co., HW-26376, p. Fc-5.

58. Gerber, WHC-SD-EN-RPT-004, p. 102; G.E. Hanford Co., HW-26376 DEL, pp. Ff-3, Ff-10.

59. G.E. Hanford Co., HW-25533 DEL, p. Ff-3; G.E. Hanford Co., HW-25781 DEL, pp. Ed-9, Ff-3; G.E. Hanford Co., HW-26047 DEL, p. Ff-3; Gerber, WHC-SD-EN-RPT-004, p. 102; Carr, HW-24800-105, pp. 2-21; G.E. Hanford Co., HW-26376 DEL, pp. Ff-3, Ff-10; G.E. Hanford Co., HW-26720 DEL, p. Ff-12.

60. G.E. Hanford Co., HW-29794 DEL, p. F-5; G.E. Hanford Co., HW-0423 DEL, p. F-4; G.E. Hanford Co., HW-30000 DEL, p. 4.

61. G.E. Hanford Co., HW-26946 DEL, p. Ed-6; G.E. Hanford Co., HW-27288 DEL, pp. A-1, E-2; G.E. Hanford Co., HW-27624 DEL, p. A-1; G.E. Hanford Co., HW-27932 DEL, p. E-3; G.E. Hanford Co., HW-28267 DEL, pp. A-1, E-3, Ed-6; G.E. Hanford Co., HW-28576 DEL, pp. A-1, E-3, Ed-5; G.E. Hanford Co., HW-28906 DEL, pp. E-2, Ed-5; G.E. Hanford Co., HW-29229 DEL, pp. A-1, E-2; G.E. Hanford Co., HW-29513 DEL, pp. A-1, E-2, Ed-2, Fc-20; G.E. Hanford Co., HW-29794 DEL, pp. A-1, E-3; G.E. Hanford Co., HW-31030 DEL, pp. A-1, E-3, Ed-6; G.E. Hanford Co., HW-30423 DEL, pp. Ed-5-6.
62. G.E. Hanford Co, HW-29513 DEL, p. Fc-19; EG&G Rocky Flats, "Building Histories...", Section 8; Buffer, RE-30; ChemRisk, "Rocky Flats History;" Chew and Associates, DE-AC-001-90-EW-48063; U.S. DOE, "Historical Release Report."
63. G.E. Hanford Co., HW-31964 DEL, p. Ff-4; G.E. Hanford Co., HW-32317, pp. Ed-9-10; G.E. Hanford Co., HW-34000 DEL, pp. 4, 17; Felts, HW-33093 RD; Felts, HW-35596; Bebbington, *History of DuPont at the Savannah River Plant*.
64. G.E. Hanford Co., HW-30724 DEL, pp. A-1, E-4, Ed-5; G.E. Hanford Co., HW-31006 DEL, pp. A-1, E-4, Ed-5-6; G.E. Hanford Co., HW-31267 DEL, pp. A-1, E-3, Ed-5; G.E. Hanford Co., HW-31734 DEL, pp. A-1, E-4, Ed-5; G.E. Hanford Co., HW-31964 DEL, pp. A-1, E-3, Ed-5; Smith, HW-32042; G.E. Hanford Co., HW-32317 DEL, pp. A-1, Ed-5; G.E. Hanford Co., HW-32624 DEL, pp. A-1, Ed-6; G.E. Hanford Co., HW-32889 DEL, pp. A-1, E-3; G.E. Hanford Co., HW-33200 DEL, pp. E-3, Ed-5; G.E. Hanford Co., HW-33585 DEL, pp. E-4, Ed-4, Ed-6; G.E. Hanford Co., HW-33962 DEL, pp. E-4, Ed-5; G.E. Hanford Co., HW-34147 DEL, pp. E-4, Ed-4.
65. G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fe-17, Ff-4-5, Ff-7-8, Fg-12; G.E. Hanford Co., HW-31267 DEL, pp. Ed-9, F-4, Fc-20, Ff-4, Ff-8, Fg-12; G.E. Hanford Co., HW-31734 DEL, pp. F-3, Fd-13, Fd-17, Fg-13; Shaw, Directive No. HW-305, Modification #3; G.E. Hanford Co., HW-31964 DEL, pp. Ed-5, Fc-18-19, Ff-5, Ff-7, Fg-12; G.E. Hanford Co., HW-32317 DEL, pp. Ed-10, F-4, Ff-5, Ff-9, Fg-13; G.E. Hanford Co., HW-32624 DEL, pp. Ed-10, Fc-17, Fg-13; G.E. Hanford Co., HW-32889 DEL, pp. Ed-9, Fc-17-18, Ff-5, Fg-12; G.E. Hanford Co., HW-33200 DEL, p. Ed-10, Fc-17, Fg-12; Wirta, HW-32810; G.E. Hanford Co., HW-33585 DEL, pp. Ed-9-11, Fc-15, Ff-5, Fg-13; G.E. Hanford Co., HW-33962 DEL, pp. Ed-10, Fc-15, Fg-11; G.E. Hanford Co., HW-34147 DEL, pp. Ed-10, Ed-12, Fc-13, Ff-5, Fg-11.
66. G.E. Hanford Co., HW-30724 DEL, pp. Fc-15, Fd-8; G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fc-18, Fd-15; Chapman, HW-30969 DEL, p. 3; G.E. Hanford Co., HW-31627 DEL, pp. Ed-7, Fc-21; G.E. Hanford Co., HW-31734 DEL, pp. Ed-7, Ed-13, Ff-5, Ff-13; Shaw, Directive No. HW-350; G.E. Hanford Co., HW-31964 DEL, p. Ff-11; G.E. Hanford Co., HW-32317 DEL, pp. A-1, F-4, Ff-12; G.E. Hanford Co., HW-32624 DEL, pp. Ed-8, Ed-12, Ed-15, Fc-18, Fg-6; G.E. Hanford Co., HW-32889 DEL, p. Fc-15-16, Fg-16; Helgeson, HW-35282 DEL; G.E. Hanford Co., HW-33200 DEL, pp. Ed-5, Ed-7, Ff-11, Fg-16; G.E. Hanford Co., HW-33585, pp. Ed-11, Ff-12, Fg-18; G.E. Hanford Co., HW-33962 DEL, pp. Ed-12, Ff-12, Fg-16; G.E. Hanford Co., HW-34147 DEL, pp. Ff-5, Ff-11, Fg-15; Mobley, "Status of Fire Protection Activities...", April 19, 1957; G.E. Hanford Co., HW-30724 DEL, p. Ed-14.

67. G.E. Hanford Co., HW-35530 DEL, p. Fg-2; G.E. Hanford Co., HW-35891 DEL, p. Fg-2; G.E. Hanford Co., HW-36440 DEL, pp. Ed-16, Fc-16; G.E. Hanford Co., HW-36928 DEL, p. Fc-16; G.E. Hanford Co., HW-38375 DEL, pp. F-2-3; G.E. Hanford Co., HW-38828 DEL, p. Fc-14; Smith, HW-36334; Travis, Directive HW-361, and Modification #1; G.E. Hanford Co., HW-39751 DEL, pp. Ff-5-6; G.E. Hanford Co., HW-40182 DEL, pp. Ed-7, Fg-5, Fg-12; G.E. Hanford Co., HW-40692 DEL, pp. Fc-53, Ff-6, Ff-12, Fg-14.

68. G.E. Hanford Co., HW-37658 DEL, pp. Fc-5-6, Fc-14, Fc-16; G.E. Hanford Co., HW-38375 DEL, pp. Fc-12-13; G.E. Hanford Co., HW-38828 DEL, pp. Ed-8, Fc-7, Fc-18-19; G.E. Hanford Co., HW-39260 DEL, pp. Ed-7, Fc-12, Ff-6; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-40182 DEL, pp. Fc-8, Fc-13, Fc-16, Ff-6; Fritz, HW-37152; G.E. Hanford Co., HW-40692 DEL, pp. Ed-4, Fc-20, Ff-6.

69. G.E. Hanford Co., HW-34631 DEL, pp. Ed-4-5; G.E. Hanford Co., HW-35530 DEL, pp. E-3, Ed-5-6, Fc-14; G.E. Hanford Co., HW-35891 DEL, p. E-3; G.E. Hanford Co., HW-36440 DEL, pp. E-3, Ed-5, Ed-7; G.E. Hanford Co., HW-36928 DEL, pp. E-3, Ed-5-6; G.E. Hanford Co., HW-37658 DEL, pp. E-3, Ed-5-6; G.E. Hanford Co., HW-38375 DEL, pp. E-4, Ed-5-6; G.E. Hanford Co., HW-38828 DEL, pp. E-3, Ed-6; G.E. Hanford Co., HW-39260 DEL, pp. E-3, Ed-5-6, Fc-13; G.E. Hanford Co., HW-39751 DEL, pp. E-2-3, Ed-5; G.E. Hanford Co., HW-40182 DEL, pp. E-2, Ed-5-6; G.E. Hanford Co., HW-40692 DEL, pp. E-3, Ed-6.

70. G.E. Hanford Co., HW-36440 DEL, pp. Ed-6, Ed-10, Fc-17, Fc-17, Ff-8, Fg-6; G.E. Hanford Co., HW-37658 DEL, p. Fc-14; G.E. Hanford Co., HW-38375 DEL, p. Fc-13; G.E. Hanford Co., HW-38828 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-40182 DEL, p. Ff-6; G.E. Hanford Co., HW-40692 DEL, pp. Fc-10, Fc-18.

71. G.E. Hanford Co., HW-34631 DEL, p. Ff-6; G.E. Hanford Co., HW-35530 DEL, pp. Fc-24, Fc-30-31, Ff-5; G.E. Hanford Co., HW-36928 DEL, pp. Fc-35, Ff-6; G.E. Hanford Co., HW-37658 DEL, pp. Fc-26, Ff-6; Reas, HW-41274; Helgeson, HW-41369; G.E. Hanford Co., HW-38375 DEL, pp. Fc-15; G.E. Hanford Co., HW-39260 DEL, p. Ff-7; Ketzlach, HW-38904; G.E. Hanford Co., HW-39751 DEL, p. Fc-55.

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73. G.E. Hanford Co., HW-50000 DEL, p. 22; Boston, RHO-CD-407; Department Managers, HW-41205 DEL, pp. Fd-6, Fe-22; Department Managers, HW-42626 DEL, pp. Ed-9-10; Department Managers, HW-43137 DEL, p. F-3; Department Managers, HW-45115, p. F-1.

74. Department Managers, HW-41205 DEL, pp. Fd-4, Fd-6; Department Managers, HW-45115 DEL, pp. F-1, Fd-5; Moulthrop, HW-47022; Operation Managers, HW-47675 DEL, pp. H-7-9.

75. Department Managers, HW-41205 DEL, p. Fe-22; Metallurgy Research Sub-Section, HW-42390; Department Managers, HW-42626 DEL, p. Fd-13; Department Managers, HW-44580 DEL, p. Fd-12; Fritz, Yuenger and Weeks, HW-44105; Travis, Directive No. HW-394 and Thomas, Directive No. HW-394, Modification #1; Beede, HW-45700; Department Managers, HW-45115 DEL, pp. Fd-9, Fe-24; Operation Managers, HW-47675 DEL, pp. E-6, H-7-8.

76. Department Managers, HW-41205 DEL, pp. Fc-17, Fd-13; Department Managers, HW-41702 DEL, pp. Fd-5, Fd-10, Fe-24; Travis, Directive No. HW-421; Travis, Directive No. AEC-121; Department Managers, HW-42219 DEL, pp. Fd-13, Fe-24; Department Managers, HW-42626 DEL, pp. Fe-21-22; Department Managers, HW-43137 DEL, pp. F-2, Fd-7, Fe-20-21; Department Managers, HW-43938 DEL, pp. Fd-7, Fe-27, Fe-29, Fd-7; Fritz, Yuenger, and Weeks, HW-44105; Department Managers, HW-44580 DEL, pp. Fd-12-13, Fd-6; Department Managers, HW-45115 DEL, pp. Fe-27-28, Fd-6; Operation Managers, HW-47675 DEL, pp. E-6-7, H-8-9.

