UCRL-ID-122666
L-20588-1

Fissile Material Disposition Program

PEIS Data Call Input Report: Ceramic Immobilization Facility Using Coated Pellets without Radionuclides

February 9, 1996

University of California
Lawrence Livermore National Laboratory

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Preface

Significant quantities of weapons—usable fissile materials (primarily plutonium and highly enriched uranium [HEU])—have become surplus to national defense needs both in the United States and Russia. The excess stocks of plutonium and HEU pose significant dangers to national and international security. The dangers exist not only in the potential proliferation of nuclear weapons but also in the potential consequences for the environment, safety, and health if excess fissile materials are not properly managed. Under the direction of the President of the United States, the Department of Energy (DOE) is examining options for placing weapons-usable nuclear materials in a form or condition that is substantially and inherently more difficult to use in weapons. The potential environmental impacts of facilities designed to implement this objective for plutonium will be described in the Fissile Material Disposition (MD) Program's *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (PEIS).

The MD PEIS will examine the following resource areas: land use, facility operations and site infrastructure; air quality and acoustics; water, geology and soils, biotic, cultural and paleontological resources; socioeconomics; human health, normal operations and facility accidents; waste management; and transportation.

The purpose of this data call input report is to provide preliminary information for use in estimating the environmental effects associated with the construction and operation of a new Ceramic Immobilization Facility (CIF), using coated pellets without radionuclide spiking, an alternative currently under consideration in the MD PEIS.

The facility may be built at any location, but this MD PEIS data report is based on a generic, or new (Greenfield) site located in Kenosha, Wisconsin. The construction of a "stand alone" facility will require many support systems including radioactive waste treatment facilities, industrial waste treatment facilities, electrical utilities, domestic water facilities, and the infrastructure to support facility construction and operation (e.g., safeguards and security, transportation, fire protection, medical, purchasing, training, financial support). If this facility is constructed on an existing DOE site, many of these infrastructure elements will already be available. Additional studies will have to be performed so that environmental and geological reports can be generated that support the geographic site location in a facility Safety Analysis Report. The preliminary information presented in this data call includes only the environmental effects associated with the construction and operation of a new Ceramic Immobilization Facility using coated pellets without radionuclide spiking. The economic advantages of building such a site on a DOE complex, from which existing support facilities and site data can be utilized, will be given the proper consideration at a later time in the MD PEIS development process.

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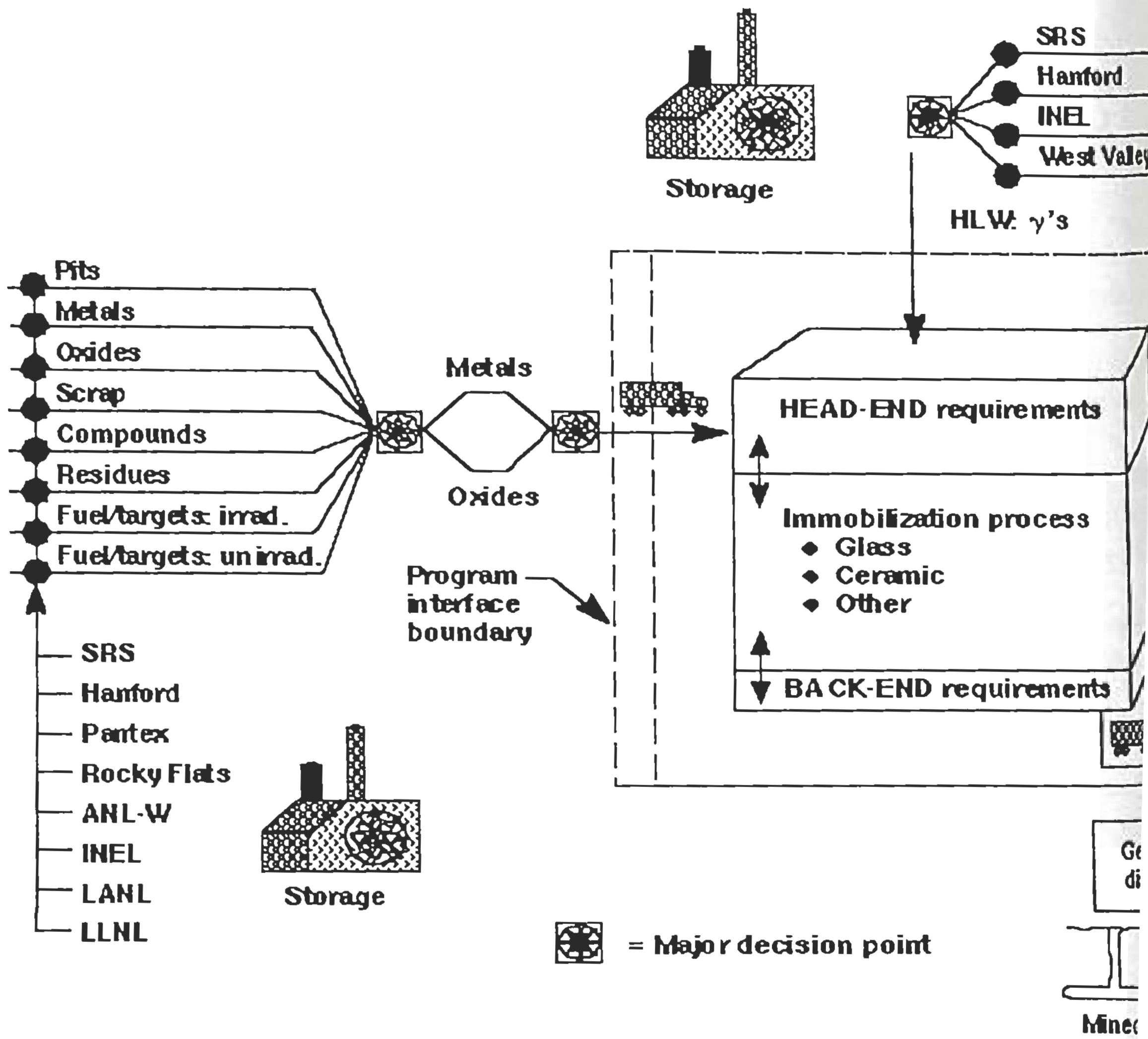

Figure 1-1. Immobilization of surplus fissile materials.

Incorporation of plutonium into ceramic would provide a form that woul relatively easy to store but would render retrieval of the plutonium more dif Many of the technologies needed to prepare plutonium in a ceramic exist to However, the effect of formulation and redox control, the plutonium reactio the optimum neutron absorber, the solubility interaction of the neutron abs plutonium, the proper equipment design for criticality process control, and optimum processing conditions are issues requiring resolution. Although th need to be studied further, research and development activities are require to verify the process to be viable and that the product is of suitable durabili desired form of the final product will determine the extent of technical issu long-term criticality safety and stability of the product after permanent dis

If plutonium were present as an abundant mineral in the earth, one wo find it in minerals containing elements that have a similar chemistry to plu uranium and thorium. Over 200 actinide-bearing minerals are found in nat these are extremely promising for plutonium immobilization since they ha demonstrated both immobilization of actinides and of decay products for periods exceeding 100 million years. The most geologic data are available for zircon ($ZrSiO_4$), monazite ($CePO_4$), and a few other related silica and phosphate minerals. However, substantial geologic data are also available for pyrochlore ($Gd_2Ti_2O_7$) and zirconolite ($CaZrTi_2O_7$) minerals, which are titania-based minerals. Because of demonstrated actinide immobilization, any of these minerals are strong candidates for plutonium disposition by immobilization in ceramic.

Because of their extreme durability, ceramic forms have been developed extensively for the immobilization of HLW. The material called Synthetic Rock (Synroc) has received extensive study both at the Australian Nuclear Science and Technology Organisation (ANSTO) and at the Lawrence Livermore National Laboratory (LLNL). Work at ANSTO has included a full-scale demonstration facility using HLW surrogates and many small-scale experiments with plutonium. Synroc is a titania-based ceramic composed approximately of 30% zirconolite, 30% hollandite ($BaA_{12}Ti_6O_{16}$), 30% perovskite ($CaTiO_3$), and 10% rutile (TiO_2). Actinides partition into the zirconolite and perovskite phases.

Considering the mineral analogues in nature and the status of development of ceramic HLW waste forms, a Synroc formulation with a high zirconolite content is considered the baseline for the ceramic immobilization form. Composition after loading of plutonium is assumed to be 90 wt% zirconolite and 10% rutile. Future research and development may show other mineral formulations to be superior, and they may become the preferred formulation.

Immobilization in the baseline formulation is accomplished by elemental substitution of the plutonium into lattice sites of the host minerals. Plutonium can substitute for the zirconium site if it is in the +4 valence, or it can substitute for the calcium site if it is in the +3 valence. The plutonium substitutes more readily into the calcium site, because the size of the +3 plutonium atom matches the +2 calcium atom more closely than the size of the +4 plutonium atom matches the +4 zirconium atom. Maximum plutonium loadings are about 10 wt% on the zirconium site and about 23 wt% on the calcium site. Higher loadings yield the pyrochlore phase which is also a desirable phase for actinide immobilization. If the Synroc formulation is 90 wt% zirconolite and if processing conditions are sufficiently reducing, plutonium contents in the form exceeding 12 wt% are easily obtained.

A small amount of titania is formulated into the form. This helps fix the phase equilibria and allows for a small amount of variation in feed composition, both in loading of plutonium and in the amount of impurities present. Excess titania also ensures that the product durability is optimized. Of all the oxide constituents within the formulation, titania is the most resistant to dissolution in water.

1.1.3 Deep Borehole Concept

The deep borehole concept relies on the great distance from the biosphere, an properties and integrity of the surrounding rock to isolate the emplaced fissile radionuclides from the biosphere over an indefinitely long performance period. Because plutonium has a very long half-life (24,400 years) and it decays to the ev longer-lived (710 million year half-life) fissile uranium-235, the length of this performance period is required to be much longer than the operational lifetimes order of 10,000 years specified for nuclear waste repositories. The latter is specif mainly on the basis of the time required for fission product decay to safe levels. depth of the emplacement zone will be selected on the basis of performance ana ensure that the radionuclides emplaced in the borehole either will never reach th biosphere, or will have decayed to innocuous levels by the time they do reach th biosphere. The expectation that the deep borehole concept will be able to offer s performance is based on the very slow movement of groundwater at great dept very slow release of radionuclides to the flowing groundwater by the disposal f retardation of the movement of dissolved radionuclides by physico-chemical interactions with the rock, and the capability to perform the drilling, emplacing borehole-sealing operations without compromising the natural barriers of the geosphere, or establishing new pathways for transport of the radionuclides to the biosphere.

The site will be carefully selected to provide a tectonically, hydrologically, t and geochemically stable host rock formation without fluid circulation at depth having strong evidence that the fluid has remained stagnant at depth for a geo long time. A site satisfying these criteria is likely to have the following characte seismic stability, low geothermal gradient, high-salinity gradient, low density fracturing, and the absence of fault zones.

The coated ceramic pellet disposal form is chosen to yield superior long-ter performance with respect to radionuclide migration to the biosphere, prolifera resistance, and criticality safety. From a radionuclide migration perspective, th pellet disposal form has very high dissolution resistance, has a dissolution sur comparable to those expected from cracked monolithic disposal forms, is stron fracture resistant, and is capable of easy emplacement and sealing in place. At loading, it is dilute in plutonium concentration and thus provides a barrier ag chemical separation into weapons-usable material. It contains neutron-absorb chemicals in its intrinsic ceramic material and in the optional neutron-absorbe additives that will be incorporated during immobilization. Thus, it is both pro resistant and criticality safe.

For superior long-term performance, the design relies on:

1) The natural system barrier, the intrinsic dissolution resistance of a high performance immobilized disposal form, and the durability of the long the isolation zone and the emplacement zone seals to ensure isolation emplaced radionuclides over an indefinitely long performance period;

2) Spatial dilution to subcritical plutonium loadings as the first line of defense against criticality, and with neutron absorbers incorporated as a supplementary optional second line of defense against criticality; and
3) The great depth of disposal as the first barrier to proliferation, dilution within a large volume of disposal form as the second barrier, and the incorporation of neutron absorbers as the third barrier to proliferation.

1.2 Assumptions and Design Basis

1.2.1 Program Assumptions

The following assumptions have been used to develop the flowsheets, block flow diagrams, chemical input and output, etc., for the coated ceramic pellet immobilization without radionuclide option.

- The CIF will receive plutonium in the form of the oxide (75%) and metal (25%). Metals will arrive as metallic ingots.
- The nominal feed of plutonium over the life of the CIF is 50 tonne (50,000 kg, 110,000 lb) of plutonium also.
- The 1% plutonium loading in the coated pellet ceramic form is consistent with the currently preferred concept for disposal of fissile material in a deep borehole. This concept assumes direct disposal of the pellets by grouting in the borehole to provide physical inaccessibility of the material at depth (4 to 10 km; 2.5 to 6.2 miles) for security. Spiking of the material with high-activity material such as ^{137}Cs or high-level waste is not required. The ceramic coating of the pellets serves to reduce handling health hazards due to generation of plutonium-loaded ceramic dust and to minimize pellet degradation during storage and transfer operations at both the CIF and the deep borehole disposal facility.
- Criticality considerations shall explicitly address both the immobilization processing/form fabrication with associated equipment (off-gas treatment, etc.) and repository storage for thousands of years into the future. Criticality control by batch mass control or equipment geometry are the preferred methods to be considered during design. The use of neutron absorbers (e.g., gadolinium, samarium, hafnium, boron, etc.) shall be considered. Throughout this report, the neutron absorber is assumed to be gadolinium, but the use of other neutron absorbers has not been ruled out. No detailed criticality analysis has been performed as yet. Criticality design issues within this report are based on engineering judgments and extrapolation from similar processes only.
- The coated ceramic pellet product package assumed for this study is a 208 L (55 gal) drum consistent with the current requirements of the deep borehole disposal concept.

1.2.2 CIF Assumptions

The actual CIF may be built at a number of locations. The site assumed for th report is the standard Electric Power Research Institute (EPRI) site defined in Appendix F of *DOE Cost Guidelines*. After actual site selection, meteorological, geological, and environmental data specific to the site chosen will be required.

The general design basis document used in design of the Ceramic Immobiliz Facilities is DOE Order 6430.1A, *General Design Criteria*. This order covers desig criteria, applicable regulatory and industry codes, and standards for the design nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facili explosive facilities) are included in this document.

Conventional design codes and standards have been used for the design bas non-nuclear facilities in the Ceramic Immobilization Facility including the follo

- Administration Building
- Support Utilities Building
- Warehouse
- Shops and Equipment Mockup Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Cold Chemical Storage Building
- Facility Cooling Tower

Design codes and standards applicable to "special facilities" as defined in Order 6430.1A include the following:

- Plutonium Processing Building
- Radwaste Management Building
- Radiologically Controlled Maintenance Facility
- Canister Storage Building
- Facility Guardhouses

A more detailed listing of compliance standards is presented in Section 1

1.2.3 Facility Capacity/Capability

The CIF will have a 10-year production mission. The facility will proces metal and oxide at a rate of 5 tonnes (5000 kg; 11,000 lb) per year (50 tonne [110,000 lb] over the life of the facility). A 10-year mission is a conservative the actual production mission time will be optimized to maximum product minimum duration.

Operations shall be three shifts per day, seven days per week. The CIF to operate with an availability factor of 75%. Allowing normal time for ma accountability, criticality control, etc., normal operations shall be considera

200-day operating year. Nominal throughput shall, therefore, be 8.34 kg (18 lb) of actinide per eight-hour shift.

Full storage capacity will be provided for Pu-ceramic pellets that will be produced during the operating mission.

The immobilized Pu-ceramic will be placed in 208 L (55 gal) drums with 1% by weight of plutonium in the ceramic. Each drum is anticipated to contain 5 kg (11 lb) of plutonium, and approximately 980 drums will be required to handle 5 tonne (5.6 ton) of plutonium per year, based on processing 50 tonne (56 ton) in 10 years; a total of approximately 9800 drums for the complete project.

Approximately 900 persons will be required to operate the CIF using coated pellets without radionuclides.

1.2.4 Facility Operating Basis

New immobilization facilities are assumed to be NRC licensed. The preliminary schedule, Fig. 1-2, shows the program start date as August 1996. The preliminary schedule indicates Title I (preliminary) design and preparation of a license application with environmental report would require about four years. NRC licensing is estimated to require five years. However, nonsafety related construction is assumed to start about 2004, a year prior to issue of license. During the NRC licensing period, an Environmental Impact Statement is issued and Title II (final) design is completed. Construction, start-up, preoperational testing, and operational readiness review are estimated to require about five years, leading to operation of the facilities about 2009. Operations are assumed to start about 2009 and be completed in 2018, for a nominal 10-year operating period. Decontamination and decommissioning of the facilities are estimated to require about three years, resulting in overall program completion date in 2020.

Since pellet production process utilizes existing mixed oxide (MOX) nuclear fuel fabrication technology, a minimal development program has been postulated to develop the facility process and equipment. The program will include development of feed and product material specifications and remotely operated process equipment and material accountability concepts.

A new capital project will be required to implement the Greenfield plutonium immobilization alternatives, which include the design and construction of new facilities. An assumption is that DOE line item projects will be conducted in accordance with DOE Orders and the congressional funding cycle. The planning basis is that key decisions (KD) for Approval of Mission Need (KD-0), Approval of New Start (KD-1), Commence Detailed Design (KD-2), Commence Construction (KD-3), and Commence Operations (KD-4) will be performed by the DOE in support of this plutonium immobilization alternative.

A research and development program has been identified to develop and demonstrate the process and equipment and to assess product performance an durability.

National Environmental Protection Act (NEPA) activities are included. For t NRC licensed facilities it is assumed that an Environmental Information report preferred site, and evaluation of alternatives is submitted to NRC for their NEP to issue a license.

Permitting activities are indicated. Preparation of a Safety Analysis Report i included. Title I & II (preliminary and detailed) design durations are indicated. Construction and procurement durations are included. Cold start-up, preoperat testing, and an Operational Readiness Review (ORR) of the facility is included, by hot start-up and operations.

The time to process the reference 50 tonne (56 ton) of plutonium will vary w plutonium loading and actual operating scenarios. For planning purposes, the estimated duration of the plutonium immobilization campaign is 10 years. Proc improvements, plutonium immobilization experience, and increased plutoniu could shorten this schedule.

Decontamination and decommissioning duration is included. The decommi method assumed for the schedule is complete dismantlement and restoration o for unrestricted use. Other methods (layaway, protective storage, etc.) or combi of methods, depending on time, cost-benefit studies, or radiation exposure mig selected with an impact to the time required.

1.2.4.1 Research and Development Basis. The duration and scope of the re and development program must be sufficient to develop and demonstrate the immobilization processes and to assess the durability and performance of the immobilized ceramic product. It is assumed that the bulk of the research and development would occur between the ROD and the end of Title I design. Prin research and development tasks will be required to:

- Determine and document the nuclear criticality safety margins of every plutonium in handling, processing, and final disposition in a repository
- Define the chemical and physical properties of the ceramic product, inc the precursor composition and product durability; and
- Develop and demonstrate acceptable performance of equipment, proces final immobilized form.

A considerable amount of research and development has already been perfo for immobilizing HLW in ceramic. The cold press and sinter ceramic fabrication process is similar to standard fuel pellet fabrication processes and has also been to a small extent for immobilization of LLW ash with RCRA regulated metals. Small-scale work on product durability and performance has also been perform plutonium-loaded ceramics.

The primary safety consideration in the processing and final disposition of the plutonium is criticality safety. All handling and processing must be in compliance with DOE Order 5480.24, *Nuclear Criticality Safety*. This order dictates that before a new operation is begun, it shall be determined that the process will be subcritical under both normal and credible abnormal conditions. The ceramic immobilized form can contain various neutron absorbers (e.g., hafnium, samarium, gadolinium, etc.) to prevent criticality. Even with the neutron absorbers present, assessments and procedures must be identified and documented according to accepted practices to ensure that criticality cannot occur.

The chemical and physical properties of the immobilized product are also extremely important. Properties of significant interest are leachability in brine solutions, susceptibility to radiation damage effects, chemical stability in a borehole, and product sintering density. Ceramic will be formulated to optimize these properties without limiting the solid solubilities of the plutonium or neutron absorbers. In addition, the effects of feed material form, composition, and morphology and process kinetics and reaction times will need to be evaluated in order to optimize the product properties.

Demonstration of reliable procedures, equipment, and product properties will be important to build confidence in the ceramic fabrication process and product. This will encompass large-scale demonstrations of the immobilization process and performance assessments of the product. The fabrication process data will be used to identify processing rates, operating limits, and related operational performance characteristics to guide design and construction. The product performance data will be used to determine long-term performance of the borehole and to certify the immobilized form.

1.2.4.2 Permitting/Licensing Basis. The ceramic immobilization in the CIF will require compliance with applicable laws, regulations, executive orders, NRC Regulations, and DOE orders. Implementing procedures will govern permit/license acquisition. This section identifies the major regulatory requirements that must be addressed.

Basic references concerning the content and procedures for issuing an Environmental Impact Statement (EIS) can be found in the Council on Environmental Quality Regulation 40 Code of Federal Regulations (CFR) 1502, *Environmental Impact Statement*; 10 CFR 1021, *National Environmental Policy Act Implementing Procedures* (for DOE); DOE Orders 5400.1, *General Environmental Protection Program*, and 5440.1E, *National Environmental Policy Act Compliance Program*.

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, guidelines, etc., as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities"; Sections 1300, "General Requirements"; 1304, "Plutonium Processing and Handling Facilities"; 1305, "Plutonium Storage Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

1.2.4.3 Construction Basis. A new capital project will be required to implem plutonium ceramic alternative, which includes the design and construction of a n facility. The DOE line item projects must be conducted in accodance with DOE and the congressional funding cycle. In certain clearly specifiel circumstances, applicable DOE Orders (4700.1 and 6430.1) allow parallel rathe than prescribed sequential activities; nevertheless, certain milestones are inviolble. A concept design and preliminary cost estimate will be developed for DOE validation. The will likely validate the project approximately two years ahead of the project Budg Year.

Key decisions for Approval of Mission Need (KD-0), Approval of New Start Commence Detailed Design (KD-2), Commence Construction (KD-3), and Comme Operations (KD-4) will be performed by the DOE in support of this plutonium ce alternative.

1.2.4.4 Operating Basis. The time to process the reference 50 tonne (56 ton) of plutonium into ceramic will vary with the plutonium loading, but in general, pro times to support the immobilization mission can be achieved. The estimated dur of the plutonium ceramic campaign will be 10 years. Operations shall be three sh day, seven days per week. Allowing normal time for remote maintenance, accountability, criticality control, etc., a normal operating year should be 200 days

Nominal throughput will, therefore, be 8.34 kg (18 lb) of plutonium per eight shift. The operating schedule assumes 10 years of operation with the last year preparing for Decontamination and Decommissioning (D&D) activities. Process improvements, plutonium ceramic experience, and increased plutonium loading shorten this schedule, so 10 years is a conservative maximum operating span.

1.2.4.5 Decontamination and Decommissioning Basis. The decommissioning method assumed for the CIF will be complete dismantlement and restoration of th for unrestricted use. Other methods (layaway, protective storage, etc.) or combin of methods, depending on time, cost-benefit studies, or radiation exposure may be selected.

An aggressive schedule for D&D activities is indicated which includes facility transition, project preparation, environmental review, engineering and planning, D operations, closeout and verification, and post-operations.

1.2.5 Compliance

1.2.5.1 Rules, Regulations, Codes, and Guidelines. Basic references concerning content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502—*Environmental Impact Statement*, 10 CFR 1021, *National Environmental Policy Act Implementing Procedures* (for DOE) & Orders 5400.1, *General Environmental Protection Program*, and 5440.1E, *National Environmental Policy Act Compliance Program*.

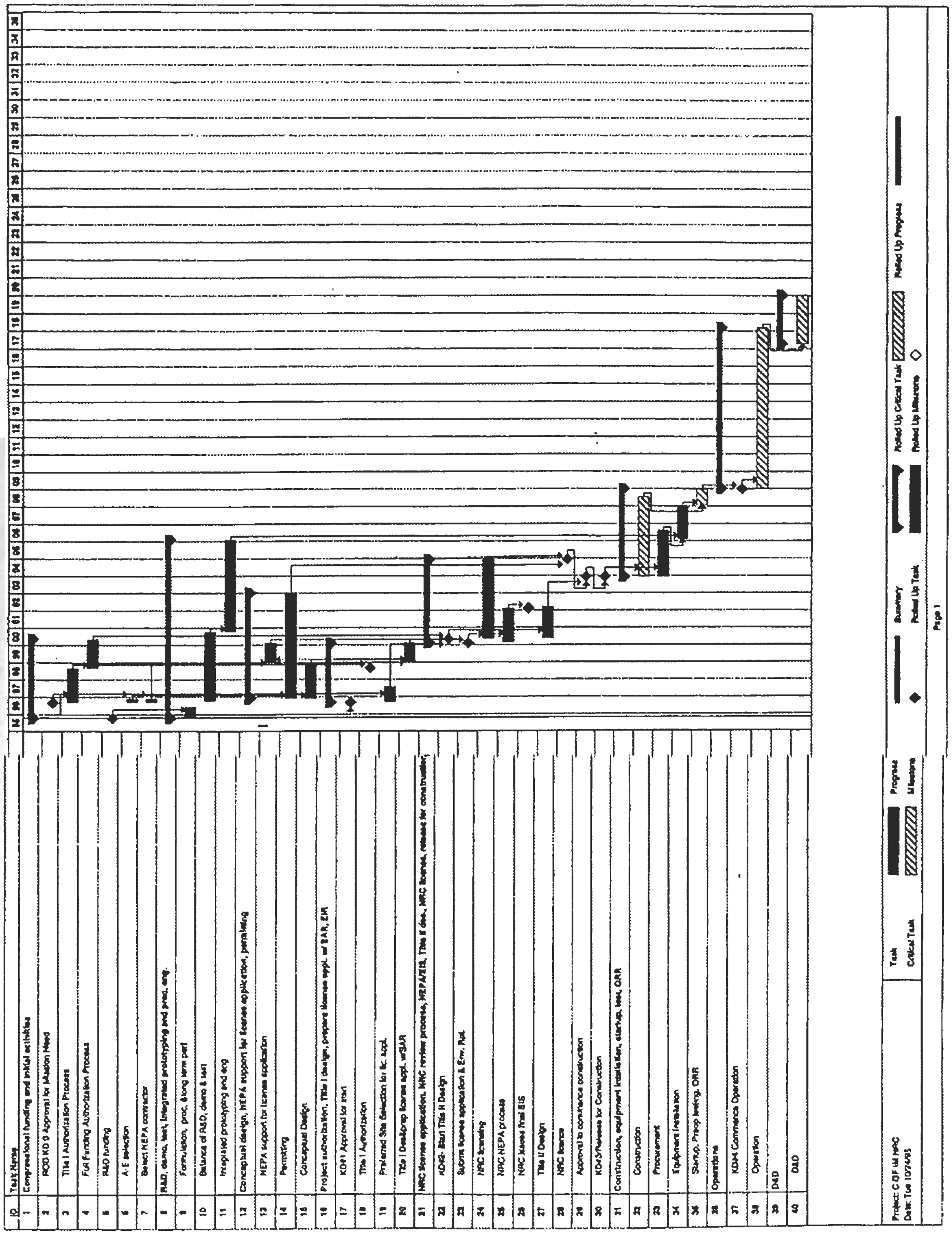

Figure 1-2. Schedule.

components to appropriate industrial standards as listed in DOE Order 6430.1A, Section 0109, "Reference Standards and Guides."

Safety class systems, components, and structures will be designed to the requirements of DOE Order 6430.1A, Section 1300-3, "Safety Class Criteria," and 1300-4, "Nuclear Criticality Safety."