77. Department Managers, HW-41205 DEL, pp. Ed-14, Fd-6; Department Managers, HW-41702 DEL, p. Fd-5; Department Managers, HW-42219 DEL, p. Fd-7; Department Managers, HW-42626 DEL, pp. F-3, Fd-6; Department Managers, HW-43137 DEL, pp. F-2, Fd-7; Mobley, HW-39408; Helgeson, HW-43784; Department Managers, HW-43938 DEL, pp. Ed-13, Fd-7; Department Managers, HW-44580 DEL, p. Fd-6; Department Managers, HW-45115 DEL, pp. Ed-12, Fd-5-6; Harmon, HW-47989.

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79. Gerber, WHC-MR-0437; Department Managers, HW-42626 DEL.

80. G.E. Hanford Co., HW-54000 DEL, pp. 26-27; G.E. Hanford Co., HW-60000 DEL, p. 18; G.E. Hanford Co., HW-64000 DEL, pp. 32-33; G.E. Hanford Co., HW-67700 DEL, p. 18; G.E. Hanford Co., HW-72000 DEL, p. 12; G.E. Hanford Co., HW-75700 DEL, p. 12; Gerber, WHC-MR-0437; Operation Managers, HW-54319 DEL, p. D-11.

81. Operation Managers, HW-68345 DEL, pp. 6, D-1-2; Operation Managers, HW-68700 DEL, pp. D-1-2; Operation Managers, HW-69051 DEL, pp. 6, D-1-2; Operation Managers, HW-69443 DEL, pp. 5-6, D-1-3; Operation Managers, HW-69803 DEL, pp. 5, D-1-3; Operation Managers, HW-70182 DEL, pp. 5, D-1-2; Operation Managers, HW-70588 DEL, pp. 5-6, D-1-2; Operation Managers, HW-70918 DEL, pp. 5, D-1-2; Operation Managers, HW-71187 DEL, pp. 5, D-1-2; Operation Managers, HW-71577 DEL, pp. 5, D-1-2; Operation Managers, HW-71895 DEL, pp. 5-6, D-1-2; Bowden, HW-68578 DEL; Hopkins, Kingsley and Conner, HW-71554; Conner and Kingsley, HW-71526; Operation Managers, HW-72154 DEL, pp. 5, D-2.

82. Operation Managers, HW-55215 DEL, p. E-2; Operation Managers, HW-63706 DEL, pp. 5, D-2; Operation Managers, HW-64991 DEL, p. 5; Operation Managers, HW-66646 DEL, pp. D-1-2; Operation Managers, HW-66958 DEL, pp. D-1-2; Operation Managers, HW-67252 DEL, pp. D-1-2; Operation Managers, HW-67985 DEL, p. 5.
83. Thomas, Directive No., HW-426; Travis, Directive No. HW-426, Modifications #1, #2 and #3; Fritz, HWS-6250; Travis, Directive No. HW-427, and Modifications #1, #2, #3, and #4; Operation Managers, HW-48132 DEL, pp. A-5, E-7, H-6-7; Operation Managers, HW-51802 DEL, pp. E-10, H-8-9; Operation Managers, HW-54319 DEL, pp. E-9, H-7; G.E. Hanford Co., "Acceptance of Completed Project, HW-427, Mod. #3"; Operation Managers, HW-63313 DEL, p. E-3; Ciccarelli, HW-58258; Operation Managers, HW-66646 DEL, p. D-2; Operation Managers, HW-63706 DEL, pp. D-2, F-5.
84. Operation Managers, HW-48132 DEL, pp. A-4, E-8-9, H-6, J-19; Baker, HW-53295; Thomas, Directive No. HW-424, and Modification #1; Operation Managers, HW-51802 DEL, pp. A-5, E-6, E-10, H-8, J-20; Operation Managers, HW-54319 DEL, pp. E-2, E-5-6, E-8, H-7.
85. Operation Managers, HW-48132 DEL, pp. E-6-9, J-19-20; Operation Managers, HW-51802 DEL, pp. E-2, E-9, H-8, J-4, J-19; Postma and Schwendiman, HW-61082; Operation Managers, HW-58305 DEL, p. E-5; Operation Managers, HW-63706 DEL, p. D-3; Operation Managers, HW-54319 DEL, pp. A-4, E-3, E-7, J-15-16.
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87. Operation Managers, HW-55215 DEL, p. E-8; Travis, Directive No. HW-452, and Modifications #2, #3 and #4; Schipper, Directive No. HW-452, Modification #1; Ager and Knights, HW-76269 Rev.
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90. Operation Managers, HW-73525 DEL, pp. 5, D-1-2; Zangar, TID-18431; Soldat, HW-77345; Investigation Committee, HW-74323; Roesch, Gamertsfelder, Larson, Watson, and Nielsen, HW-SA-2730; Hanford Laboratories, HW-75546; Unruh, HW-77295; Callihan, "Accidental Nuclear Excursion..."; Health Operation, HW-81010; Backman, HW-84619, pp. 9-10; Parker and Newton, "The Hanford Criticality..."

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97. Travis, Directive No. AEC-219, and Modification #1.
98. Wodrich, HW-77339; Hollinghead, HW-77349.
99. Sloat, HW-77807; Sloat, HW-65616 Rev; Sloat, HW-79829; Sloat, HW-74716; Braden and Stivers, HW-76689.
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140. Streid, HM-253, pp. 16-17; Work, HW-08140; G.E. Hanford Co., HW-14042 DEL, pp. 269-270.
141. G.E. Hanford Co., HW-14043 DEL, pp. 3-6, 21, 39, 52, 58, 74, 84, 132, 133; Lane, RL-SEP-855 DEL, p. 6; Bell, HW-15953, pp. 7-10; G.E. Hanford Co., HW-14338 DEL, pp. 108, 5.

142. G.E. Hanford Co., HW-24800-36, p. 10; G.E. Hanford Co., HW-13190 DEL, p. 92; G.E. Hanford Co., HW-13561 DEL, p. 80, 96; G.E. Hanford Co., HW-13793 DEL, pp. 93-94; Bell, HW-23232, p. 8. See also: G.E. Hanford Co., HW-25781 DEL, p. Ed-10; Gross and Greninger, HW-14231.

143. G.E. Hanford Co., HW-14338, pp. 49, 55, 72, 78; Lowe, HAN-26626; G.E. Hanford Co., HW-14596 DEL, pp. 4, 61; G.E. Hanford Co., HW-14916 DEL, pp. 4-5, 50, 55, 57, 74-73, 79; G.E. Hanford Co., HW-15267 DEL, pp. 4, 25, 54, 58, 95; G.E. Hanford Co., HW-15550 DEL, pp. 50, 59-60, 56-57, 81, 93-94.

144. G.E. Hanford Co., HW-14338 DEL, pp. 138-139, 283; G.E. Hanford Co., HW-14596 DEL, pp. 137-138, 277; G.E. Hanford Co., HW-14916 DEL, pp. 143-145, 295-296; G.E. Hanford Co., HW-15267 DEL, pp. 141, 145-146, 290-292; G.E. Hanford Co., HW-15550 DEL, pp. 145-146, 285-287; Bell, HW-15953, pp. 6-17.

145. G.E. Hanford Co., HW-15843 DEL, pp. 4-5, 87, 106, 163; Collins, HW-17080; G.E. Hanford Co., HW-17660 DEL, pp. 96, 118; G.E. Hanford Co., HW-17971 DEL, p. 4; Work, HW-17996; G.E. Hanford Co., HW-18473 DEL, pp. 127; Work, HW-18672; G.E. Hanford Co., HW-19021 DEL, p. 73; Shaw, Directive No. HW-198, and Modification #1.

146. G.E. Hanford Co., HW-15843 DEL, pp. 4-5, 87, 106; G.E. Hanford Co., HW-17056 DEL, pp. 87, 106; G.E. Hanford Co., HW-17410 DEL, pp. 5, 126; G.E. Hanford Co., HW-18221 DEL, pp. 4, 93.

147. G.E. Hanford Co., HW-15483 DEL, pp. 5, 87; G.E. Hanford Co., HW-17660 DEL, pp. 95, 111; G.E. Hanford Co., HW-18740 DEL, p. 102; G.E. Hanford Co., HW-19325 DEL, pp. 6, 100; G.E. Hanford Co., HW-19622 DEL, p. 7.

148. G.E. Hanford Co., HW-17056 DEL, p. 124; G.E. Hanford Co., HE-17410 DEL, pp. 5, 121; G.E. Hanford Co., HW-17660 DEL, pp. 5, 96; G.E. Hanford Co., HW-17971 DEL, pp. 4-5, 96, 122-124; G.E. Hanford Co., HE-18221 DEL, pp. 5, 123, 134; G.E. Hanford Co., HW-19622 DEL, pp. 6, 48, 75, 132; 139-140; G.E. Hanford Co., HW-19842 DEL, pp. 6, 142, 133, 143.

149. G.E. Hanford Co., HW-15843 DEL, pp. 54, 61, 66; G.E. Hanford Co., HW-17056 DEL, pp. 54-55, 63, 66; G.E. Hanford Co., HW-17410 DEL, pp. 64-65, 69-70; G.E. Hanford Co., HW-17660 DEL, pp. 65, 72; Hildreth, HW-17763; G.E. Hanford Co., HW-18221 DEL, pp. 59, 65, 69; G.E. Hanford Co., HW-18473 DEL, pp. 59, 66-67, 70; G.E. Hanford Co., HW-18740 DEL, pp. 72, 77; G.E. Hanford Co., HW-19021 DEL, 69, 75; G.E. Hanford Co., HW-19622 DEL, p. 71; G.E. Hanford Co., HW-19842 DEL, pp. 66, 71, 83, 133.

150. G.E. Hanford Co., HW-15843 DEL, pp. 307-308, 310; Groswith, HW-15821; G.E. Hanford Co., HW-17410 DEL, pp. 335-336; G.E. Hanford Co., HW-17660 DEL, p. 348; G.E. Hanford Co., HW-17971 DEL, pp. 337-338; G.E. Hanford Co., HW-18221 DEL, pp. 345, 350, 362-363; G.E. Hanford Co., HW-24800-36, p. 11; G.E. Hanford Co., HW-18740 DEL, p. 372-373; G.E. Hanford Co., HW-19325 DEL, pp. 393-394; G.E. Hanford Co., HW-19622 DEL, p. 372; Shaw, Directive No. HW-211, Modification #1; G.E. Hanford Co., HW-24800-90, pp. 7-8; G.E. Hanford Co., HW-19842 DEL, pp. 379-381; Bell, HW-23232, pp. 4-8.

151. G.E. Hanford Co., HW-20161 DEL, pp. 74, 98-99, 363-65, 379, 381, 383-384; G.E. Hanford Co., HW-20438 DEL, pp. 407-409; Bell, HW-20506 DEL; Beaulieu, HW-20674; Bell, HW-21097 DEL; G.E. Hanford Co., HW-20671 DEL, pp. 399-401; G.E. Hanford Co., HW-20991 DEL, pp. 382-383; Bell, HW-21563 DEL; G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25.

152. G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25; G.E. Hanford Co., HW-21260 DEL, pp. 132, 389, 395, 397-398; Shaw, Directive No. HW-186, Modification #1; Travis, Directive No. HW-233; Shaw, Directive No. 239, and Modification #1; G.E. Hanford Co., HW-20506 DEL, p. 85; Bell, HW-21563 DEL; Wood, HW-55196, p. 2; Bell, HW-23232, pp. 4-8.

153. G.E. Hanford Co., HW-20161, pp. 6, 108, 144; Gast, HW-22004; G.E. Hanford Co., HW-20438 DEL, pp. 6, 114, 140, 149, 156; Pugh, HW-21616; Shaw, Directive No. HW-244; G.E. Hanford Co., HW-20671 DEL, pp. 6, 100, 126; G.E. Hanford Co., HW-20991 DEL, pp. 7, 100, 137, 146-147; Quinn, HW-21825; Desposato, HW-22195, Cooper, HW-22205; G.E. Hanford Co., HW-21506 DEL, pp. 5, 8, 55, 104, 146, 151; G.E. Hanford Co., HW-21802 DEL, pp. 94, 125-126, 134-135, 149; G.E. Hanford Co., HW-22075 DEL, pp. 89-98; G.E. Hanford Co., HW-22304 DEL, pp. 82, 102; Christy, HAN-63671 DEL, pp. 68, 88; Healy, HW-20522; Healy, HW-22403; Endow, HW-21457; G.E. Hanford Co., HW-22610 DEL, pp. 90, 195; G.E. Hanford Co., G.E. Hanford Co., HW-22875 DEL, pp. 90, 100; G.E. Hanford Co., HW-23140 DEL, pp. 100-103; G.E. Hanford Co., HW-21260 DEL, pp. 6, 104, 145, 132.

154. G.E. Hanford Co., HW-20161 DEL; G.E. Hanford Co., HW-20671 DEL; G.E. Hanford Co., HW-21260 DEL; G.E. Hanford Co., HW-22075 DEL; G.E. Hanford Co., HW-22875 DEL.

155. G.E. Hanford Co., HW-24928, pp. Ed-5, Fe-5; G.E. Hanford Co., HW-25227 DEL, pp. Ed-2, Fc-7; G.E. Hanford Co., HW-25533 DEL, p. Ed-7; G.E. Hanford Co., HW-25781 DEL, pp. Ed-7, Fe-5, Fc-6; G.E. Hanford Co., HW-26047 DEL, pp. Ed-4, Ed-6, Fc-4-5, Fc-6, Fe-3, Fe-5; G.E. Hanford Co., HW-26376 DEL, pp. Ed-5-6, Fc-4-5, Fe-4, Fe-6, Ff-4; G.E. Hanford Co., HW-26720 DEL, pp. Ed-2, Ed-5-6, Fc-10-12, Fe-4, Ff-5, Fg-6.

156. G.E. Hanford Co., HW-23437 DEL, pp. 94, 117, 93; Shaw, Directive No. HW-245, and Modification #1; Chapman, HW-23423 DEL; Chapman, HW-23692 DEL; G.E. Hanford Co., HW-23638 DEL, p. 115; G.E. Hanford Co., HW-26720 DEL, p. Fc-11.

157. Chapman and Mobley, HW-25131; G.E. Hanford Co., HW-25227 DEL, p. Fc-18; G.E. Hanford Co., HW-25533 DEL, p. Fc-7; G.E. Hanford Co., HW-25781 DEL, p. Fc-6; G.E. Hanford Co., HW-26047 DEL, p. Ed-5; G.E. Hanford Co., HW-26720 DEL, p. Fc-11; G.E. Hanford Co., HW-26376 DEL, pp. Fc-5, Fc-22.

158. G.E. Hanford Co., HW-24928 DEL, p. Fb-27; G.E. Hanford Co., HW-25227 DEL, p. Fc-31; G.E. Hanford Co., HW-25781 DEL, p. Fc-7; G.E. Hanford Co., HW-26376 DEL, p. Fc-5; G.E. Hanford Co., HW-26720 DEL, p. Fc-11.

159. G.E. Hanford Co., HW-23437 DEL, pp. 45, 241; G.E. Hanford Co., HW-23638 L, p. 147; G.E. Hanford Co., HW-23982 DEL, p. Ff-17; G.E. Hanford Co., HW-24337, pp. Ff-16-18.

151. G.E. Hanford Co., HW-20161 DEL, pp. 74, 98-99, 363-65, 379, 381, 383-384; G.E. Hanford Co., HW-20438 DEL, pp. 407-409; Bell, HW-20506 DEL; Beaulieu, HW-20674; Bell, HW-21097 DEL; G.E. Hanford Co., HW-20671 DEL, pp. 399-401; G.E. Hanford Co., HW-20991 DEL, pp. 382-383; Bell, HW-21563 DEL; G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25.
152. G.E. Hanford Co. HW-24800-90, pp. 7, 11, 25; G.E. Hanford Co., HW-21260 DEL, pp. 132, 389, 395, 397-398; Shaw, Directive No. HW-186, Modification #1; Travis, Directive No. HW-233; Shaw, Directive No. 239, and Modification #1; G.E. Hanford Co., HW-20506 DEL, p. 85; Bell, HW-21563 DEL; Wood, HW-55196, p. 2; Bell, HW-23232, pp. 4-8.
153. G.E. Hanford Co., HW-20161, pp. 6, 108, 144; Gast, HW-22004; G.E. Hanford Co., HW-20438 DEL, pp. 6, 114, 140, 149, 156; Pugh, HW-21616; Shaw, Directive No. HW-244; G.E. Hanford Co., HW-20671 DEL, pp. 6, 100, 126; G.E. Hanford Co., HW-20991 DEL, pp. 7, 100, 137, 146-147; Quinn, HW-21825; Desposato, HW-22195, Cooper, HW-22205; G.E. Hanford Co., HW-21506 DEL, pp. 5, 8, 55, 104, 146, 151; G.E. Hanford Co., HW-21802 DEL, pp. 94, 125-126, 134-135, 149; G.E. Hanford Co., HW-22075 DEL, pp. 89-98; G.E. Hanford Co., HW-22304 DEL, pp. 82, 102; Christy, HAN-63671 DEL, pp. 68, 88; Healy, HW-20522; Healy, HW-22403; Endow, HW-21457; G.E. Hanford Co., HW-22610 DEL, pp. 90, 195; G.E. Hanford Co., G.E. Hanford Co., HW-22875 DEL, pp. 90, 100; G.E. Hanford Co., HW-23140 DEL, pp. 100-103; G.E. Hanford Co., HW-21260 DEL, pp. 6, 104, 145, 132.
154. G.E. Hanford Co., HW-20161 DEL; G.E. Hanford Co., HW-20671 DEL; G.E. Hanford Co., HW-21260 DEL; G.E. Hanford Co., HW-22075 DEL; G.E. Hanford Co., HW-22875 DEL.
155. G.E. Hanford Co., HW-24928, pp. Ed-5, Fe-5; G.E. Hanford Co., HW-25227 DEL, pp. Ed-2, Fc-7; G.E. Hanford Co., HW-25533 DEL, p. Ed-7; G.E. Hanford Co., HW-25781 DEL, pp. Ed-7, Fe-5, Fc-6; G.E. Hanford Co., HW-26047 DEL, pp. Ed-4, Ed-6, Fc-4-5, Fc-6, Fe-3, Fe-5; G.E. Hanford Co., HW-26376 DEL, pp. Ed-5-6, Fc-4-5, Fe-4, Fe-6, Ff-4; G.E. Hanford Co., HW-26720 DEL, pp. Ed-2, Ed-5-6, Fc-10-12, Fe-4, Ff-5, Fg-6.
156. G.E. Hanford Co., HW-23437 DEL, pp. 94, 117, 93; Shaw, Directive No. HW-245, and Modification #1; Chapman, HW-23423 DEL; Chapman, HW-23692 DEL; G.E. Hanford Co., HW-23638 DEL, p. 115; G.E. Hanford Co., HW-26720 DEL, p. Fc-11.
157. Chapman and Mobley, HW-25131; G.E. Hanford Co., HW-25227 DEL, p. Fc-18; G.E. Hanford Co., HW-25533 DEL, p. Fc-7; G.E. Hanford Co., HW-25781 DEL, p. Fc-6; G.E. Hanford Co., HW-26047 DEL, p. Ed-5; G.E. Hanford Co., HW-26720 DEL, p. Fc-11; G.E. Hanford Co., HW-26376 DEL, pp. Fc-5, Fc-22.
158. G.E. Hanford Co., HW-24928 DEL, p. Fb-27; G.E. Hanford Co., HW-25227 DEL, p. Fc-31; G.E. Hanford Co., HW-25781 DEL, p. Fc-7; G.E. Hanford Co., HW-26376 DEL, p. Fc-5; G.E. Hanford Co., HW-26720 DEL, p. Fc-11.
159. G.E. Hanford Co., HW-23437 DEL, pp. 45, 241; G.E. Hanford Co., HW-23638 DEL, p. 147; G.E. Hanford Co., HW-23982 DEL, p. Ff-17; G.E. Hanford Co., HW-24337 DEL, pp. Ff-16-18.

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171. G.E. Hanford Co., HW-20438 DEL; G.E. Hanford Co., HW-24437 DEL, pp. F-3-4, Ff-7.

172. G.E. Hanford Co., HW-24800-90, pp. 24, 11, 9; G.E. Hanford Co., HW-21506 DEL, pp. 81, 126, 336, 339, 392-393; Bell, HW-20506 DEL; Bell, HW-21097 DEL; Shaw, Directive No. HW-265, Modification #1; Travis, Directive No. HW-265, Modification #2; Beaulieu, HW-22031; Quinn, HW-22175; G.E. Hanford Co., HW-21802 DEL, pp. 70, 127, 373, 387

173. G.E. Hanford Co., HW-22075 DEL, pp. 42, 131-132, 125, 127; Anicetti, HW-21195; G.E. Hanford Co., HW-22304 DEL, pp. 42, 83, 130, 133, 135-136; G.E. Hanford Co., HW-24800-90, p. 24; G.E. Hanford Co., HW-22610 DEL, pp. 138, 148-149; G.E. Hanford Co., G.E. Hanford Co., HW-22875 DEL, pp. 90, 142, 146-147; Chapman, HW-23125 DEL; G.E. Hanford Co., HW-23140 DEL, pp. 91-93, 142, 147-148, 158; Shaw, Directive No. HW-280; G.E. Hanford Co., HW-23698, p. 147; Schalliol and Wick, HW-22572, pp. 19-21; G.E. Hanford Co., HW-23437 DEL, p. 45.

174. Burke, "Recollections of Processing..."; Hazen, LA-1387, pp. 11-12; Christensen and Maraman, LA-3542, pp. 4-35; Maraman, LA-1699; G.E. Hanford Co., HW-24800-90, pp. 11-12.

175. G.E. Hanford Co., HW-23437 DEL; G.E. Hanford Co., HW-23638 DEL; G.E. Hanford Co., HW-23982 DEL, pp. A-1, F-1, Fb-6.

176. G.E. Hanford Co., HW-23982 DEL, pp. A-1, F-1, Fb-6; Stark, HW-24046; Quinn, HW-24084; Quinn, HW-24165; G.E. Hanford Co., HW-24800-90, pp. 13, 18; Bell, HW-23232, pp. 10-14; G.E. Hanford Co., HW-24800-36, p. 23.

177. G.E. Hanford Co., HW-23982 DEL, pp. F-2, Fb-6, Fb-29; G.E. Hanford Co., HW-24605 DEL, pp. Ed-6, Fb-6-7, Fb-29; G.E. Hanford Co., HW-24337 DEL, pp. F-1, Fb-7; G.E. Hanford Co., HW-23982 DEL, pp. Fb-7, Fc-6.

178. G.E. Hanford Co., HW-25227 DEL, pp. Ed-7, Fc-7; G.E. Hanford Co., HW-25533 DEL, pp. Fc-4, Fc-6; G.E. Hanford Co., HW-25781 DEL, pp. Ed-6, Fc-6; G.E. Hanford Co., HW-26047 DEL, pp. Ed-4, Ed-5-6, F-2, Fc-3-4, Fc-6; G.E. Hanford Co., HW-26376 DEL, pp. Ed-5-6, Fc-4-5; G.E. Hanford Co., HW-26720 DEL, pp. Ed-5-6, Fc-10.