The facility safety analysis and risk assessment will comply with DOE Orders 5480.23, *Nuclear Safety Analysis Reports*, and 5481.1B, *Safety Analysis and Review System*; and DOE Order 6430.1A, Section 0110-5.2, "Safety Analysis."

Design basis natural phenomena, such as design basis earthquake, design basis tornado, and design basis flood will be chosen in accordance with DOE-STD-1020-92, *Design and Evaluation Guidelines for DOE Facilities Subject to Natural Phenomena Hazards*. Accident risk assessments will be in accordance with DOE-STD-3005-YR, *Evaluation Guidelines for Accident Analysis for Safety Structures, Systems, and Components*.

1.2.5.7 Toxicological/Radiological Exposure. Exposures to hazardous effluents (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.8 Waste Management. Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1304-7, "Effluent Control and Monitoring (of Plutonium Processing and Handling Facilities)"; 1305-6 "Effluent Control and Monitoring (of Plutonium Storage Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)."

Specific DOE design and operating requirements for radioactive wastes, including low-level waste (LLW) and transuranic (TRU) waste, appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program—including waste minimization, source reduction, and recycling of solid, liquid, and air emissions—will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

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2.0 Ceramic Immobilization Facility Description

2.1 General Facility Description

2.1.1 Functional Description

The process presented in this report consists of immobilizing plutonium in a coated ceramic pellet form without addition of radionuclides. The feed materials are plutonium in both the oxide and metal forms and nonradioactive ceramic precursor materials. It is assumed that gadolinium (or samarium, hafnium, etc.) is added as a neutron absorber although preliminary calculations indicate that it is not required for criticality control during ceramic processing and final product storage. The plutonium is assumed to be thoroughly mixed to ensure homogeneous liquids and powders.

The final ceramic product is contained in 55-gal (208 L) drums and is stored onsite until it is transported to its final disposition in a deep borehole. Each product drum contains approximately 500 kg (1100 lb) of ceramic, which includes approximately 5 kg (11 lb) of plutonium and 3.3 kg (7.3 lb) gadolinium.

The processing is performed remotely in gloveboxes located in processing rooms.

The ceramic product is assumed to be similar to Synroc-C, which contains the mineral phases zirconolite ($CaZrTi_2O_7$), hollandite ($BaAl_2Ti_6O_{16}$), and perovskite ($CaTiO_3$), and rutile (TiO_2). The optimum mix of these phases selected will be the result of a research and development program.

Figure 2-1 is a facility flow diagram of the process through the Ceramic Immobilization Facility (CIF).

2.1.2 Plot Plan

The CIF plot plan is shown in Fig. 2-2

The major structures on the site are as follows:

- Plutonium Processing Building.
- Radwaste Management and Radiologically Controlled Maintenance Buildings.
- Product Storage Building.
- Miscellaneous support buildings, including the Administration Building, the Support Utilities Building, the Industrial Waste and Sanitary Waste Treatment Buildings, the Shops Building, and the Warehouse.
- Forced draft cooling tower.
- Ventilation exhaust and boiler stacks.

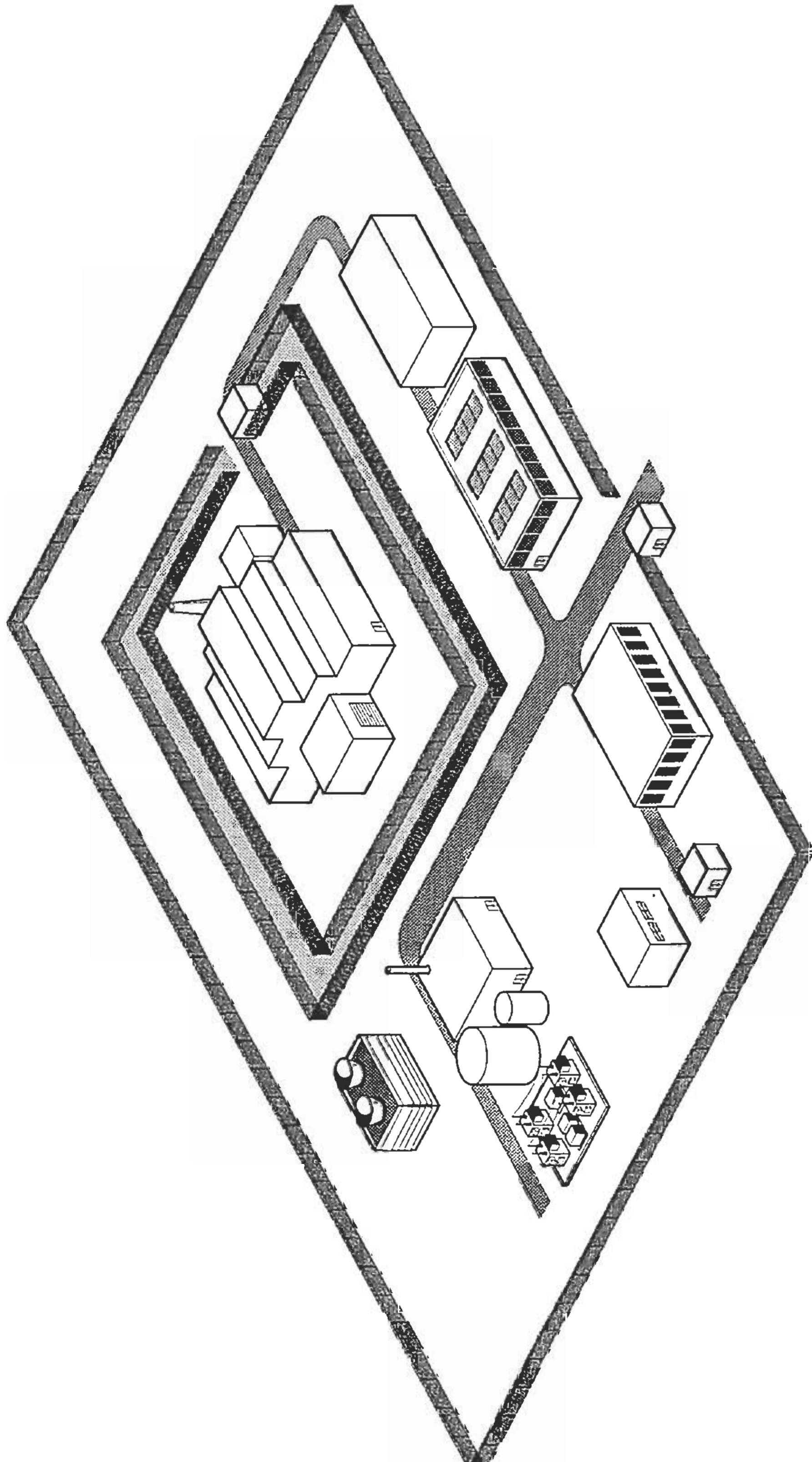

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Figure 2-2. Plot plan (rendering).

2.1.3 Building Descriptions

Facility data are summarized in Table 2-1.

Table 2-1. Facility data.

Building Name	Footprint Sq. m (Sq. Ft.)	Number of Levels	Special Materials	Construction Type
Pu Processing Building	4,500 (48,000)	2	SNM	Reinforced Concrete
Radwaste Management Building	2,300 (25,000)	1	SNM	Reinforced Concrete
Radiologically Controlled Maintenance Building	1,400 (15,000)	1	SNM	Reinforced Concrete
Canister Storage Building	460 (5000)	1	SNM	Reinforced Concrete
Support Utilities Building	1,400 (15,000)	1	None	Metal Frame
Administration Building	1,700 (18,000)	1	None	Metal Frame
Warehouse	2,300 (25,000)	1	None	Metal Frame
Shops Building	2,300 (25,000)	1	None	Metal Frame
Industrial Waste Treatment Building	930 (10,000)	1	None	Metal Frame
Sanitary Waste Treatment Building	150 (1,600)	1	None	Metal Frame
Guardhouses (3)	150 (1,600)	2	None	Reinforced Concrete
Cold Chemical Storage Building	460 (5,000)	1	None	Metal Frame
Cooling Tower	930 (10,000)	—	—	—

2.1.3.1 Pu Processing Building. The Plutonium Processing Building is shown in Figs. 2-3 and 2-4. The building is a reinforced concrete structure housing a central processing area where the main immobilization process is located, surrounded by various support areas. The building houses the following main functional areas:

- An area for receiving plutonium in Safe Secure Trailers (SSTs) in either metal oxide form.
- A shipping and receiving area for cold chemical feed materials, ceramic precursor, and other nonradioactive materials.


Storage Vault

Waste Treatment ding	150 (1,600)
houses (3)	150 (1,600)
Chemical Storage ng	460 (5,000)
g Towwer	930 (10,000)

.1. Pu Processing Building. The Pluto...
3 and 2-4. The building is a reinforced...
ing area where the main immobilizati...
support areas. The building houses the...

An area for receiving plutonium in Sa...
oxide form.

A shipping and receiving area for ...
precursor, and other nonradioactive ...

- Facilities for accountability measurements of the special nuclear material received or shipped.
- A storage vault for special nuclear material received.
- Glovebox areas for plutonium and ceramic processing.
- An analytical laboratory for analysis of process samples.
- A cold feed storage and preparation area for nonradioactive feed materials for the ceramic process (ceramic precursors, chemicals, etc.).
- An equipment decontamination area for decontamination, maintenance and repair of process equipment.
- Facilities for mechanical and electrical support systems and clean equipment maintenance.
- A control room.
- A stacker/retriever vault containing a remotely operated stacker/ retriever for transport of materials between storage and processing areas.
- A scrap treatment area to allow treatment and recycle of plutonium from contaminated process materials.
- An area for entry control to the facility, personnel rooms and health physics operations.

A Product Storage Building sized to store one year of product drums production with space provided for the full 10 years operation; a Radiologically Controlled Maintenance Building for maintenance and repair of process equipment; and a Radwaste Management Building for handling, treatment, packaging and shipping of low-level and transuranic wastes are immediately adjacent to the Plutonium Processing Building (See Sections 2.1.3.2 and 2.1.3.3).

The facility will be designed in accordance with DOE Order 6430.1A, *General Design Criteria.*

The plutonium processing equipment is housed in glovebox enclosures located in processing rooms. Glovebox equipment layout is grouped by primary process operations. Normal process operations will be controlled remotely from a process control room with minimum manual intervention. Both liquid and solid material transfers within and between gloveboxes will be accomplished by remotely operated pumps, vacuum transfers, conveyors, robots, manipulators, etc., as required. Maintenance of equipment within the process gloveboxes will be by gloves after remote removal of plutonium from the process equipment.

Typical process area layouts are shown on Figs. 2-5 through 2-13.

The process support systems are primarily housed within the process building with the exception of the process gas supply systems, which will be located in the yard adjacent to the process building.

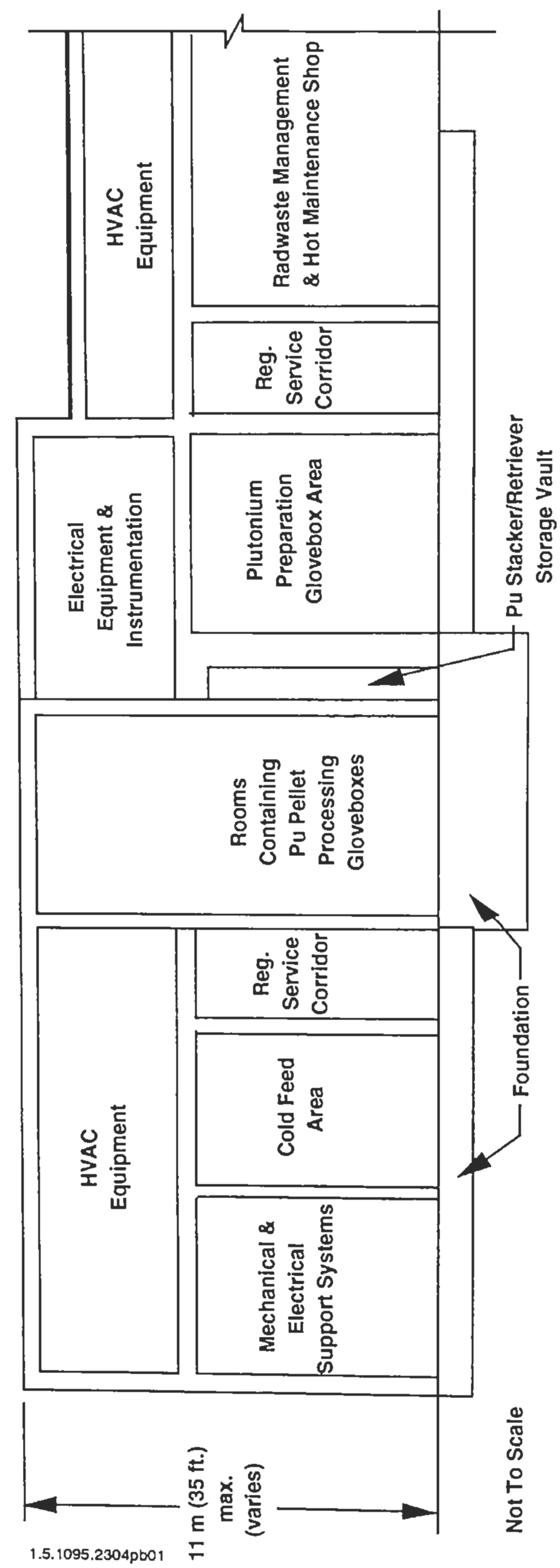

Figure 2-4. Pu Processing Building section.