179. Ingalls, HW-25728; Collins, HW-25340, p. 1.

180. G.E. Hanford Co., HW-23638, p. 139; G.E. Hanford Co., HW-23982 DEL, p. Fe-5; Benoliel, HW-24153; G.E. Hanford Co., HW-24337 DEL, p. Fe-6; G.E. Hanford Co., HW-24605 DEL, pp. Ed-6, Fe-6; G.E. Hanford Co., HW-24928, pp. Ed-5, Fe-5; G.E. Hanford Co., HW-25227 DEL, pp. Ed-2, Fc-7; G.E. Hanford Co., HW-25533 DEL, p. Ed-7; G.E. Hanford Co., HW-25781 DEL, pp. Ed-7, Fe-5, Fc-6; G.E. Hanford Co., HW-26047 DEL, pp. Ed-4, Ed-6, Fc-4-5, Fc-6, Fe-3, Fe-5; G.E. Hanford Co., HW-26376 DEL, pp. Ed-5-6, Fc-4-5, Fe-4, Fe-6, Ff-4; Kerr, HW-26515; G.E. Hanford Co., HW-26720 DEL, pp. Ed-2, Ed-5-6, Fc-10-12, Fe-4, Ff-5, Fg-6.

181. G.E. Hanford Co., HW-23437 DEL, pp. 94, 117, 93; Shaw, Directive No. HW-245, and Modification #1; Chapman, HW-23423 DEL; Chapman, HW-23692 DEL; G.E. Hanford Co., HW-23638 DEL, p. 115; G.E. Hanford Co., HW-26720 DEL, p. Fc-11.
182. G.E. Hanford Co., HW-23437 DEL, pp. 45, 241; G.E. Hanford Co., HW-23638 DEL, p. 147; G.E. Hanford Co., HW-23982 DEL, p. Ff-17; G.E. Hanford Co., HW-24337 DEL, pp. Ff-16-18; G.E. Hanford Co., HW-24605 DEL, pp. Ff-5, Ff-13, Ff-17; G.E. Hanford Co., HW-24928 DEL, pp. Ff-8, Ff-13, Ff-18; G.E. Hanford Co., HW-35227 DEL, pp. Ff-9, Ff-12, Ff-17; G.E. Hanford Co., HW-25533 DEL, pp. Ed-10, Ff-8-9, Ff-12-13, Ff-18; G.E. Hanford Co., HE-25781 DEL, pp. Ff-10, Fg-6, Fg-12-14, Fg-18; G.E. Hanford Co., HW-26047 DEL, pp. Ff-10, Fg-6, Fg-18; G.E. Hanford Co., HW-26376 DEL, pp. Fg-7, Fg-13, Fg-15, Fg-19-20; G.E. Hanford Co., HW-26720 DEL, pp. Ed-11, Fg-7, Fg-12, Fg-19.
183. G.E. Hanford Co., HW-26946 DEL, pp. Ff-5, Ff-12; G.E. Hanford Co., HW-27288 DEL, pp. Fg-7, Fg-18; G.E. Hanford Co., HW-27624 DEL, pp. Ed-9, Ff-6, Fg-7, Fg-16, Fg-19-20; Ingalls, HW-29041; G.E. Hanford Co., HW-27932 DEL, pp. Ed-10, F-4, Ff-10, Fg-6, Fg-14, Fg-16, Fg-19; Helgeson, HW-28918; G.E. Hanford Co., HW-28267 DEL, pp. Ed-12, Ff-10-11, Fg-19; Falk, HW-29443; G.E. Hanford Co., HW-28576 DEL, pp. Ed-10, F-4, Ff-6, Ff-10, Fg-7, Fg-16; G.E. Hanford Co., HW-29513 DEL, p. Ed-10; Shaw, Directive No. HW-304; Shaw, Directive No. HW-305.
184. Brown, HW-26776; G.E. Hanford Co., HW-26946 DEL, pp. H-14, Ed-8; G.E. Hanford Co., HW-27288 DEL, pp. Ed-7, Fc-21; G.E. Hanford Co., HW-27624 DEL, p. Fc-19; G.E. Hanford Co., HW-27932 DEL, p. Ed-9; G.E. Hanford Co., HW-28267, p. Ed-10; G.E. Hanford Co., HW-28576 DEL, pp. Ed-9, Fc-21; G.E. Hanford Co., HW-29806 DEL, pp. Ed-9, Fc-17, Fd-6; G.E. Hanford Co., HW-29229 DEL, p. Ed-8; Hay, HW-26562; G.E. Hanford Co., HW-29513 DEL, pp. Fc-19, Fc-21; G.E. Hanford Co., HW-29794, pp. Fc-19, Fd-5; G.E. Hanford Co., HW-30130 DEL, p. Ed-9; G.E. Hanford Co., HW-30423 DEL, p. Fc-18.
185. G.E. Hanford Co., HW-26946 DEL, pp. Ed-5, Fc-19; G.E. Hanford Co., HW-27288 DEL, pp. Fc-17, Fc-21; G.E. Hanford Co., HW-27624 DEL, p. Fc-16; G.E. Hanford Co., HW-27932 DEL, pp. Ed-9, Fc-17; G.E. Hanford Co., HW-28267 DEL, p. Fc-18; G.E. Hanford Co., HW-28576 DEL, p. Fc-16; G.E. Hanford Co., HW-28906 DEL, p. Fc-17; G.E. Hanford Co., HW-29229 DEL, pp. Ed-7, Fc-18, Fc-21; G.E. Hanford Co., HW-29513 DEL, p. Fc-18; G.E. Hanford Co., HW-29794 DEL, pp. Ed-9, Fc-19; G.E. Hanford Co., HW-31030 DEL, p. Fc-14; Pierick, HW-27487; G.E. Hanford Co., HW-30423 DEL, pp. Ed-5, Fc-18.
186. G.E. Hanford Co., HW-26946 DEL, pp. F-2, Fd-15-16; G.E. Hanford Co., HW-27288 DEL, pp. Fc-20-21; G.E. Hanford Co., HW-27624 DEL, pp. F-1-2, Fd-16; G.E. Hanford Co., HW-27932 DEL, pp. Fc-20, Fd-4; G.E. Hanford Co., HW-28267 DEL, pp. Fc-18, Fd-4; G.E. Hanford Co., HW-28576 DEL, pp. F-2-3, Fc-19-20, Fd-8-9, Fd-17; G.E. Hanford Co., HW-28906 DEL, p. Fd-11; G.E. Hanford Co., HW-29229 DEL, p. Fd-12; G.E. Hanford Co., HW-29794 DEL, pp. Ed-9, Fc-19, Fd-10-11. See also: G.E. Hanford Co., HW-34147 DEL, p. Fc-11.
187. G.E. Hanford Co., HW-26946 DEL, pp. Ed-5, Fc-21; G.E. Hanford Co., HW-27932 DEL, p. Fc-20; G.E. Hanford Co., HW-28576 DEL, p. Fc-16; G.E. Hanford Co., HW-28906 DEL, p. Fc-17; G.E. Hanford Co., HW-29229 DEL, p. Fc-19; G.E. Hanford Co., HW-31030 DEL, p. Fc-14; G.E. Hanford Co., HW-30423 DEL, pp. Ed-9, Fc-19; G.E. Hanford Co., HW-27288 DEL, pp. Ed-5, Fc-21; G.E. Hanford Co., HW-27624, p. Fc-18.

188. G.E. Hanford Co., HW-27288 DEL, pp. Fc-19, Ed-4; G.E. Hanford Co., HW-27624 DEL, p. Fc-16; G.E. Hanford Co., HW-29513 DEL, p. Fc-19; G.E. Hanford Co., HW-29794 DEL, pp. Ed-4-5; Chapman, HW-29499 DEL; Hayes, TID-5360, p. 36.

189. G.E. Hanford Co., HW-26946 DEL, p. Ed-6; G.E. Hanford Co., HW-27288 DEL, pp. A-1, E-2; G.E. Hanford Co., HW-27624 DEL, p. A-1; G.E. Hanford Co., HW-27932 DEL, p. E-3; G.E. Hanford Co., HW-28267 DEL, pp. A-1, E-3, Ed-6; G.E. Hanford Co., HW-28576 DEL, pp. A-1, E-3, Ed-5; G.E. Hanford Co., HW-28906 DEL, pp. E-2, Ed-5; G.E. Hanford Co., HW-29229 DEL, pp. A-1, E-2; G.E. Hanford Co., HW-29513 DEL, pp. A-1, E-2, Ed-2, Fc-20; G.E. Hanford Co., HW-29794 DEL, pp. A-1, E-3; G.E. Hanford Co., HW-31030 DEL, pp. A-1, E-3, Ed-6; G.E. Hanford Co., HW-30423 DEL, pp. Ed-5-6.

190. Thomas, Directive No., HW-426; Travis, Directive No. HW-426, Modifications #1, #2 and #3; Fritz, HWS-6250; Travis, Directive No. HW-427, and Modifications #1, #2, #3, and #4; Operation Managers, HW-48132 DEL, pp. A-5, E-7, H-6-7; Operation Managers, HW-51802 DEL, pp. E-10, H-8-9; Operation Managers, HW-54319 DEL, pp. E-9, H-7.

191. G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fe-17, Ff-4-5, Ff-7-8, Fg-12; G.E. Hanford Co., HW-31267 DEL, pp. Ed-9, F-4, Fc-20, Ff-4, Ff-8, Fg-12; G.E. Hanford Co., HW-31734 DEL, pp. F-3, Fd-13, Fd-17, Fg-13; Shaw, Directive No. HW-305, Modification #3; G.E. Hanford Co., HW-31964 DEL, pp. Ed-5, Fc-18-19, Ff-5, Ff-7, Fg-12; G.E. Hanford Co., HW-32317 DEL, pp. Ed-10, F-4, Ff-5, Ff-9, Fg-13; G.E. Hanford Co., HW-32624 DEL, pp. Ed-10, Fc-17, Fg-13; G.E. Hanford Co., HW-32889 DEL, pp. Ed-9, Fc-17-18, Ff-5, Fg-12; G.E. Hanford Co., HW-33200 DEL, p. Ed-10, Fc-17, Fg-12; Wirta, HW-32810; G.E. Hanford Co., HW-33585 DEL, pp. Ed-9-11, Fc-15, Ff-5, Fg-13; G.E. Hanford Co., HW-33962 DEL, pp. Ed-10, Fc-15, Fg-11; G.E. Hanford Co., HW-34147 DEL, pp. Ed-10, Ed-12, Fc-13, Ff-5, Fg-11.

192. G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fe-17, Ff-4-5, Ff-7-8, Fg-12; G.E. Hanford Co., HW-31267 DEL, pp. Ed-9, F-4, Fc-20, Ff-4, Ff-8, Fg-12; G.E. Hanford Co., HW-31734 DEL, pp. F-3, Fd-13, Fd-17, Fg-13; Shaw, Directive No. HW-305, Modification #3; G.E. Hanford Co., HW-31964 DEL, pp. Ed-5, Fc-18-19, Ff-5, Ff-7, Fg-12; G.E. Hanford Co., HW-32317 DEL, pp. Ed-10, F-4, Ff-5, Ff-9, Fg-13; G.E. Hanford Co., HW-32624 DEL, pp. Ed-10, Fc-17, Fg-13; G.E. Hanford Co., HW-32889 DEL, pp. Ed-9, Fc-17-18, Ff-5, Fg-12; G.E. Hanford Co., HW-33200 DEL, p. Ed-10, Fc-17, Fg-12; Wirta, HW-32810; G.E. Hanford Co., HW-33585 DEL, pp. Ed-9-11, Fc-15, Ff-5, Fg-13; G.E. Hanford Co., HW-33962 DEL, pp. Ed-10, Fc-15, Fg-11; G.E. Hanford Co., HW-34147 DEL, pp. Ed-10, Ed-12, Fc-13, Ff-5, Fg-11.