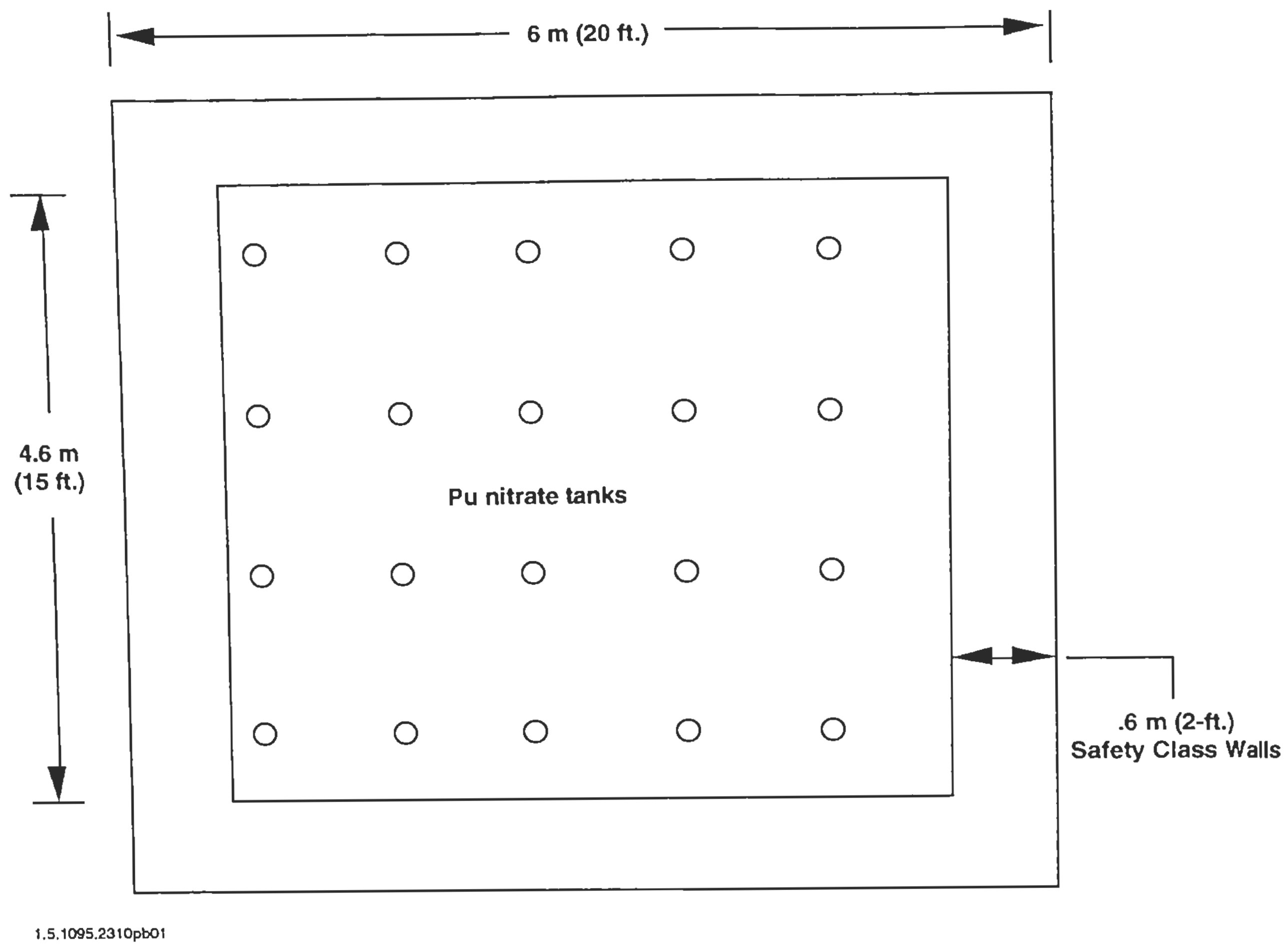

Figure 2-5. Pu solution storage area equipment arrangement.

Cold chemical storage and makeup includes areas at grade level where chemicals, ceramic additives, cement, etc., can be stored. Storage capacity of approximately 3 months is provided. Chemical and additive makeup and process run tanks are located at upper levels of the building to allow gravity feed to the process.

As noted above, the process gas supply bottles/storage tanks are located in the yard as required by DOE Order 6430.1A. Supply manifolds will deliver gas to the appropriate process equipment or gloveboxes. Gloveboxes containing plutonium metal will be operated under a nitrogen atmosphere to prevent a plutonium metal fire.

The plutonium feed material storage and handling system consists of a plutonium shipping container crane; a plutonium storage container unloading, weighing, bar code reading and assay device; and a plutonium storage container transfer device. A plutonium storage vault meeting the requirements of DOE Orders 6430.1A Section 1305 with a capacity of six months feed and served by a stacker-retriever is provided.

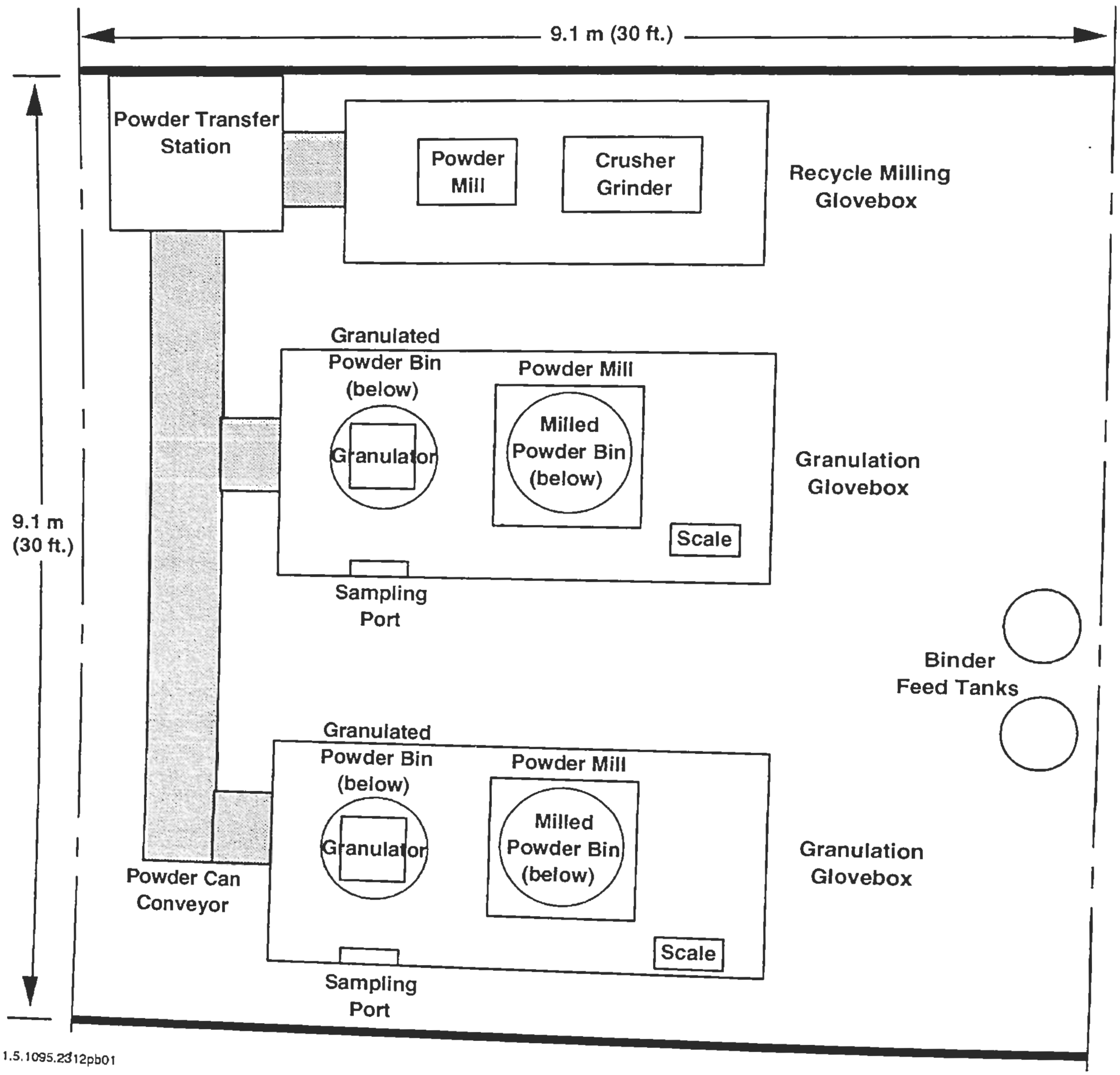

Figure 2-7. Milling and granulation area equipment arrangement.

Equipment, piping and other components can be decontaminated in the equipment decontamination area.

A scrap treatment area has been provided to allow treatment of off-specification process materials, contaminated equipment, and components to recover plutonium and recycle it back into the process. The cell will be furnished with equipment suitable for size reduction and process feed makeup of off-specification ceramic material from the pressing, sintering, and coating operations. Also, decontamination and leaching

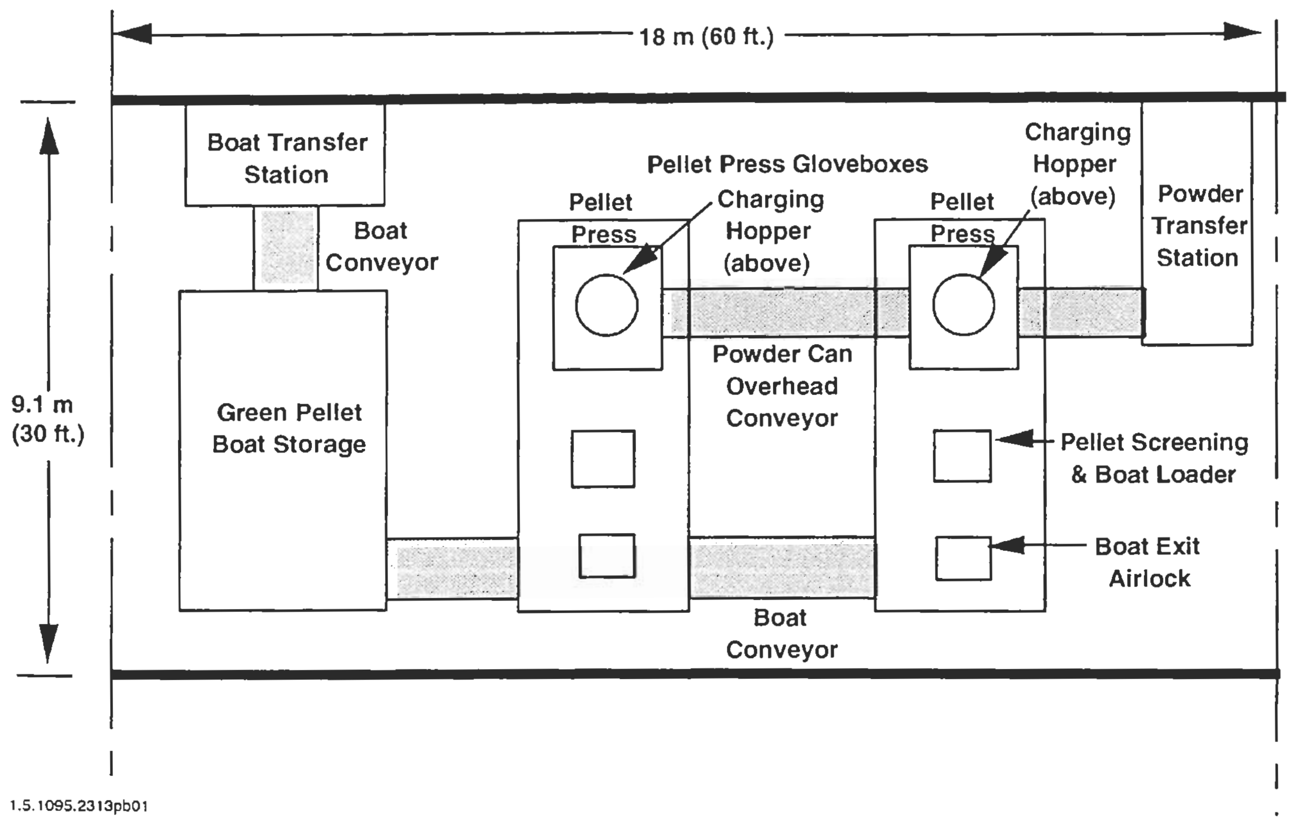

Figure 2-8. Pelletizing area equipment arrangement.

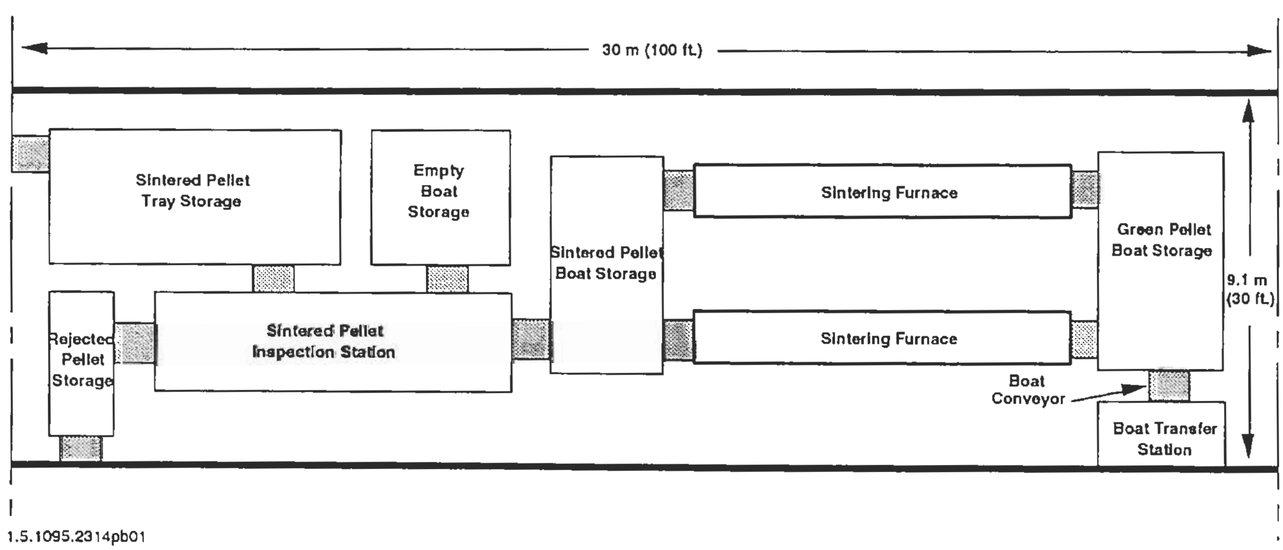

Figure 2-9. Pellet sintering area equipment arrangement.

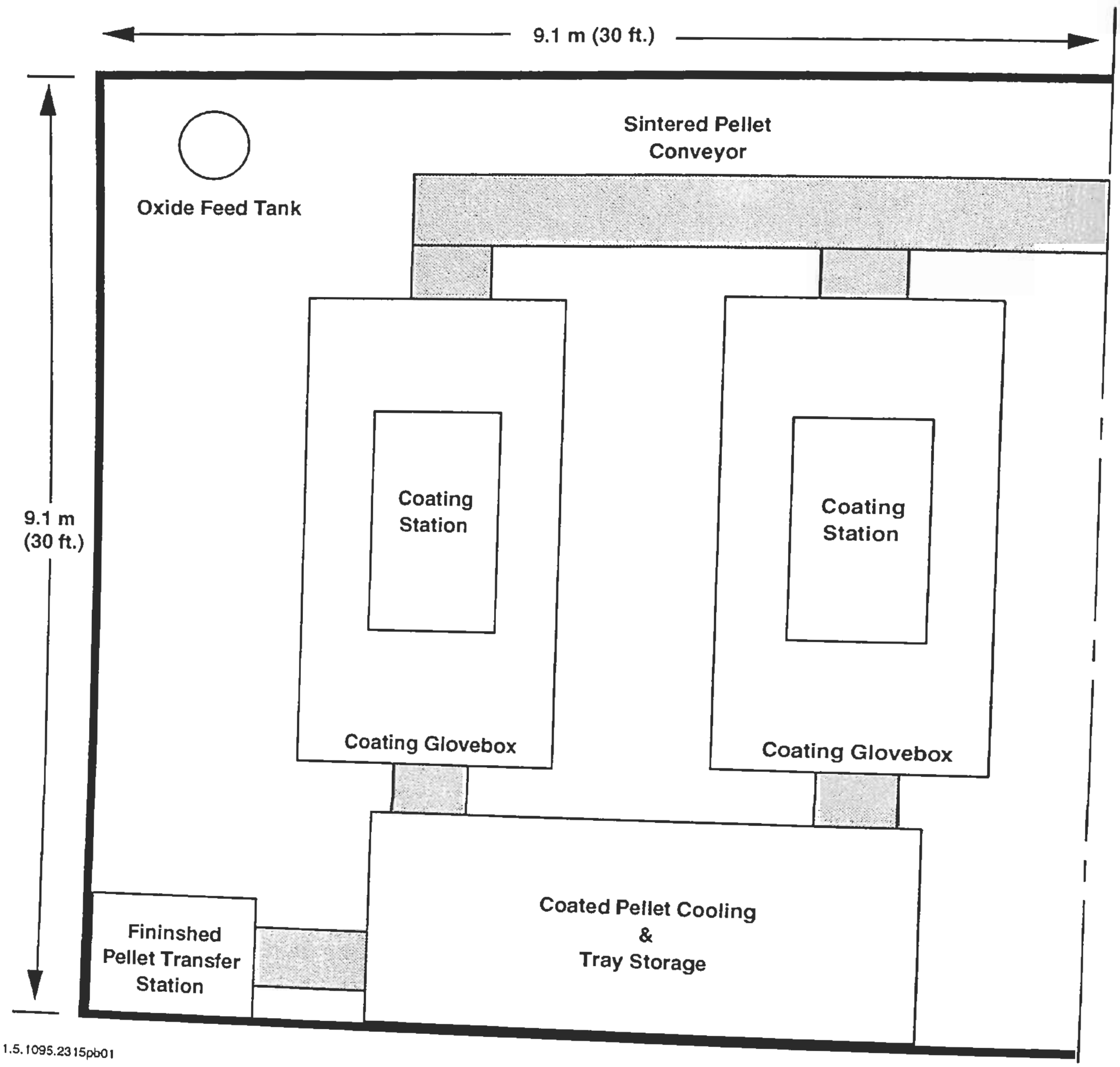

Figure 2-10. Pellet coating area equipment arrangement.

equipment will be provided to allow recovery of plutonium from process equipment and return the solutions to the process. Other off-specification materials from the process will be recycled to the appropriate equipment in the plutonium process.

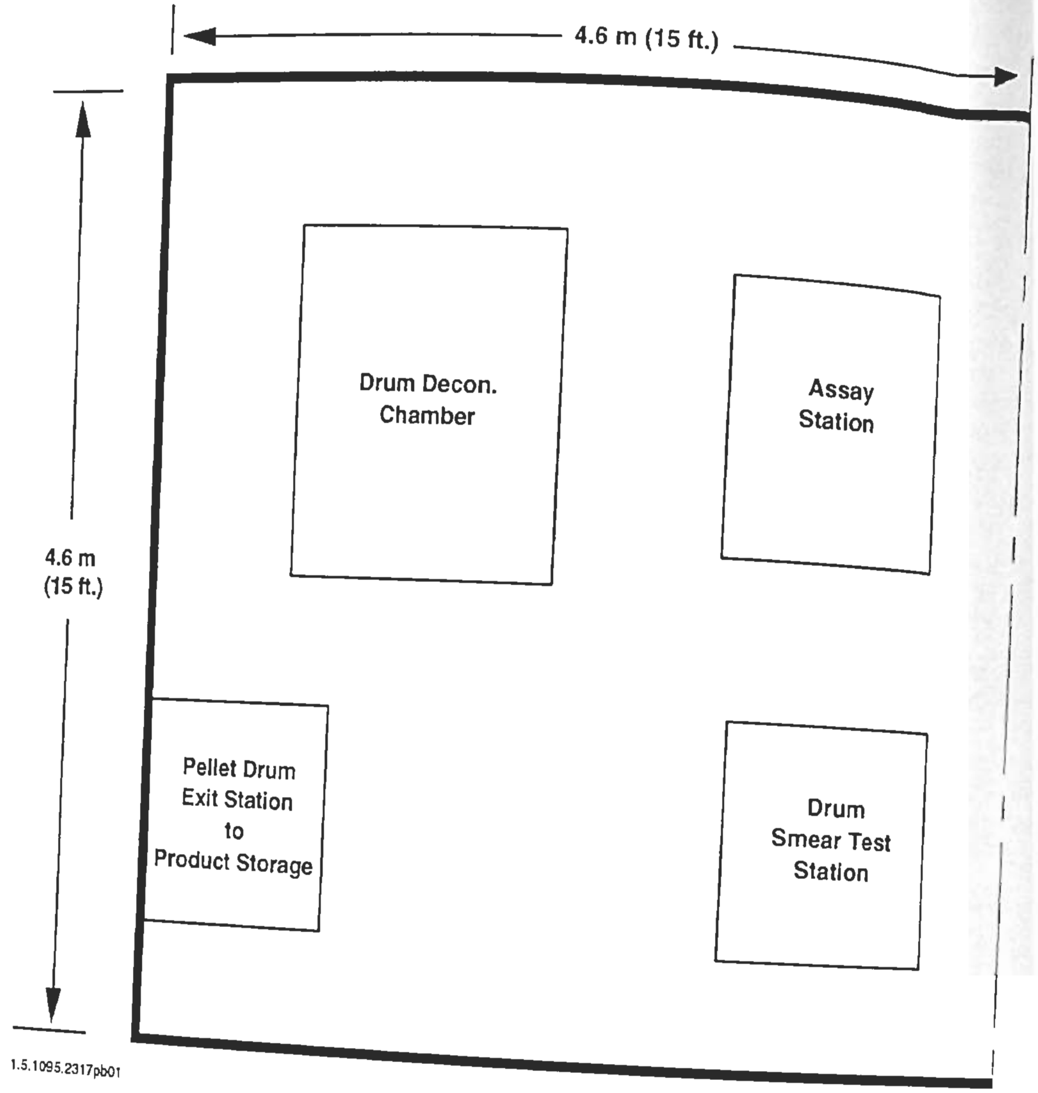

Figure 2-12. Pellet drum decontamination area equipment arrangement.

An analytical laboratory will be provided to allow analysis of process materials to assure product specifications and plutonium MC&A goals are met. The laboratory w... be provided with mass spectrographs, calorimeters, nondestructive assay equipment, radiological chemical analytical equipment, etc., as necessary to provide a fully self-sufficient on-site laboratory to meet the needs of the facility.

2.1.3.2 Product Storage and Radiologically Controlled Maintenance Buildings. Storage of product drums is provided in a the Product Storage Building equipped wit... drum storage racks, a remotely operated forklift (or stacker-retriever), and a computerized tamper-indicating system to monitor and permit only authorized drum movement. Initial on-site storage capacity is one year with space provided for expansion of this capacity to the full 10 years of operation.

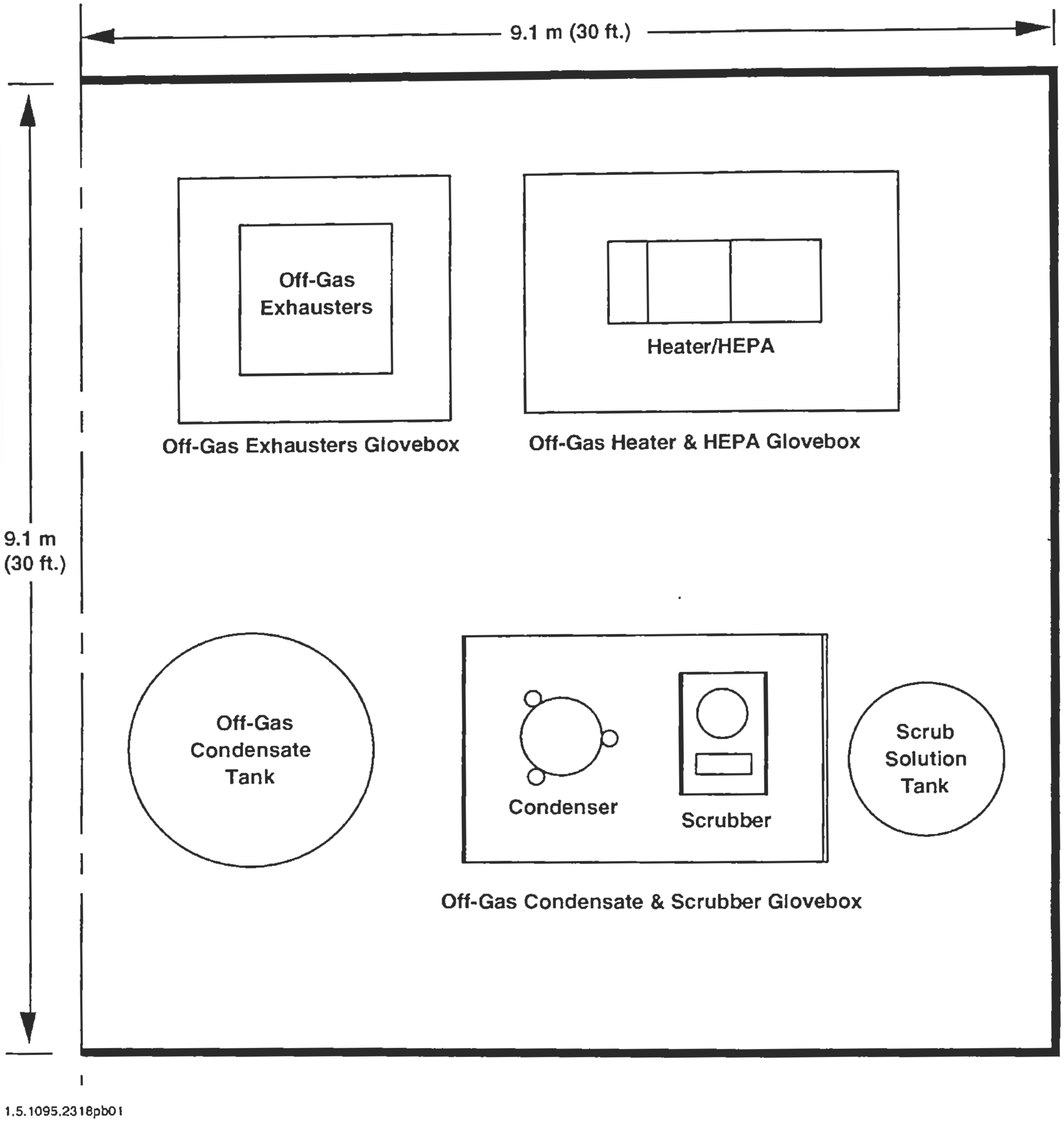

Figure 2-13. Off-gas treatment area equipment arrangement.

The Radiologically Controlled Maintenance Building is an approximately 15,000 ft^2 (1394 m^2) building located inside the inner security fence adjacent to the Plutonium Processing Building. It provides facilities for the maintenance and repair of process equipment from the Plutonium Processing Facility, the Radwaste Management Building or the Product Storage Building. Shop areas are provided for equipment receiving and decontamination, equipment disassembly and repair, machining, electrical and controls repair, and equipment testing. An area is also provided for entry control to the facility, personnel change rooms, and a health protection room. Equipment is decontaminated prior to transfer to the Radiologically Controlled Maintenance Shop. Failed process equipment and other low-level waste materials generated in shop operations will be transferred to the adjacent Radwaste Management Building to be packaged for shipment offsite.

2.1.3.3 Radwaste Management Facilities. Waste management facilities to handle the radwastes generated by facility operations are located in the Radwaste Management Building (See Figure 2-14) immediately adjacent to the Plutonium Processing Building.

Radwaste treatment systems housed in this area include the following:

- **Process liquid radwaste.** The process liquid radwaste treatment facilities include the recycle waste evaporator, nitric acid recovery system, and the LLW/TRU radwaste solidification systems. Since these systems will handle relatively low-activity waste streams, they will generally be located in controlled-access processing rooms equipped with room ventilation confinement zoning appropriate to the expected levels of contamination within the room.