193. G.E. Hanford Co., HW-30724 DEL, pp. Ed-8-9; G.E. Hanford Co., HW-31006 DEL, p. Fd-16; Piereck, HW-33952; G.E. Hanford Co., HW-31267 DEL, p. Fd-18; G.E. Hanford Co., HW-31734 DEL, p. Fd-13; G.E. Hanford Co., HW-31964 DEL, p. Fd-13, Fd-17; G.E. Hanford Co., HW-32317 DEL, pp. Ed-8, Fd-16; G.E. Hanford Co., HW-32624 DEL, p. Fd-9; G.E. Hanford Co., HW-32889 DEL, p. Fc-16; G.E. Hanford Co., HW-33220 DEL, p. Ff-5; G.E. Hanford Co., HW-33585 DEL, p. Ff-6; G.E. Hanford Co., HW-33962 DEL, pp. Fc-16, Ff-6; G.E. Hanford Co., HW-34147 DEL, pp. Fc-13-14, Ff-5; Priode, Benoliel, Gilbert, McGrath, Tomlinson and Zuhr, HW-55767 EEL, pp. 93-94.

194. G.E. Hanford Co., HW-30724 DEL, pp. A-1, E-4, Ed-5; G.E. Hanford Co., HW-31006 DEL, pp. A-1, E-4, Ed-5-6; G.E. Hanford Co., HW-31267 DEL, pp. A-1, E-3, Ed-5; G.E. Hanford Co., HW-31734 DEL, pp. A-1, E-4, Ed-5; G.E. Hanford Co., HW-31964 DEL, pp. A-1, E-3, Ed-5; Smith, HW-32042; G.E. Hanford Co., HW-32317 DEL, pp. A-1, Ed-5; G.E. Hanford Co., HW-32624 DEL, pp. A-1, Ed-6; G.E. Hanford Co., HW-32889 DEL, pp. A-1, E-3; G.E. Hanford Co., HW-33200 DEL, pp. E-3, Ed-5; G.E. Hanford Co., HW-33585 DEL, pp. E-4, Ed-4, Ed-6; G.E. Hanford Co., HW-33962 DEL, pp. E-4, Ed-5; G.E. Hanford Co., HW-34147 DEL, pp. E-4, Ed-4.

195. G.E. Hanford Co., HW-30724 DEL, p. Fc-13; G.E. Hanford Co., HW-31006 DEL, p. Fc-14, Fc-16; Smith, HW-32077; G.E. Hanford Co., HW-31267 DEL, pp. Ed-8, Fc-18-19; G.E. Hanford Co., HW-31734 DEL, pp. Ed-5, Ed-9, Fc-17; G.E. Hanford Co., HW-31964 DEL, pp. Ed-5, Fc-17; G.E. Hanford Co., HW-32317 DEL, pp. Ed-5, Fc-13; Guenther, HW-33399; G.E. Hanford Co., HW-32624 DEL, pp. Ed-8-9, Fc-14; G.E. Hanford Co., HW-32889 DEL, p. Fc-15; G.E. Hanford Co., HW-33200 DEL, p. Fc-15; G.E. Hanford Co., HW-33585 DEL, pp. Ed-4-5, Fc-14; Swain, HW-33313; G.E. Hanford Co., HW-33962 DEL, p. Fc-13; G.E. Hanford Co., HW-34147 DEL, p. Fc-11; Gumprecht, HW-31952; Gumprecht, HW-33874.

196. Helgeson, HW-32494 DEL; G.E. Hanford Co., HW-32624 DEL, pp. Ed-5, Ed-14, Fc-15; Pierick, HW-33125; Hill, HW-33007; G.E. Hanford Co., HW-32889 DEL, pp. E-3, Ed-14, Fc-16; Hayes, TID-5360, pp. 48-50.

197. G.E. Hanford Co., HW-34147 DEL, pp. Ed-15, Fc-11.

198. G.E. Hanford Co., HW-34631 DEL, pp. Ed-4-5; G.E. Hanford Co., HW-35530 DEL, pp. E-3, Ed-5-6, Fc-14; G.E. Hanford Co., HW-35891 DEL, p. E-3; G.E. Hanford Co., HW-36440 DEL, pp. E-3, Ed-5, Ed-7; G.E. Hanford Co., HW-36928 DEL, pp. E-3, Ed-5-6; G.E. Hanford Co., HW-37658 DEL, pp. E-3, Ed-5-6; G.E. Hanford Co., HW-38375 DEL, pp. E-4, Ed-5-6; G.E. Hanford Co., HW-38828 DEL, pp. E-3, Ed-6; G.E. Hanford Co., HW-39260 DEL, pp. E-3, Ed-5-6, Fc-13; G.E. Hanford Co., HW-39751 DEL, pp. E-2-3, Ed-5; G.E. Hanford Co., HW-40182 DEL, pp. E-2, Ed-5-6; G.E. Hanford Co., HW-40692 DEL, pp. E-3, Ed-6.

199. G.E. Hanford Co., HW-34631 DEL, pp. Fc-16, Fg-10; G.E. Hanford Co., HW-35530 DEL, pp. Ed-10, Fc-14, Ff-5, Fg-10; G.E. Hanford Co., HW-35891 DEL, pp. E-3, Ed-5, Ed-11, Fc-15, Ff-5, Fg-10; G.E. Hanford Co., HW-36440 DEL, pp. Ed-6, Ed-10, Fc-16, Fg-10-11; G.E. Hanford Co., HW-36928 DEL, pp. Fc-16-17, Fc-19; G.E. Hanford Co., HW-37658 DEL, pp. Fc-5-6, Fc-14, Fc-16; G.E. Hanford Co., HW-38375 DEL, pp. Fc-12-13; Ketzlach, HW-38029; G.E. Hanford Co., HW-38828 DEL, pp. Ed-8, Fc-7, Fc-18-19; G.E. Hanford Co., HW-39260 DEL, pp. Ed-7, Fc-12, Ff-6; Mobley, HW-38341; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-40182 DEL, pp. Fc-8, Fc-13, Fc-16, Ff-6; Fritz, HW-37152; G.E. Hanford Co., HW-40692 DEL, pp. Ed-4, Fc-20, Ff-6; Newell, HW-40321.

200. G.E. Hanford Co., HW-34631 DEL, pp. Ed-9-10, Ed-15, Ff-6, Fg-11; G.E. Hanford Co., HW-35530 DEL, pp. Ed-9, Ff-5, Fg-10; G.E. Hanford Co., HW-35891 DEL, pp. E-3, Ed-5, Ed-10, Ff-5, Ff-7, Fg-10; G.E. Hanford Co., HW-36440 DEL, pp. Ed-6, Ed-10, Fc-17, Fc-17, Ff-8, Fg-6; G.E. Hanford Co., HW-36928 DEL, pp. Fc-11, Fc-18; G.E. Hanford Co., HW-37658 DEL, p. Fc-14; G.E. Hanford Co., HW-38375 DEL, p. Fc-13; Pierick, HW-35882 RD; G.E. Hanford Co., HW-38828 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-39260 DEL, pp. Fc-13, Ff-7; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-40182 DEL, p. Ff-6; Newell, HW-40321; G.E. Hanford Co., HW-40692 DEL, pp. Fc-10, Fc-18.

201. G.E. Hanford Co., HW-34631 DEL, p. Ff-6; G.E. Hanford Co., HW-35530 DEL, pp. Fc-24, Fc-30-31, Ff-5; G.E. Hanford Co., HW-36928 DEL, pp. Fc-35, Ff-6; G.E. Hanford Co., HW-37658 DEL, pp. Fc-26, Ff-6; Reas, HW-41274; Helgeson, HW-41369; G.E. Hanford Co., HW-38375 DEL, pp. Fc-15, Ff-6; G.E. Hanford Co., HW-38828 DEL, p. Ff-6; G.E. Hanford Co., HW-39260 DEL, p. Ff-7; Ketzlach, HW-38904; G.E. Hanford Co., HW-39751 DEL, p. Fc-55; G.E. Hanford Co., HW-40692 DEL, p. Ed-17.

202. G.E. Hanford Co., HW-34631 DEL, pp. Fc-14-15, Ff-6; G.E. Hanford Co., HW-35530 DEL, pp. Fc-14-15, Ff-5; G.E. Hanford Co., HW-35891 DEL, p. Ff-5; G.E. Hanford Co., HW-36440 DEL, pp. Fc-17, Ff-6; G.E. Hanford Co., HW-36928 DEL, pp. Fc-16-18, Ff-6; G.E. Hanford Co., HW-37658 DEL, pp. Ed-7, Fc-16; G.E. Hanford Co., HW-38375 DEL, p. Fc-13; G.E. Hanford Co., HW-38828 DEL, pp. Ed-8, Fc-14; G.E. Hanford Co., HW-39260 DEL, p. Fc-12; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-40182 DEL, p. Ff-6; G.E. Hanford Co., HW-40692 DEL, pp. Fc-21, Ff-6.

203. G.E. Hanford Co., HW-34631 DEL, pp. Ff-6, Ff-12-13, Fg-6; Shaw, Directive HW-350; G.E. Hanford Co., HW-35530 DEL, pp. Ed-15, Fc-15, Ff-6, Ff-9, Ff-11, Fg-13; G.E. Hanford Co., HW-35891 DEL, pp. Ed-5, Fc-15-16, Ff-5, Ff-9, Ff-11, Fg-13; G.E. Hanford Co., HW-36440 DEL, pp. Fc-17-18, Ff-6, Ff-10, Ff-12; G.E. Hanford Co., HW-36928 DEL, pp. Ff-10, Fg-12; G.E. Hanford Co., HW-37658 DEL, pp. Ed-7, Ed-11, Fc-16, Ff-6, Ff-11, Fg-12; G.E. Hanford Co., HW-38375 DEL, pp. Ed-7, Fc-14, Ff-6, Ff-12, Fg-11; G.E. Hanford Co., HW-38828 DEL, pp. Ed-12, Fc-15, Ff-6, Ff-11-12, Fg-3, Fg-12; G.E. Hanford Co., HW-39260 DEL, pp. Ed-7, Ff-12-13, Fg-11; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-3, Ff-5-6, Ff-9, Fg-5, Fg-12; G.E. Hanford Co., HW-40182 DEL, p. Ed-7, Ed-9, Ff-6, Fg-6; G.E. Hanford Co., HW-40692 DEL, pp. Fc-21-22, Ff-6, Fg-14.

204. G.E. Hanford Co., HW-36928 DEL, p. Ed-13; G.E. Hanford Co., HW-37658 DEL, p. Ed-13; G.E. Hanford Co., HW-38375 DEL, p. Fc-13; G.E. Hanford Co., HW-39260 DEL, p. Ed-15; G.E. Hanford Co., HW-39751 DEL, p. Ed-14; G.E. Hanford Co., HW-40182 DEL, p. Ed-15; G.E. Hanford Co., HW-34147 DEL, p. Fc-18.

205. Department Managers, HW-42626 DEL, p. Fd-13; Department Managers, HW-44580 DEL, p. Fd-12; Fritz, Yuenger and Weeks, HW-44105; Travis, Directive No. HW-394 and Thomas, Directive No. HW-394, Modification #1; Beede, HW-45700; Department Managers, HW-45115 DEL, pp. Fd-9, Fe-24; Operation Managers, HW-47675 DEL, pp. E-6, H-7-8.

206. Department Managers, HW-41205 DEL, pp. A-1, F-2, Fc-16; Department Managers, HW-41702 DEL, pp. Fc-19, Fd-5; Department Managers, HW-42219 DEL, pp. Fc-18-19, Fd-6; Department Managers, HW-42626 DEL, pp. Fc-19, Fd-6; Department Managers, HW-43137 DEL, pp. Fc-18, Fd-6; Department Managers, HW-43938 DEL, pp. Ed-13, Fc-17, Fd-7; Ketzlach, HW-42440; Department Managers, HW-44580 DEL, pp. Fc-17-18, Fd-6; Operation Managers, HW-47675 DEL, p. E-5.

207. Department Managers, HW-41205 DEL, pp. Fc-17, Fd-13; Department Managers, HW-41702 DEL, pp. Fd-5, Fd-10, Fe-24; Travis, Directive No. HW-421; Travis, Directive No. AEC-121; Department Managers, HW-42219 DEL, pp. Fd-13, Fe-24; Department Managers, HW-42626 DEL, pp. Fe-21-22; Department Managers, HW-43137 DEL, pp. F-2, Fd-7, Fe-20-21; Department Managers, HW-43938 DEL, pp. Fd-7, Fe-27, Fe-29, Fd-7; Fritz, Yuenger, and Weeks, HW-44105; Department Managers, HW-44580

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208. Department Managers, HW-41205 DEL, pp. Ed-14, Fd-6; Department Managers, HW-41702 DEL, p. Fd-5; Department Managers, HW-42219 DEL, p. Fd-7; Department Managers, HW-42626 DEL, pp. F-3, Fd-6; Department Managers, HW-43137 DEL, pp. F-2, Fd-7; Helgeson, HW-43784; Department Managers, HW-43938 DEL, pp. Ed-13, Fd-7; Department Managers, HW-44580 DEL, p. Fd-6; Department Managers, HW-45115 DEL, pp. Ed-12, Fd-5-6; Harmon, HW-47989.

209. Department Managers, HW-41205 DEL, p. Fc-14; Operation Managers, HW-47675 DEL, pp. E-3, H-7, J-12.

210. Department Managers, HW-41702 DEL, p. Ed-9; Department Managers, HW-43938 DEL, p. Ed-8; Department Managers, HW-45115 DEL, p. Ed-8; Operation Managers, HW-47675 DEL, p. E-3; Department Managers, HW-42219 DEL, p. Fc-16.

211. Department Managers, HW-41205 DEL, p. Fc-14; Department Managers, HW-41702 DEL, p. Fc-18; Department Managers, HW-42219, p. Ed-9; Department Managers, HW-43137 DEL, p. Fc-16; Department Managers, HW-43938 DEL, pp. Ed-8, Fc-18; Department Managers, HW-44580 DEL, p. Ed-9; Operation Managers, HW-47675 DEL, p. E-3.

212. Department Managers, HW-41702 DEL, p. Ed-9; Department Managers, HW-43137 DEL, p. Ed-8; Department Managers, HW-43938 DEL, p. Ed-8; Department Managers, HW-44580 DEL, p. Ed-9; Department Managers, HW-45115 DEL, p. Ed-8; Operation Managers, HW-47675 DEL, p. E-3.

213. Department Managers, HW-41205 DEL, pp. Ed-13-14, Fc-17; Department Managers, HW-41702 DEL, p. Ed-13; Department Managers, HW-42219 DEL, p. Ed-12; Department Managers, HW-43938 DEL, p. Ed-8; Department Managers, HW-44580 DEL, p. Ed-9; Department Managers, HW-45115 DEL, p. Ed-8; Operation Managers, HW-47675 DEL, pp. E-3, J-18.

214. Department Managers, HW-41205 DEL, p. A-1; Department Managers, HW-41702 DEL, pp. Ed-5-6, Fc-17-18.

215. Department Managers, HW-42219 DEL, pp. Ed-6, Fc-15, Fc-17, Ed-2; Department Managers, HW-42626 DEL, pp. Ed-5, F-1-2, Fc-16, Ed-5; Department Managers, HW-41205 DEL, pp. Ed-5-6; Browne, HW-44305; Department Managers, HW-43137 DEL, p. E-2; Department Managers, HW-43938 DEL, pp. Fc-16; Pugh, HW-45940; Bunch, HW-54559; Department Managers, HW-44580 DEL, p. Ed-5.

216. Department Managers, HW-41205 DEL, pp. Ed-7, Ed-17, Fc-15; Department Managers, HW-41702 DEL, p. Ed-17; Department Managers, HW-42219 DEL, p. Fc-16; Department Managers, HW-43137 DEL, p. Ed-15; Department Managers, HW-45115 DEL, p. Ed-14; Operation Managers, HW-47675 DEL, pp. E-5, E-10.

217. Operation Managers, HW-55215 DEL, p. E-2; Operation Managers, HW-63706 DEL, pp. 5, D-2; Operation Managers, HW-64991 DEL, p. 5; Operation Managers, HW-67985 DEL, p. 5.

213. Department Managers, HW-41205 DEL, pp. Ed-13-14, Fc-17; Department Managers, HW-41702 DEL, p. Ed-13; Department Managers, HW-42219 DEL, p. Ed-12; Department Managers, HW-43938 DEL, p. Ed-8; Department Managers, HW-44580 DEL, p. Ed-9; Department Managers, HW-45115 DEL, p. Ed-8; Operation Managers, HW-47675 DEL, pp. E-3, J-18.

214. Department Managers, HW-41205 DEL, p. A-1; Department Managers, HW-41702 DEL, pp. Ed-5-6, Fc-17-18.

215. Department Managers, HW-42219 DEL, pp. Ed-6, Fc-15, Fc-17, Ed-2; Department Managers, HW-42626 DEL, pp. Ed-5, F-1-2, Fc-16, Ed-5; Department Managers, HW-41205 DEL, pp. Ed-5-6; Browne, HW-44305; Department Managers, HW-43137 DEL, p. E-2; Department Managers, HW-43938 DEL, pp. Fc-16; Pugh, HW-45940; Bunch, HW-54559; Department Managers, HW-44580 DEL, p. Ed-5.

216. Department Managers, HW-41205 DEL, pp. Ed-7, Ed-17, Fc-15; Department Managers, HW-41702 DEL, p. Ed-17; Department Managers, HW-42219 DEL, p. Fc-16; Department Managers, HW-43137 DEL, p. Ed-15; Department Managers, HW-45115 DEL, p. Ed-14; Operation Managers, HW-47675 DEL, pp. E-5, E-10.

217. Operation Managers, HW-55215 DEL, p. E-2; Operation Managers, HW-63706 DEL, pp. 5, D-2; Operation Managers, HW-64991 DEL, p. 5; Operation Managers, HW-67985 DEL, p. 5.

218. Operation Managers, HW-48132 DEL, pp. A-4, E-8-9, H-6, J-19; Thomas, Directive No. HW-394, Modification #3; Travis, Directive No. HW-394, Modification #4; Harmon and Reas, HW-49597A; Baker, HW-53295; Thomas, Directive No. HW-424, and Modification #1; Operation Managers, HW-51802 DEL, pp. A-5, E-6, E-10, H-8, J-20; Operation Managers, HW-54319 DEL, pp. E-2, E-5-6, E-8, H-7.

219. G.E. Hanford Co., HW-64000 DEL, pp. 32-33.

220. Operation Managers, HW-48132 DEL, pp. E-6-9, J-19-20; Operation Managers, HW-51802 DEL, pp. E-2, E-9, H-8, J-4, J-19; Postma and Schwendiman, HW-61082; Operation Managers, HW-58305 DEL, p. E-5; Operation Managers, HW-63706 DEL, p. D-3; Operation Managers, HW-54319 DEL, pp. A-4, E-3, E-7, J-15-16.

221. Operation Managers, HW-48132 DEL, pp. E-6-9, J-19-20; Operation Managers, HW-51802 DEL, pp. E-2, E-9, H-8, J-4, J-19; Postma and Schwendiman, HW-61082; Operation Managers, HW-58305 DEL, p. E-5; Operation Managers, HW-63706 DEL, p. D-3; Operation Managers, HW-54319 DEL, pp. A-4, E-3, E-7, J-15-16.

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225. Operation Managers, HW-55571 DEL, pp. J-18-19; Operation Managers, HW-58305 DEL, p. A-4; Operation Managers, HW-63313 DEL, p. E-4; Members..., HW-64991 G, p. G-11; Rasmussen, HW-671565 RD; Hopkins, HW-61570 RD; Operation Managers, HW-67459 RD, pp. D-1-2; Operation Managers, HW-59849 DEL, p. E-2; Operation Managers, HW-64089 DEL, p. D-1.

226. Operation Managers, HW-68345 DEL, pp. 6, D-1-2; Operation Managers, HW-68700 DEL, pp. D-1-2; Operation Managers, HW-69051 DEL, pp. 6, D-1-2; Operation Managers, HW-69443 DEL, pp. 5-6, D-1-3; Operation Managers, HW-69803 DEL, pp. 5, D-1-3; Operation Managers, HW-70182 DEL, pp. 5, D-1-2; Operation Managers, HW-70588 DEL, pp. 5-6, D-1-2; Operation Managers, HW-70918 DEL, pp. 5, D-1-2; Operation Managers, HW-71187 DEL, pp. 5, D-1-2; Operation Managers, HW-71577 DEL, pp. 5, D-1-2; Operation Managers, HW-71895 DEL, pp. 5-6, D-1-2; Bowden, HW-68578 DEL; Hopkins, Kingley and Conner, HW-71554; Conner and Kingsley, HW-71526; Operation Managers, HW-72154 DEL, pp. 5, D-2.

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228. Braden, Berglund, Smolen, and Stevenson, HW-75134; Travis, Directive No. HW-542; Operation Managers, HW-74151 DEL, p. 6; Operation Managers, HW-75145 DEL, p. 6; Curtis, HW-78655; Operation Managers, HW-76054 DEL, pp. 6, D-1; Operation Managers, HW-78076 DEL, p. D-2.

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233. Operation Managers, HW-72551 DEL, pp. D-1-2; Operation Managers, HW-72890 DEL, p. D-1; Operation Managers, HW-74151 DEL, pp. D-1-3; Bruns, Lyon, and Unzicker, HW-72224 RD; Operation Managers, HW-77504 DEL, pp. 5-6, D-1-2; Sloat, HW-77807; Operation Managers, HW-78076 DEL, p. D-2; Unzicker and Lyon, HW-76162 RD. Note: The all-time high in the number of laboratory analyses performed in the 234-5 Building process control laboratory occurred in March 1964, when the number just topped 25,000. G.E. Hanford Co., HW-81620 DEL, p. D-2.

234. Operation Managers, HW-73193 DEL, p. D-1; Operation Managers, HW-74151 DEL, p. D-3.

235. "Hanford to Cut Back in 1965," January 8, 1964.

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275. G.E. Hanford Co., HW-26376 DEL, p. Fd-5; G.E. Hanford Co., HW-26720 DEL, pp. Fd-11-12; Roemer, ARH-1853.

276. G.E. Hanford Co., HW-15843 DEL, pp. 5, 87; G.E. Hanford Co., HW-17056 DEL, pp. 5, 88, 117; G.E. Hanford Co., HW-17410 DEL, pp. 5, 125; G.E. Hanford Co., HW-18473 DEL, p. 126; Members of the Technical Divisions, HW-19301 DEL, p. 10.

277. Kendall, HW-13145; G.E. Hanford Co., HW-14338 DEL, pp. 78, 87, 97-98; G.E. Hanford Co., HW-14596 DEL, pp. 4, 78, 87, 103; G.E. Hanford Co., HW-14916 DEL, pp. 4, 80, 102, 114, 116; G.E. Hanford Co., HW-15267 DEL, pp. 4-5, 105, 146-148; G.E. Hanford Co., HW-15550 DEL, pp. 4, 82, 103.

278. G.E. Hanford Co., HW-17056 DEL, pp. 116-117; G.E. Hanford Co., HW-17410 DEL, pp. 5, 121; G.E. Hanford Co., HW-17660 DEL, p. 120; G.E. Hanford Co., HW-17971 DEL, p. 96; G.E. Hanford Co., HW-18473 DEL, pp. 122, 126; G.E. Hanford Co., HW-19021 DEL, pp. 131, 6, 99, 135; Barton, HW-18319; G.E. Hanford Co., HW-19325 DEL, pp. 134, 137; G.E. Hanford Co., HW-19622 DEL, pp. 7, 103; G.E. Hanford Co., HW-19842 DEL, pp. 139-140, 6, 142; Groswith, HW-14710; G.E. Hanford Co., HW-18740 DEL, pp. 6, 102, 137; Facer and Lyon, HW-18796; Barton, HW-19545.