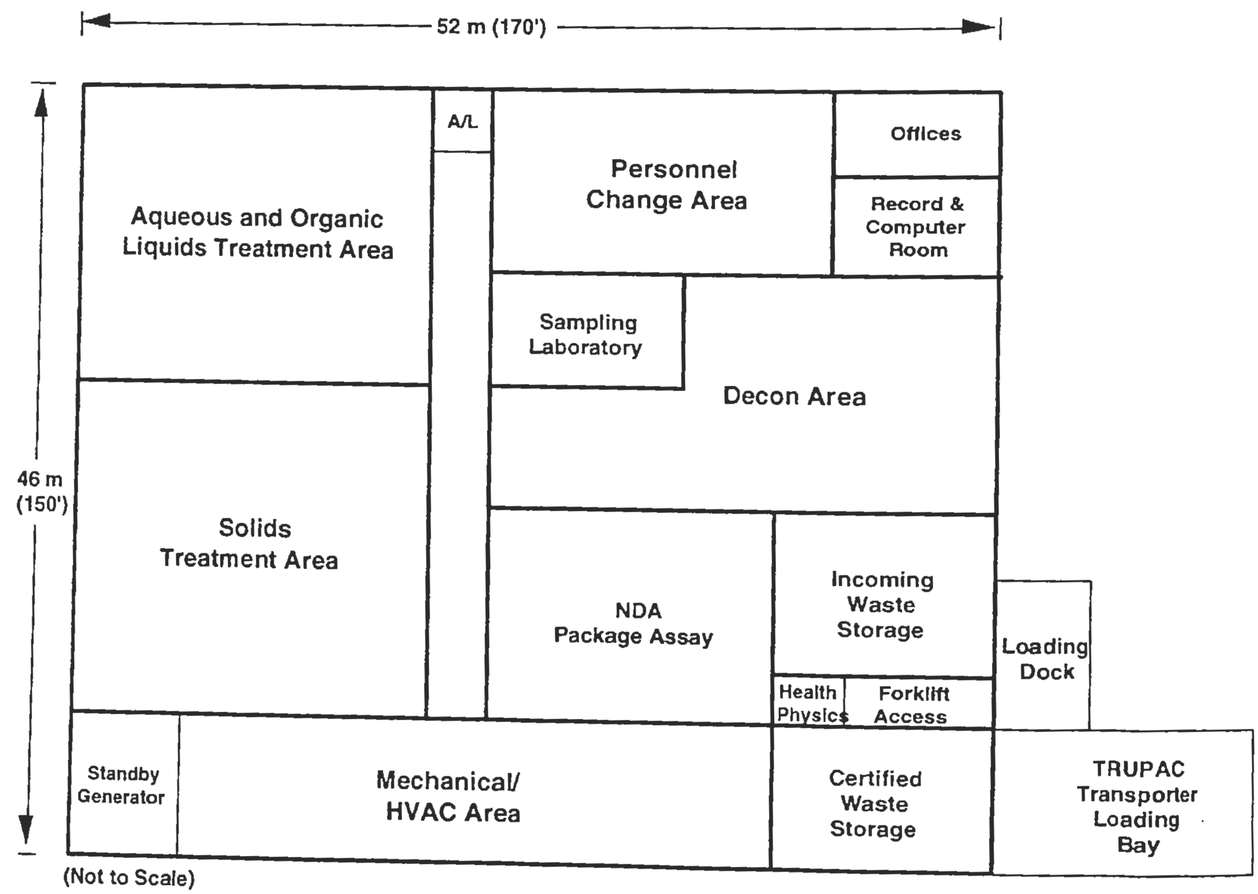

Figure 2-14. Waste handling facility layout.

Mixed waste will be segregated from other waste forms and stored for shipment to offsite treatment facilities.

- **Process solid radwaste.** Process solid radwaste treatment systems will also be housed in the Radwaste Management Building.

Solid waste generated from the glovebox operations will generally be handled and processed in glovebox enclosures. Where fume or dust generation is anticipated, (i.e., cementing, volume reduction, etc.) equipment will be installed in glovebox enclosures supplied with local filters, mist eliminators, condensers, etc., as required to minimize the spread of contamination to the glovebox ventilation system. The equipment will be further isolated in processing rooms provided with ventilation zoning appropriate to the levels of contamination expected.

Solid wastes generated within the process will be segregated into low-level, TRU, and mixed waste.

Solid waste assay, segregation, decontamination, and volume reduction facilities will be provided to minimize the volume of waste shipped from the facility. Waste packaging and shipping facilities for both LLW and TRU waste will be provided.

Solid radwaste consisting of process gaseous radwaste equipment components, such as local sintered stainless steel filters, condensers, etc., are generally not expected to be highly contaminated and will normally be designed to be contact handled and processed within glovebox enclosures or bagged out into suitable containers.

- **Gaseous radwaste.** As described in Sec. 4.8, gaseous radwaste will be filtered, condensed, scrubbed, absorbed, etc., as required to meet DOE and other applicable regulatory requirements. Local condensers, mist eliminators, and sintered metal filters with blowback to the process are provided for plutonium oxidation, calcination, pressing, and other operations where particulate generation is expected. HEPA filters are provided at both inlets and outlets of glovebox enclosures handling plutonium. Two stages of HEPA filters are provided in the process off-gas system and a NO_x absorption column and appropriate heaters, knockout drums, etc., as required to assure that releases are below acceptable limits. Chemical removal of NO_x may be required to meet effluent limits. Discharge of building HVAC exhaust air will be through three stages of HEPA filters prior to release.
- **Utility wastewater discharges.** These discharges, including cooling tower and boiler blowdown, cold chemical area liquid effluents and nonradioactive liquid ceramic additive liquid wastes will be treated and discharged in an industrial wastewater treatment plant to assure that wastewater discharges meet applicable environmental standards.

An on-site sanitary treatment plant will treat sanitary wastes generated from CIF operations.

2.1.3.4 Balance of Plant Facilities. In addition to the process facilities descri the sections above, the CIF includes the following facilities and systems (faciliti shown on Site Map Fig. 3-1):

- An approximately 30-m × 76–m (100-ft × 250-ft) metal framed standard construction Shops Building for housing clean maintenance and repair sh
- The Support Utilities Area, located outside the inner security fence, inclu raw water treatment systems, water storage tanks for 95,000 L (25,000 gal) domestic water and 190,000 L (50,000 gal) of service water, 900,000 L (240, gal) of fire water storage, redundant 8000 Lpm (2000-gpm) fire-water pu and a 30-m × 30-m (100-ft × 100-ft) metal framed building to house all equipment. The building also houses the central chilled water cooling and heating boiler systems.
- The cooling tower, a multiple cell, wood construction, induced draft, cros type tower with a capacity of 16,000 Lpm (4000 gpm) to provide cooling f the process and HVAC systems.
- An approximately 1675-m^2 (18,000-ft^2) Administration Building.
- An approximately 2325-m^2 (25,000 -ft^2) Warehouse.
- The Industrial Waste Treatment Facility for the receipt, treatment and disp of noncontaminated chemical, liquid, and solid wastes other than liquid wa disposed of through the sanitary waste system.
- Utility wastewater discharges. These discharges, including cooling tower boiler blowdown, cold chemical area liquid effluents and nonradioactive ceramic additive liquid wastes, will be treated and discharged in this facil assure that wastewater discharges meet applicable environmental standar
- An on-site sanitary treatment plant to treat sanitary wastes generated from operations.
- The Sanitary Waste Treatment Facility with a capacity of 38,000 Lpd (10,000 gpd).
- The perimeter security system, including a guardhouse at each entry point site or to the inner security area. All facilities where radioactive materials a handled and facilities necessary for the safe operation of the process faciliti surrounded by double security fences within the outer site perimeter fence.
- Compressed air systems. These include plant air, instrument air, and breat air. A single set of two redundant 14,160 Lpm (500 cfm) reciprocating air compressors provide compressed air to both systems. The plant air system provided through a receiver set at 700 kPa g (100 psig). Instrument air is dr desiccant type air dryers to a dew point of –40°C (–40°F) and is supplied to piping distribution system from a separate air receiver set at 700 kPa g (100 psig). The breathing air system provides air to breathing air manifolds located throughout the Plutonium Processing Building.
- Cooling of process equipment, provided by a closed-loop cooling water sys that is cooled with cooling-tower water in plate-type heat exchangers. The c cooling loop isolates any radioactive contamination should a leak occur in a piece of process equipment. The loop is continuously monitored for

contamination, and provision is made to use a deionization column to clean the closed loop should any contamination occur.

- Building heating, ventilating and air conditioning (HVAC). These systems use a central chilled water system for building cooling. Three 50% capacity, 1.9-MW (550-ton) centrifugal water chillers, and three 2300 Lpm (600 gpm) circulating pumps are provided.
- Cooling water systems. All cooling water systems are connected to the cooling tower system described above.
- A central steam plant. This is provided in the Support Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces 20,000 kg/hr (45,000 lb/hr) of 350 kPa g (50 psig) steam that is distributed around the site by outside overhead piping.
- Electric power. The site receives electric power at 13.8 kV from the utility grid system and distributes it onsite at the required voltages. The Electrical Substation has a capacity of 5000 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 700 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety-related systems during a power outage. Uninterruptible power supply (UPS) systems ensure continued operation of safety-related equipment and systems during a power outage.

2.2 Design Safety

Special design considerations are required to ensure that (1) radioactive solutions are properly contained during processing operations, (2) ventilation air from process operations is properly filtered, (3) operating personnel are adequately protected from radiation and airborne contamination, and (4) process streams are properly treated and handled for release or disposal. The total confinement system consists of one or more individual confinement barriers and systems that restrict releases of radioactive or hazardous materials to the environment or into areas normally occupied by plant personnel. Engineered safety features are designed and used to prevent radioactive material and hazardous chemical releases. Development of the CIF for plutonium immobilization will require incorporation of these requirements through the following systems:

- **Confinement systems and barriers**—Two types of confinement barriers are used in the facility. "Total barriers" are those fabricated of material that prevent penetration of confined material without regard to the physical or chemical nature of the material. "Selective barriers" are mass transfer devices or filters to remove selected chemicals or particulate matter from a process or ventilation stream while allowing the bulk of the stream to pass. Barriers are designed to withstand loadings due to pressure differentials imposed by the process off-gas, building ventilation systems, as well as pressure differentials caused by natural phenomena. Confinement systems are constructed of nonflammable materials except where special functional requirements exist. Construction materia resistant to the corrosive effect of process and decontamination fluids at th temperatures and pressures encountered.

- **Ventilation and Off-gas**—The building ventilation and process off-gas sy control the spread of airborne contamination through openings in barriers regulating the path of air or gas flow between these zones, gas leakage is directed from zones.

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the CIF and are treated as design basis events:

- Earthquake
- Tornado
- Flooding.

Other natural phenomena such as volcanic activity or tidal waves are not consid likely to be credible for the CIF site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures and components (SSCs) must withstand the consequences of all of these natural phenom

2.2.1.1 Earthquake. The design basis earthquake (DBE) for the CIF will be chose accordance with UCRL-15910 (DOE-STD-1020-92). All safety class systems, structure and components (SSCs) are designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3005-YR. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

2.2.1.2 Tornadoes. The design basis tornado (DBT) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). All processing and storage buildi structures housing plutonium, the Zone 1 exhaust system, and site effluent monitori systems are designed to withstand the DBT and DBT-generated tornado missiles. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3005-YR. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

2.2.1.3 Floods. Flooding is of particular concern at plutonium processing facilitie such as the CIF because of the potential for nuclear criticality accidents. The CIF facil will be designed to preclude flooding of areas in the CIF that contain plutonium. The design basis flood (DBF) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). All processing and storage building structures housing plutoniu the Zone 1 exhaust stack, site effluent monitoring systems and product storage vault racks in the Product Storage Building are designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3005-YR. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

2.2.2 Fire Protection

The requirements for fire protection in the CIF are contained in DOE 6430.1A, *General Design Criteria;* DOE 5480.4, *Environmental, Safety and Health Protection Standards;* and DOE 5480.7, *Fire Protection.*

The CIF fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480.7. This criterion requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis shall be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire-rated barriers to limit the maximum possible fire loss and to protect life by providing fire-rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building-exterior fire protection is provided. Two redundant 912,000-L (240,000-gal) fire water storage tanks are provided. Two redundant 7,600 Lpm (2,000-gpm) fire water pumps, one electric-motor-driven and one diesel-engine-driven are provided.
- Since the Zone 1 HVAC exhaust system is a Safety Class system, a Safety Class deluge fire water system is provided to protect the final HEPA filters in the event of a fire.

2.2.3 Safety Class Instrumentation and Control

The following control, electrical and monitoring systems, and equipment necessary for criticality safety, and for the confinement of plutonium after a design basis accident will be designated safety class items:

- The emergency electric power system including the diesel generators necessary to ensure the operation of the Zone 1 exhaust fans.
- The criticality alarm system.
- Control system components identified as necessary for ensuring criticality safety in the handling and mixing of plutonium with the ceramic material constituents or for maintaining the integrity of the Zone 1 confinement system will be identified as safety class items.

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ANSI/ANS-8.1 allows use of neutron absorbers for criticality control. Extreme care is required with solutions of absorbers because of the difficulty of exercising this type of control.

ANSI/ANS-8.1 requires that subcritical limits shall be established with adequate allowances for uncertainties. Methods of calculation used to determine k_{eff} for a system or used to establish subcritical limits shall be validated. The bias in the results shall be determined. The calculation shall incorporate sufficient margin to insure subcriticality. The margin of subcriticality shall include allowances for the uncertainty in the bias.

No criticality analysis of the CIF has been done. A discussion of the criticality issues for each stage of the ceramic immobilization process (including emplacement in a deep borehole) is given below. These issues are assessed based on engineering judgment and extrapolation from similar processes. These assessments produce criticality safety assumptions used to size the facility. They also provide an indication that it will be possible to produce facility, process, material handling, and waste form designs that satisfy all applicable criticality safety requirements. However, all of these criticality safety assumptions and assessments require confirmation that can be provided only by a detailed criticality safety evaluation.

2.2.4.2 Plutonium Storage. The configuration of the CIF Pu storage vault contains two planar arrays of pallets of approximately 800 storage locations. The pallets in each array are separated by 51 cm (20 in.) horizontally and by 61 cm (24 in.) vertically. Each storage position was assumed to contain a cylindrical button of pure ^{239}Pu metal weighing 5 kg (11 lb). This design provides an adequate margin of subcriticality even with double batching of four central units, but it does not allow for flooding of the vault. The CIF requires storage for about 2700 kg (5,940 lb) of plutonium and PuO_2. To meet this requirement, the design will need to address internal sources of water such as fire suppression systems as well as natural phenomena.

2.2.4.3 Plutonium Oxidation. The metal oxidation process at CIF is similar to the pyrochemical processes proposed for the Special Isotope Separation (SIS) Plutonium Processing Facility. This facility was part of the SIS plant designed to provide laser separation of plutonium isotopes. The CIF processes 7 kg (15.5 lb) of metal per day. The SIS preliminary design allowed plutonium metal batches as large as 3 kg (6.6 lb) (in the form of 11.4-cm (4.5-in.)-diam button with nominal reflection). Using the same batch size in the CIF, it is reasonable to assume that criticality considerations will not constrain the plutonium metal oxidation process at the CIF. Precise criticality controls and batch sizes will be specified as process requirements and geometries are established.

2.2.4.4 Plutonium Oxide Dissolution. The CIF dissolves PuO_2 in a Mediated Electrochemical Oxidation (MEO) dissolver. Approximately 25 kg (55 lb) of plutonium are processed batchwise per day. The product of this process is about 126 Lpd (33.3 gal/d) of 200 g Pu/L (26 oz/gal) solution of plutonyl nitrate in 4 *M* (molar) nitric acid and 0.1 *M* silver nitrate. The solution is stored in tanks. These tanks are 10.2 cm (4 in.) in diameter × 244 cm (96 in.) high.

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2.2.4.8 Pressing, Sintering, and Coating. The ceramic feed hopper fills individual presses. The press creates the initial 2.4-cm (1 in.)-diam by 2.5-cm (1 in)-high cylindrical ceramic pellets. Each pellet contains approximately 31 g (1.1 oz) of material. The composition is the same as the composition of the ceramic feed (see Sec. 2.2.4.6). It is assumed that the pellet composition including plutonium and gadolinium loading is critically safe in all geometries provided that water intrusion or flooding of the process equipment is precluded.

2.2.4.9 Drum Filling, Decontamination, and Storage. Each 208-L (55-gal) drum container contains 500 kg (1100 lb) of ceramic pellets. This means that each drum contains approximately 5 kg (11 lb) of plutonium. Again, it is assumed that this composition is critically safe in all configurations due to the low mass of plutonium and the presence of gadolinium inside the ceramic provided that water intrusion or flooding of the storage vault can be precluded.

2.2.4.10 Criticality Safety after Emplacement. It is necessary to ensure long term criticality safety after the pellets have been emplaced in the deep borehole. At this point, it is assumed that the ceramic pellets are mixed with grout in the borehole in a 60%/40% volumetric ratio of ceramic pellets to cement. The borehole is assumed to be surrounded by 1 m (3.28 ft) of granite. Given these conditions, preliminary calculations indicate that the assumed 1% plutonium loading is sufficiently conservative to ensure long-term criticality safety.

2.2.4.11 Criticality Alarms. In cases where the mass of ^{239}Pu exceeds 450 g (15.9 oz) and the frequency of a nuclear criticality accident is greater than 10^{-6} per year, DOE Order 5480.24 requires that a criticality alarm system (CAS) meeting the requirements of ANSI/ANS-8.3 shall be provided to cover occupied areas in which the expected dose exceeds 0.12 Gy (12 rads) in free air. At the CIF, this condition applies to the glovebox areas and adjacent occupied areas.

In cases where the mass of ^{239}Pu exceeds 450 g (15.9 oz) and the frequency of a nuclear criticality accident is greater than 10^{-6} per year, but the expected dose in occupied areas does not exceed 0.12 Gy (12 rads) in free air, DOE Order 5480.24 requires that a criticality detection system shall be provided. This condition does not exist at the CIF.

In cases where the mass of ^{239}Pu exceeds 450 g (15.9 oz) and the frequency of a nuclear criticality accident is less than 10^{-6} per year, DOE Order 5480.24 does not require a CAS. At the CIF, this condition applies to the plutonium storage vault, to the drum storage vault, and to other areas that are not affected by the criticality accidents postulated for the glovebox lines.

2.2.5 Ventilation and Confinement

Confinement barriers and systems are selected in accordance with proven practices to perform the following functions:

- To limit the airborne spread of radioactive materials, the facility will be separated by confinement barriers into zones of various levels of contami
- The building ventilation and process offgas systems will control the sprea airborne contamination through openings in barriers. By regulating the p air or gas flow between these zones, gas leakage will be directed from zon low potential to zones of higher potential for contamination.
- The capacity of the ventilation system (in relation to confinement system requirements) to ensure that the velocity of gas flowing through any barri opening will be sufficient to prevent the backflow of airborne contaminant through such openings; air flow patterns must not be disrupted by winds, movement of equipment or personnel, or temporary opening of passagew through confinement barriers.
- Cooling water that could become contaminated by leakage of process solu through defects in heat exchanger components will be contained in closed secondary circuits with independent primary heat transfer circuits. These circuits will be monitored for radioactivity.
- Steam with potential for contamination will be contained in a closed loop system. The condensate will be monitored and reused as feed to the proce steam generator; contaminated condensate will be purged and flushed to t drain waste collection tank.
- Penetrations through confinement barriers that could provide potential pathways for release of radioactivity to the environment will have means f isolating the penetration such as airlocks at entrances to zones. Penetratio wiring, piping, and instrumentation will be sealed to prevent backflow of radioactivity to normally occupied areas.
- Two types of confinement barriers will be used in the facility. "Total barri are those fabricated of material that prevent penetration of confined materi without regard to the physical or chemical nature. "Selective barriers" are transfer devices or filters to remove selected chemicals or particulate matte from a process or ventilation stream while allowing the bulk of the stream t pass.
- Barriers will be designed to withstand loadings due to pressure differentials imposed by the process off-gas, building ventilation systems, and natural phenomena.
- To monitor the integrity of total confinement barriers for gases, differential pressure monitors will be provided to indicate pressure differentials betwee confinement zones. To monitor total confinement barrier liquids, leakage w detected by a liquid high-level alarm in a specially designated leakage colle sump. Leakage can also be measured by analytical devices that sound an al for contamination intrusion into normally uncontaminated tanks or process streams. Continuous air monitors will be used to indicate loss of function o barrier, which could release radioactivity from a designated confinement are into an occupied area.
- Confinement systems will be constructed of nonflammable materials except where special functional requirements prohibit.

- Construction materials will be resistant to the corrosive effect of process and decontamination fluids at the temperatures and pressures encountered.
- Backup power will be provided to those confinement barriers and systems where loss of confinement could result from loss of primary electrical service.
- Standby fans will be provided to function for essential fans that may become inoperative.
- The confinement barriers will be designed to maintain functional integrity under the hypothesized major and DBAs where required.
- The confinement systems and components will be designed to allow maintenance to the system during operation.

2.3 Safeguards and Security

Protection of nuclear material involves both material control and accountability and physical security activities. Accountable nuclear materials include SNMs, source materials, and other nuclear material identified in DOE Order 5633.3A, *Control and Accountability of Nuclear Materials*. Integrated safeguards and security systems will effectively deter, prevent, detect, and respond to theft and diversion of nuclear material. In support of the U.S. nonproliferation policy, the DOE will make plutonium, that is surplus to the Nation's defense requirements, available for verification and inspection by the IAEA.

The plutonium raw feed and ceramic product will be classified as special nuclear material; and according to DOE Order 5633.3A provisions for safeguards and security and material control and accountability will be implemented to protect, control, and account for the materials at all times. Per Figure I-2 of DOE Order 5633.3A the special nuclear material category dictates the level of security necessary to ensure appropriate protection of the material. From Figure I-2 data, the raw plutonium feed and oxide will qualify as nuclear material safeguards Category I or II with a B or C Attractiveness Level depending on material form and quantity. The immobilized ceramic product will qualify as Category II, Attractiveness Level D.

Special Nuclear Material classification is affected by the quantity of fissile material present in kg and the Attractiveness Level. The DOE defines the attractiveness level of nuclear material through a categorization of types and compositions that reflects the relative ease of processing and handling required to convert that material to a nuclear explosive device. Table 2.2 comes from the DOE Order for *Control and Accountability of Materials* (5632.33B) dated 9-7-94.

The level of protection accorded to an attractiveness level is dependent on the quantity or concentration of the material. Each category of protection has its own requirements ranging from the highest level of protection, Category I, for assembled weapons, to Category IV for irradiated forms and less than 3 kg (6.6 lb) of low-grade material. Protection of the material is accomplished through a graded system of deterrence, detection, delay, and response as well as material control and accountability.

Layers of protection may then be applied to protect material of greatest attractiveness within the innermost layer and with the highest controls. Material of lesser attractiveness does not require as many layers of protection and fewer controls.

Table 2-2. (DOE) Nuclear Material Attractiveness and Safeguards Categories for Plutonium.

	Attractiveness level	Pu/U-233 Category			
		I	II	III	IV*
WEAPONS Assembled weapons and test devices	A	All quantities	N/A	N/A	N/A
PURE PRODUCTS Pits, major components, buttons, ingots, recastable metal, directly convertible materials	B	≥ 2 kg (≥4.4 lb)	≥ 0.4 <2 kg (≥0.9<4 lb)	≥0.2 <0.4 kg (≥0.4<0.9 lb)	<0.2 kg (<0.4 lb)
HIGH-GRADE MATERIAL Carbides, oxides, solutions (≥25 g/l) nitrates, etc., fuel, elements and assemblies, alloys and mixtures, UF_4 or UF_6 (≥50% U-235)	C	≥ 6 kg (≥13 lb)	≥2 <6 kg (≥4.4<13 lb)	≥0.4 <2 kg (≥0.9<4.4 lb)	<0.4 kg (<0.9 lb)
LOW-GRADE MATERIAL Solutions (1–25 g/l), process residues requiring extensive reprocessing, moderately irradiated material, Pu-238 (except waste), UF_4 or UF_6 (≥20% <50%U-235)	D	N/A	≥16 kg (≥35 lb)	≥3 <16 kg (≥6.6<35 lb)	<3 kg (<6.6 lb)
ALL OTHER MATERIALS Highly irradiated forms, solutions (≥1 g/l), uranium containing <20% U-235 (any form or quantity)	E	N/A	N/A	N/A	Reportable quantities

*The lower limit for category IV is equal to reportable limits in this Order.

A "B" Attractiveness Level (the raw plutonium feed) represents material in the form of pits, major components, buttons, ingots, recastable metal, or directly convertible materials and is considered a "pure product" with the second highest security risk.

A "C" Attractiveness Level (the pretreated plutonium oxide) represents "high-grade" fissile materials in the form of carbides, oxides, solutions, nitrates, etc., fuel elements and assemblies, alloys and mixtures, uranium hexafluoride or uranium fluoride (≥50% enriched). For Special Nuclear Material Category I, Attractiveness Level "B," ≥2 kg (4.4 lb) of Pu/^{233}U, or ≥5 kg (11 lb) of ^{235}U will be needed to qualify.

For Category I, Attractiveness Level C, ≥ 6 kg (13 lb) of Pu/^{233}U or ≥20 kg (44 lb) of ^{235}U will be necessary.

The highest category, Attractiveness Level "D," represents material in Category II and is based on quantities ≥16 kg (35 lb) of Pu/^{233}U or ≥50 kg (110 lb) of ^{235}U.

Because of the high radiation levels of spent fuel and other Attractiveness Level "E" materials, theft or sabotage potential should be greatly reduced; and therefore, Categories I, II, or III rankings are not necessary for Level E material.

Although the CIF may have several categories of SNM onsite at any given time, the most conservative classification for design and overall facility safeguards and security will be Category I, Attractiveness Level B while specific areas of the facility could be designed to other categories or attractiveness levels as noted in the preceding paragraphs. Consequently, the facility requirements for the protection of safeguards and security interests originate from appropriate Special Nuclear Material Category I criteria outlined in DOE Order 5632.1C, *Protection and Control of Safeguards and Security Interests*, the DOE M 5632.1C-1, *Manual for Protection and Control of Safeguards and Security Interests*, and other applicable DOE Orders. For the CIF, general safeguards and security requirements are described below.

2.3.1 Requirements for the Physical Protection of Category I Special Nuclear Material and Other Vital Equipment

Category I Special Nuclear Material (SNM) will be used or processed within material access areas (MAA) requiring a material surveillance program to detect unauthorized material flows and transfers. Locations within a MAA that contain unattended Category I SNM in use or process will be equipped with intrusion detection systems or other effective means of detection. A MAA will be contained within a protected area and will have defined physical barriers constructed to provide sufficient delay time to control, impede, or deter unauthorized access. Material access area barriers will direct the flow of personnel and vehicles through designated portals and will include entry and exit inspections to provide reasonable assurance against the unauthorized introduction of prohibited items or the removal of SNM. Strategies and planning for the physical protection of SNM and vital equipment will be developed and will incorporate applicable DOE Order requirements for the protection of safeguards and security interests. Site safeguards and security plans will define applicable threats and measures to protect vital equipment from hostile actions and vulnerability assessment (VA) performed as required by DOE Order 5630.13A, *Master Safeguards and Security Agreements*.

2.3.1.1 Storage. Special nuclear material will be stored within a Material Access Area. Category I SNM characterized as Attractiveness Level "B" will be stored in a vault or provided enhanced protection that exceeds vault-type room storage (e.g., protective force response and/or activated barriers). For Attractiveness Level "C," Special Nuclear Material will be stored in a vault or vault-type room. Vaults and vault-type rooms will conform with the vault construction requirements described in D Order 6430.1A, *General Design Criteria*.

Third Party Inspection (IAEA)

A suite of rooms will be provided adjacent to the vault entrance for third-party inspection (e.g., IAEA). The area includes the following features:

- A separate area for processing records, studying reports, calibrating and repairing instruments, and loading and unloading cameras, etc.
- A camera located at the vault entry point for recording the entry and remo[illegible] containers from the vault and identifying the containers by bar code numb[illegible] etc. The proximity of the material entering the vault will trigger the camera.
- Power to the equipment will be separated from the main facility, isolated f[illegible] surges, and should be uninterruptible.
- Power (including an UPS) and other utilities will be provided, but equipm[illegible] will be provided by the inspection agency.