279. G.E. Hanford Co., HW-17056 DEL, p. 124; G.E. Hanford Co., HW-17410 DEL, pp. 5, 121; G.E. Hanford Co., HW-17660 DEL, pp. 5, 96; G.E. Hanford Co., HW-17971 DEL, pp. 4-5, 96, 122-124; G.E. Hanford Co., HW-18221 DEL, pp. 5, 123, 134; G.E. Hanford Co., HW-19622 DEL, pp. 6, 48, 75, 132; 139-140; G.E. Hanford Co., HW-19842 DEL, pp. 6, 142, 133, 143.

280. G.E. Hanford Co., HW-21260 DEL; G.E. Hanford Co., HW-22875 DEL.

281. Facer and Weidenbaum, HW-22136; G.E. Hanford Co., HW-20161, pp. 6, 108, 144; Gast, HW-22004; G.E. Hanford Co., HW-20438 DEL, pp. 6, 114, 140, 149, 156; Pugh, HW-21616; Shaw, Directive No. HW-244; G.E. Hanford Co., HW-20671 DEL, pp. 6, 100, 126; G.E. Hanford Co., HW-20991 DEL, pp. 7, 100, 137, 146-147; G.E. Hanford Co., HW-21506 DEL, pp. 5, 8, 55, 104, 146, 151; G.E. Hanford Co., HW-21802 DEL, pp. 94, 125-126, 134-135, 149; G.E. Hanford Co., HW-22075 DEL, pp. 89-98; G.E. Hanford Co., HW-22304 DEL, pp. 82, 102; Christy, HAN-63671 DEL, pp. 68, 88; Healy, HW-20522; Endow, HW-21457; G.E. Hanford Co., HW-22610 DEL, pp. 90, 195; G.E. Hanford Co., G.E. Hanford Co., HW-22875 DEL, pp. 90, 100; G.E. Hanford Co., HW-23140 DEL, pp. 100-103; G.E. Hanford Co., HW-21260 DEL, pp. 6, 104, 145, 132.
282. G.E. Hanford Co., HW-23437 DEL, p. 107; G.E. Hanford Co., HW-23982 DEL, p. Fb-20; G.E. Hanford Co., HW-24337 DEL, p. Fc-12; G.E. Hanford Co., HW-24605 DEL, p. Fc-14; G.E. Hanford Co., HW-26047 DEL, p. Ed-3.
283. G.E. Hanford Co., HW-25227 DEL, p. Fg-17; G.E. Hanford Co., HW-25781 DEL, p. Ff-10.
Note: This laboratory addition or annex to the 234-5 Building was not built.
284. G.E. Hanford Co., HW-23437 DEL, p. 103; G.E. Hanford Co., HW-25227 DEL, p. Fc-28; G.E. Hanford Co., HW-26720 DEL, p. Fc-15.
285. G.E. Hanford Co., HW-24605 DEL; G.E. Hanford Co., HW-24928 DEL; G.E. Hanford Co., HW-25527 DEL; G.E. Hanford Co., HW-25533 DEL; G.E. Hanford Co., HW-25781 DEL.
286. G.E. Hanford Co., HW-23427 DEL, pp. 94, 117, 93; G.E. Hanford Co., HW-23638 DEL, p. 115; G.E. Hanford Co., HW-24605 DEL, pp. Fc-9, Fc-9-10, Fc-13; G.E. Hanford Co., HW-25781 DEL, p. Fd-16; Bushey, HW-25250 pp. 29-32; G.E. Hanford Co., HW-25533 DEL, pp. Fd-12, Fd-15; G.E. Hanford Co., HW-25227 DEL, p. Fd-10; G.E. Hanford Co., HW-26720 DEL, p. Fc-11. See also: McIntosh and Heiling, HW-24403.
287. G.E. Hanford Co., HW-23437 DEL, p. 119; G.E. Hanford Co., HW-23638 DEL, p. 118; Ebright, HW-38428, pp. 1-2; G.E. Hanford Co., HW-23982 DEL, pp. Ed-8, Fb-5, H-5; G.E. Hanford Co., HW-25533 DEL, p. Fd-16; Ward, HW-25042; Ward, HW-25285; G.E. Hanford Co., HW-23676 DEL, p. Fd-5.
288. G.E. Hanford Co., HW-26946 DEL, pp. F-2, Fd-15-16; G.E. Hanford Co., HW-27288 DEL, pp. Fc-20-21; G.E. Hanford Co., HW-27624 DEL, pp. F-1-2, Fd-16; G.E. Hanford Co., HW-27932 DEL, pp. Fc-20, Fd-4; G.E. Hanford Co., HW-28267 DEL, pp. Fc-18, Fd-4; G.E. Hanford Co., HW-28576 DEL, pp. F-2-3, Fc-19-20, Fd-8-9, Fd-17; G.E. Hanford Co., HW-28906 DEL, p. Fd-11; G.E. Hanford Co., HW-29229 DEL, p. Fd-12; G.E. Hanford Co., HW-29794 DEL, pp. Ed-9, Fc-19, Fd-10-11. See also: G.E. Hanford Co., HW-34147 DEL, p. Fc-11.
289. G.E. Hanford Co., HW-26946 DEL, p. Fc-21; G.E. Hanford Co., HW-27288 DEL, pp. Fc-17, Fc-21, G.E. Hanford Co., HW-27624 DEL, p. Fc-18; G.E. Hanford Co., HW-27932 DEL, pp. Ed-9, Fc-19; G.E. Hanford Co., HW-29229 DEL, p. Fc-18; G.E. Hanford Co., HW-29794 DEL, pp. Ed-7, Ed-9, Fc-22; G.E. Hanford Co., HW-30130 DEL, pp. Fc-16-17.

290. G.E. Hanford Co., HW-27288 DEL, pp. F-2, Fd-15; G.E. Hanford Co., HW-27624 DEL, p. Fd-16; G.E. Hanford Co., HW-27932 DEL, pp. Fd-4-5; G.E. Hanford Co., HW-28267 DEL, pp. Fd-4-5; Bushey, HW-25250, pp. 52-54; G.E. Hanford Co., HW-28576 DEL, p. Fd-9; G.E. Hanford Co., HW-30130 DEL, p. Fd-10; G.E. Hanford Co., HW-30423 DEL, p. Fd-12. See also: Mullins, Leary and Bjorklund, LAMS-2441; Mullins, Leary, Morgan, and Maraman, LA-2666; Mullins, Leary and Morgan, LA-2758.

291. G.E. Hanford Co., HW-29794 DEL, p. Fd-10; G.E. Hanford Co., HW-30423 DEL, pp. Fd-11-12; Tolley and Smith, HW-30753.

292. G.E. Hanford Co., G.E. Hanford Co., HW-26946 DEL, p. Fc-21, G.E. Hanford Co., HW-27288 DEL, pp. Ed-8, Fc-20; G.E. Hanford Co., HW-27932 DEL, p. Fc-16; G.E. Hanford Co., HW-28576 DEL, pp. Ed-9, Fd-9; G.E. Hanford Co., HW-29229 DEL, p. Fc-20; G.E. Hanford Co., HW-29513 DEL, p. Fd-12; G.E. Hanford Co., HW-29794 DEL, p. Ff-8; G.E. Hanford Co., HW-30130 DEL, pp. F-3, Ff-9, Fg-12; G.E. Hanford Co., HW-30423 DEL, pp. F-3, Ff-9; Branin, HW-30039; Hopkins, RL-SEP-817.

293. G.E. Hanford Co., HW-26946 DEL, pp. Fd-5-6; G.E. Hanford Co., HW-27288 DEL, pp. Fc-20, Fd-7-8, Fd-11; G.E. Hanford Co., HW-27624 DEL, pp. Ed-8, Fd-15; Upson, HW-29028; G.E. Hanford Co., HW-27932 DEL, pp. Fd-5-6; G.E. Hanford Co., HW-28267 DEL, p. Fd-5; G.E. Hanford Co., HW-28906 DEL, pp. Fd-15-16; G.E. Hanford Co., HW-29229 DEL, pp. Fd-10-11; G.E. Hanford Co., HW-29513 DEL, pp. Fd-12-13; Roesch and Watson, HW-27194; G.E. Hanford Co., HW-29794 DEL, pp. F-1, Fd-11-12; G.E. Hanford Co., HW-30130 DEL, p. Fd-11; G.E. Hanford Co., HW-30423 DEL, pp. Fc-21, Fd-12-13.

294. G.E. Hanford Co., HW-30130 DEL, pp. Ed-14, H-4; G.E. Hanford Co., HW-30423 DEL, p. H-5.

295. G.E. Hanford Co., HW-30724 DEL, pp. F-4, Ff-9, Fg-12-13; G.E. Hanford Co., HW-31006 DEL, pp. Ed-9, F-3, Fc-17-18, Ff-8, Fg-12; G.E. Hanford Co., HW-31267 DEL, pp. Ed-9, F-4, Fc-20, Ff-8, Fg-12; G.E. Hanford Co., HW-31734 DEL, pp. F-3, Fc-19, Ff-9; Shaw, Directive No. HW-304, Modifications #1 and #2; G.E. Hanford Co., HW-31964 DEL, pp. Ed-5, Fc-19, Ff-7, Fg-12; G.E. Hanford Co., HW-32317 DEL, pp. Fc-14, Ff-9, Fg-13; G.E. Hanford Co., HW-32624 DEL, pp. Fc-17, Ff-8, Fg-13; G.E. Hanford Co., HW-32889 DEL, pp. Fg-11-12; G.E. Hanford Co., HW-33200 DEL, p. Fg-12; G.E. Hanford Co., HW-33585 DEL, p. Fg-13; G.E. Hanford Co., HW-33962 DEL, pp. Fc-14, Fg-11; G.E. Hanford Co., HW-34147 DEL, p. Fg-11.

296. G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fe-17, Ff-4-5, Ff-7-8, Fg-12; G.E. Hanford Co., HW-31267 DEL, pp. Ed-9, F-4, Fc-20, Ff-4, Ff-8, Fg-12; G.E. Hanford Co., HW-31734 DEL, pp. F-3, Fd-13, Fd-17, Fg-13; Shaw, Directive No. HW-305, Modification #3; G.E. Hanford Co., HW-31964 DEL, pp. Ed-5, Fc-18-19, Ff-5, Ff-7, Fg-12; G.E. Hanford Co., HW-32317 DEL, pp. Ed-10, F-4, Ff-5, Ff-9, Fg-13; G.E. Hanford Co., HW-32624 DEL, pp. Ed-10, Fc-17, Fg-13; G.E. Hanford Co., HW-32889 DEL, pp. Ed-9, Fc-17-18, Ff-5, Fg-12; G.E. Hanford Co., HW-33200 DEL, p. Ed-10, Fc-17, Fg-12; Wirta, HW-32810; G.E. Hanford Co., HW-33585 DEL, pp. Ed-9-11, Fc-15, Ff-5, Fg-13; G.E. Hanford Co., HW-33962 DEL, pp. Ed-10, Fc-15, Fg-11; G.E. Hanford Co., HW-34147 DEL, pp. Ed-10, Ed-12, Fc-13, Ff-5, Fg-11.

297. G.E. Hanford Co., HW-30724 DEL, pp. Fc-15, Fd-8; G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fc-18, Fd-15; Chapman, HW-30969 DEL, p. 3; G.E. Hanford Co., HW-31267 DEL, pp. Ed-7, Fc-21; G.E. Hanford Co., HW-32889 DEL, p. Fc-15; Helgeson, HW-35282 DEL; G.E. Hanford Co., HW-33220 DEL, pp. Ed-5, Ed-7; G.E. Hanford Co., HW-34147 DEL, p. Ff-5.

298. G.E. Hanford Co., HW-30724 DEL, pp. Fc-15, Fd-8; G.E. Hanford Co., HW-31006 DEL, pp. F-3, Fc-18, Fd-15; Chapman, HW-30969 DEL, p. 3; G.E. Hanford Co., HW-31267 DEL, pp. Ed-7, Fc-21; G.E. Hanford Co., HW-32889 DEL, p. Fc-15; Helgeson, HW-35282 DEL; G.E. Hanford Co., HW-33220 DEL, pp. Ed-5, Ed-7; G.E. Hanford Co., HW-34147 DEL, p. Ff-5.

299.. G.E. Hanford Co., HW-30724 DEL, pp. Ed-8-9; G.E. Hanford Co., HW-31006 DEL, p. Fd-16; Piereck, HW-33952; G.E. Hanford Co., HW-31267 DEL, p. Fd-18; G.E. Hanford Co., HW-31734 DEL, p. Fd-13; G.E. Hanford Co., HW-31964 DEL, p. Fd-13, Fd-17; G.E. Hanford Co., HW-32317 DEL, pp. Ed-8, Fd-16; G.E. Hanford Co., HW-32624 DEL, p. Fd-9; G.E. Hanford Co., HW-32889 DEL, p. Fc-16; G.E. Hanford Co., HW-33220 DEL, p. Ff-5; G.E. Hanford Co., HW-33585 DEL, p. Ff-6; G.E. Hanford Co., HW-33962 DEL, pp. Fc-16, Ff-6; G.E. Hanford Co., HW-34147 DEL, pp. Fc-13-14, Ff-5; Priode, Benoliel, Gilbert, McGrath, Tomlinson, and Zuhr, HW-55767 EEL, pp. 93-94.

300. G.E. Hanford Co., HW-31964 DEL, pp. Ed-14, Fc-19, H-4.

301. G.E. Hanford Co., HW-37658 DEL, pp. Fc-5-6, Fc-14, Fc-16; G.E. Hanford Co., HW-38375 DEL, pp. Fc-12-13; Ketzlach, HW-38029; G.E. Hanford Co., HW-38828 DEL, pp. Ed-8, Fc-7, Fc-18-19; G.E. Hanford Co., HW-39260 DEL, pp. Ed-7, Fc-12, Ff-6; Mobley, HW-38341; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Ff-6; G.E. Hanford Co., HW-40182 DEL, pp. Fc-8, Fc-13, Fc-16, Ff-6; Fritz, HW-37152; G.E. Hanford Co., HW-40692 DEL, pp. Ed-4, Fc-20, Ff-6; Newell, HW-40321.

302. G.E. Hanford Co., HW-34631 DEL, p. Ff-6; Pierick, HW-35882; G.E. Hanford Co., HW-35530 DEL, pp. Fc-24, Fc-30-31, Ff-5; G.E. Hanford Co., HW-36928 DEL, pp. Fc-35, Ff-6; G.E. Hanford Co., HW-37658 DEL, pp. Fc-14, Fc-26, Ff-6; Reas, HW-41274; Helgeson, HW-41369; G.E. Hanford Co., HW-38375 DEL, pp. Fc-13, Fc-15, Ff-6; Newell, HW-40321; G.E. Hanford Co., HW-38828 DEL, p. Fc-14, Ff-6; G.E. Hanford Co., HW-39260 DEL, pp. Fc-13, Ff-7; Ketzlach, HW-38904; G.E. Hanford Co., HW-39751 DEL, p. Fc-55; G.E. Hanford Co., HW-40182 DEL, p. Ff-6; G.E. Hanford Co., HW-40692 DEL, pp. Ed-17, Fc-10, Fc-18.

303. G.E. Hanford Co., HW-34631 DEL, pp. Ff-6, Ff-12-13, Fg-6; Shaw, Directive HW-350; G.E. Hanford Co., HW-35530 DEL, pp. Ed-15, Fc-15, Fc-24, Fc-30-31, Ff-5-6, Ff-9, Ff-11, Fg-13; G.E. Hanford Co., HW-35891 DEL, pp. Ed-5, Fc-15-16, Ff-5, Ff-9, Ff-11, Fg-13; G.E. Hanford Co., HW-36440 DEL, pp. Fc-17-18, Ff-6, Ff-10, Ff-12; G.E. Hanford Co., HW-36928 DEL, pp. Fc-35, Ff-6, Ff-10, Fg-12; G.E. Hanford Co., HW-37658 DEL, pp. Ed-7, Ed-11, Fc-16, Fc-26, Ff-6, Ff-11, Fg-12; G.E. Hanford Co., HW-38375 DEL, pp. Ed-7, Fc-14-15, Ff-6, Ff-12, Fg-11; Reas, HW-41274; Smith and Wirta, HW-39080; Ketzlach, HW-38904; G.E. Hanford Co., HW-38828 DEL, pp. Ed-12, Fc-15, Ff-6, Ff-11-12, Fg-3, Fg-12; G.E. Hanford Co., HW-39260 DEL, pp. Ed-7, Ff-12-13, Fg-11; G.E. Hanford Co., HW-39751 DEL, pp. Fc-14, Fc-55, Ff-3, Ff-5-6, Ff-9, Fg-5, Fg-12; G.E. Hanford Co., HW-40182 DEL, p. Ed-7, Ed-9, Ff-6, Fg-6; G.E. Hanford Co., HW-40692 DEL, pp. Ed-17, Fc-21-22, Ff-6, Fg-14.

304. G.E. Hanford Co., HW-38828 DEL, p. Ed-14; G.E. Hanford Co., HW-39751 DEL, p. Ed-14; G.E. Hanford Co., HW-39260 DEL.
305. Department Managers, HW-41205 DEL, pp. A-1, F-2, Fc-16; Department Managers, HW-41702 DEL, pp. Fc-19, Fd-5; Department Managers, HW-42219 DEL, pp. Fc-18-19, Fd-6; Department Managers, HW-42626 DEL, pp. Fc-19, Fd-6; Department Managers, HW-43137 DEL, pp. Fc-18, Fd-6; Department Managers, HW-43938 DEL, pp. Ed-13, Fc-17, Fd-7.
306. Brunstad, HW-46779.
307. Department Managers, HW-41205 DEL, p. Fc-16; Myers, HW-44987; Department Managers, HW-41702 DEL, pp. Fc-20-21; Department Managers, HW-426256 DEL, pp. Fc-17-18; Department Managers, HW-43938 DEL, p. Fc-18; Hopkins, RL-SEP-817.
308. Schipper, Directive No. AEC-121; Hanford Site Drawing H-2-20936.
309. Ciccarelli, HW-58025; Schipper, Directive No. HW-479; Tabasinske, HW-58897; LaRiviere, HW-59156; Operation Managers, HW-59079 DEL, p. E-2; Travis, Directive No. HW-479, Modification #1.
310. Operation Managers, HW-55571 DEL, pp. J-18-19; Operation Managers, HW-58305 DEL, p. A-4; Operation Managers, HW-63313 DEL, p. E-4; Members..., HW-64991 G, p. G-11; Rasmussen, HW-671565 RD; Hopkins, HW-61570 RD; Operation Managers, HW-67459 RD, pp. D-1-2; Operation Managers, HW-59849 DEL, p. E-2; Operation Managers, HW-64089 DEL, p. D-1.
311. Richardson, HW-52378: Members of the Research and Engineering Operation, Chemical Processing Department, HW-64991 G; Brunstad, HW-56606 RD.
312. Operation Managers, HW-59849 DEL, pp. E-4-5.
313. Operation Managers, HW-69051 DEL, pp. 6, D-1-2; Operation Managers, HW-69443 DEL, pp. 5-6, D-1-3; Operation Managers, HW-69803 DEL, pp. 5, D-1-3; Operation Managers, HW-70182 DEL, pp. 5, D-1-2; Operation Managers, HW-70588 DEL, pp. 5-6, D-1-2; Rosenfels, HW-68910; Operation Managers, HW-70918 DEL, pp. 5, D-1-2; Operation Managers, HW-71187 DEL, pp. 5, D-1-2; Operation Managers, HW-71577 DEL, pp. 5, D-1-2.
314. Kingsley and Crocker, HW-69910; Crocker, HW-69515; Stiffler, HW-70406.
315. Operation Managers, HW-72890 DEL, p. D-1; Operation Managers, HW-74151 DEL, pp. D-1-3; Bruns, Lyon and Unzicker, HW-72224 RD; Operation Managers, HW-77504 DEL, pp. 5-6, D-1-2; Sloat, HW-77807; Operation Managers, HW-78076 DEL, p. D-2; Unzicker and Lyon, HW-76162 RD; Curtis, HW-77369; Operation Managers, HW-81620 DEL, p. D-2; Operation Managers, RL-SEP-197 DEL, p. D-2; Operation Managers, RL-SEP-618 DEL; Operation Managers, RL-SEP-837 DEL; Operation Managers, RL-SEP-913 DEL; Barber, ISO-90 DEL.
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319. Curtis, HW-55363; Curtis, RL-SEP-30; Soine, RL-SEP-244; Fullam, RL-SEP-712.
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323. Engineers of Plutonium Process Engineering. ARH-294 RD DEL, pp. 98, 124.
324. Engineers, Plutonium Chemistry Laboratory, ISO-791 RD; Skinner and Felt, ARH-808; Felt, ARH-IR-157; Felt, ARH-SA-72.
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423. Borgeson, "Chopper Glove Box...", September 1964; and Walser and Lyon, HW-80356 RD, pp. 4, 7, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 41, 44, 48, 50, 53, 55, 57, 60, 62, 64, 66, 69, 71.

Note: The direct quotations are from Walser and Lyon, HW-80356 RD, pp. 50 and 18.

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Note: Although an ultrasonic leach bath had been recommended in 1962, the new leach facilities operated using the older, traditional method of mechanical agitation.

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441. Creighton, RL-SEP-507; Knights, RL-SEP-895.

442. Larkin, Carter, Kimble, and Laws, ARH-1884.

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453. Kesel and Laws, ISO-SA-14; Lorenzen, ISO-SA-29.

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580. Wheeler, ARH-CD-346; Easley, ARH-CD-467; Easley and Wheeler, ARH-CD-473; Marshall, ARH-CD-473 Rev; ARHCO, ARH-LD-201 B, p. 4; ARHCO, ARH-LD-204 B, p. 4; ARHCO, ARH-LD-209 B, p. 6; Harlow, ARH-CD-236 Book 2; Anderson, ARH-CD-594; Harlow, ARH-CD-533 Book 1.

581. Marshall, ARH-CD-753; Marshall, ARH-CD-798 1; Marshall, ARH-CD-921-RD; Smetana, ARH-CD-323; Harlow, ARH-CD-533 Book 2.

582. Pinto, RHO-CD-200; Program Business Management, RHO-LD-10 B Jan 80, p. 16; Pinto, RHO-CD-246; Pinto, RHO-CD-245 1; Corbell, RHO-CD-B-183a, Rev. 1.

583. Pinto, RHO-CD-245 1.

584. Pinto, RHO-CD-513; Corbell, RHO-CD-36-B-137; Pinto, RHO-CD-666; Cockeram, RHO-LD-10 B Jul 77, p. 15..

585. Haddad, ARH-CD-255; ARH-CD-155 Rev 1.

586. Socking, "Solidification of Z Plant Aqueous Salt Waste," April 16, 1975; Haddad, ARH-CD-399; Haddad, ARH-CD-478; ARHCO, "Environmental Assessment, Z Plant Aqueous Waste Solidification Facility"; Barnhill and Haddad, ARH-CD-502; Corbell, ARH-CD-560; Haddad, ARH-CD-502 Rev.

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