2.3.1.2 In-Transit. Protection requirements for quantities of Special Nuclear Material in transit include

- Domestic offsite shipments of Category I Special Nuclear Material are gove[illegible] by the transportation safeguards system under the auspices of the Albuque[illegible] Operations Office.
- Packages or containers containing special nuclear material will be sealed w[illegible] tamper-indicating devices.
- Protection measures for movement of material between Protected Areas on[illegible] and between protected areas and staging areas will be under direct surveil[illegible] by the security officers to protect against threats established by site policy.

2.3.1.3 Intrusion Detection and Lighting. Intrusion detection systems will be installed to provide reasonable assurance that breaches of security boundaries are detected and that intrusion information is provided to security personnel. Intrusio[illegible] detection systems will also be provided for vaults and vault-type rooms. Twenty-f[illegible] hour protective lighting will be provided to permit detection and assessment of adversaries and to reveal unauthorized persons.

2.3.1.4 Access Control and Entry/Exit Inspections. Access is restricted to perso[illegible] with a need to enter the Protected Area and Material Access Area. At routine exits [illegible] Material Access Areas, metal detectors, Special Nuclear Material monitors, explosiv[illegible] detectors, and x-ray machines will be used to conduct inspections for prohibited arti[illegible] and government property. Data and equipment access controls are applied on a gr[illegible] basis. In addition to DOE Order 5633.3A, access controls may be governed by the D[illegible] requirements for the control of classified documents and for computer security.

2.3.1.5 Barriers and Locks. Physical barriers such as fences, walls, doors, or activated barriers will be used to delay unauthorized access to security areas. Physi[illegible] barriers will serve as the physical demarcation of the security area. When used for protection purposes, fencing will meet the construction requirements of DOE Order 6430.1A. Locks used in the protection of classified matter and Categories I and II SNM (e.g., security containers, safes, vaults) will meet Federal Specification FF-L-2740, Locks, Combination, or Military Specification MIL-P-43607, Padlock, Key Operated, High Security, Shrouded Shackle.

2.3.1.6 Vaults and Vault-Type Rooms. Most Category I materials are stored in vaults or vault-type rooms. These rooms are equipped with approved intrusion alarm systems, and two authorized Q-cleared employees will be present to access Category I storage locations. Security devices assure the presence of two people. Most facilities use two combination locks. Each lock has a unique combination and access list. Nobody assigned to the vault has the combination to both locks. Facility personnel maintain lists of employees who may access storage areas, and security forces receive a copy of these lists. Security inspectors stationed in the central alarm station verify the presence of two authorized persons before granting access. Facility personnel update the access lists quarterly, and facility-specific procedures contain directions for accessing vaults and vault-type rooms. The minimum standards required for construction of Special Nuclear Material storage vaults other than modular vaults are detailed in DOE Order 6430.1A, *General Design Criteria*, and apply to new construction, reconstruction, alterations, modifications, and repairs.

2.3.1.7 Communications. Communications equipment will be provided to aid in reliable information exchange between security personnel. The equipment must have two different technologies of voice communications to link the facility with each fixed post, central alarm station, secondary alarm station (SAS), and protected personnel dispatch point. Backup or alternative communications capabilities will be readily available upon failure of the primary communications system.

2.3.1.8 Acceptance and Validation Testing. Acceptance and validation tests are performed to confirm the ability of an implemented and operating system or element to meet an established protection requirement. Two levels of tests will be addressed in an overall safeguards and security acceptance and validation test program.

2.3.1.9 Maintenance. Security-related subsystems and components will be maintained in operable condition per the DOE 4330.4B, *Maintenance Management Program*.

2.3.1.10 Posting Notices. Selection of facilities, installations, and real property for posting of signs will be based upon need for protecting against espionage, sabotage, or depredation of safeguards and security interests.

2.3.1.11 Security Badges. Security badges shall indicate individuals access limitations and/or approvals for the purpose of controlling entrance and exit to security areas and facilities and for safeguards and security-related identification purposes.

3.0 Site Map and Land Use Requirements

3.1 Site Map

The CIF Site Map is shown in Fig. 3-1. The site is surrounded by multiple fences for security. The main processing facilities are located within a double security fence and include the Plutonium Processing Facility, the adjacent Radwaste Management Building, Radiologically Controlled Maintenance Shop, and Product Storage Building. Support facilities include the Administration Building, Warehouse, Shops Building, the Support Utilities Building, the Cooling Tower, and the Electrical Substation. Industrial Waste Treatment Building and the Sanitary Waste Treatment Facility are located outside the security area, but within the overall Site Perimeter Fence.

Access to the site is controlled at guardhouses located at both the perimeter fence and at the security fence surrounding the process area. A ventilation exhaust stack discharges process and ventilation air from the Plutonium Processing Building, the Radwaste Management Building, the Product Storage Building, and the Radiologically Controlled Maintenance Shop. Other sources of airborne emissions from the site are the boiler stack at the Support Utilities Building and HVAC exhaust outlets from the non-process support buildings outside the security fence. All liquid effluents from the site are from either the Industrial Waste Treatment Facility or from the Sanitary Waste Treatment Facility.

3.2 Land Area Requirements during Operation

The overall site occupies approximately 18.2 hectares (45 acres) during operation.

3.3 Land Area Requirements during Construction

Land area requirements during construction (as shown in Fig. 3-2) are approximately 28.3 hectares (70 acres), which will include the necessary area for construction activities, such as

- Construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing on-site engineering support, construction supervision, and management personnel.

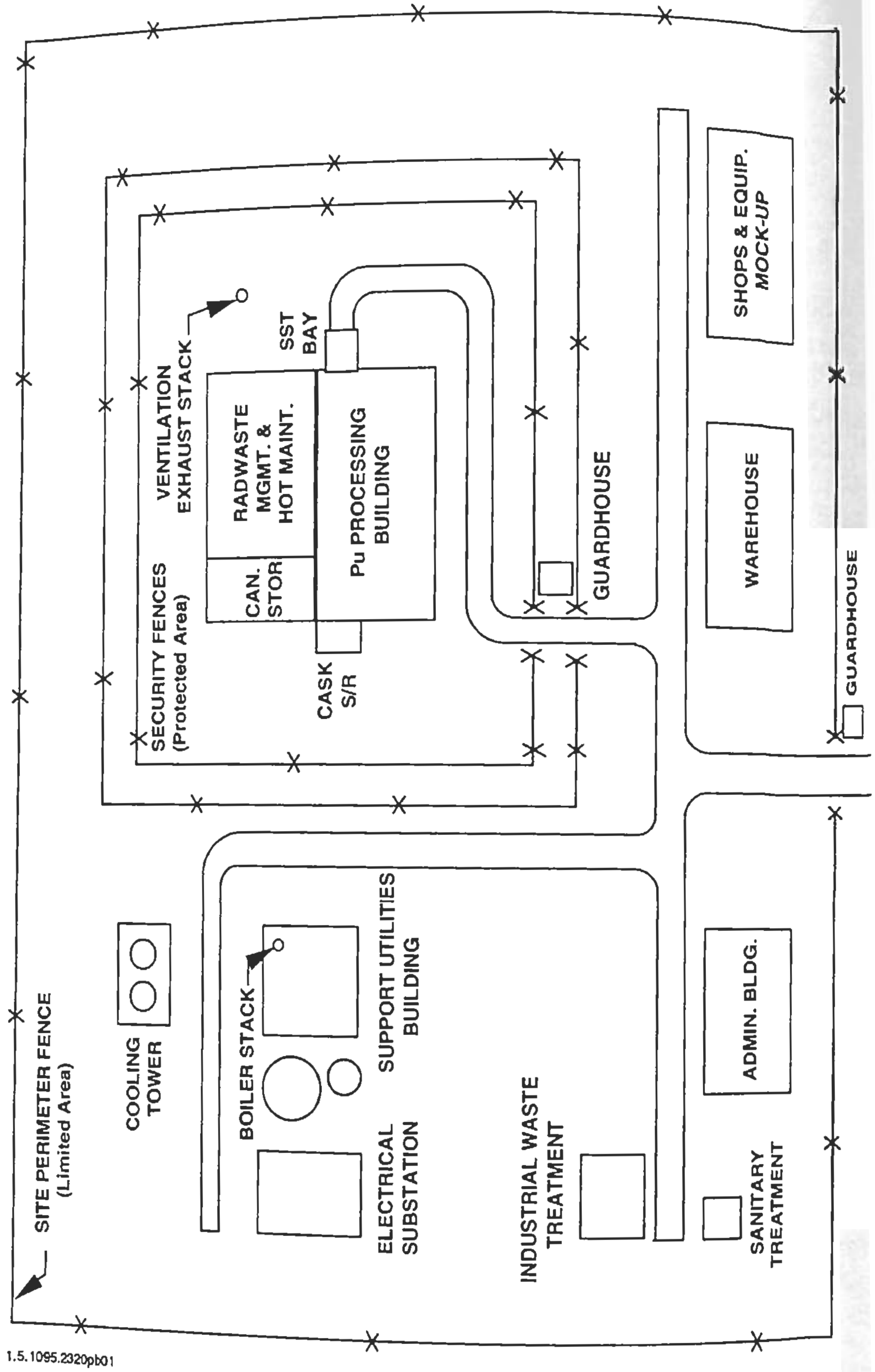

Figure 3-1. CIF site map.

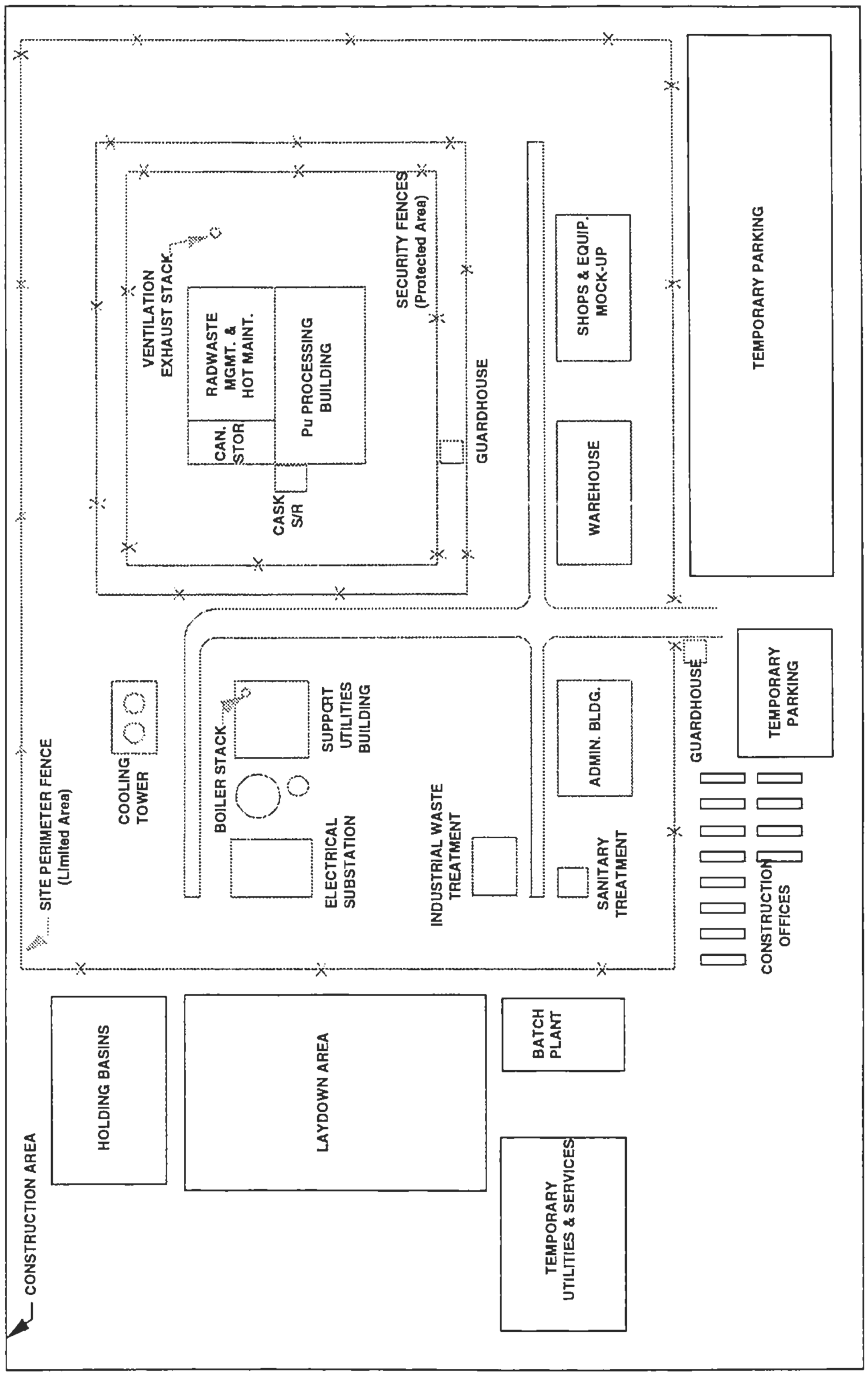

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Figure 3-2. Site map during construction.

- An on-site concrete batch plant to produce the concrete required for the m facility buildings and structures.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle

Note that the estimated construction area is based on a generic site (Kenosha, W and will require adjustment for the actual site selected.

4.0 Process Descriptions

Plutonium is immobilized in coated, ceramic pellets. The main processing steps are:

- Plutonium Metal Oxidation
- Plutonium Oxide Dissolution
- Ceramic Precursor/Neutron Absorber Addition
- Calcination
- Milling and Granulation
- Pellet Pressing
- Pellet Sintering
- Pellet Coating
- Drum Loading

A simplified block flow diagram of the ceramic immobilization process is shown in Fig. 4-1.

4.1 Plutonium Oxidation and Dissolution

4.1.1 Plutonium Oxidation and Dissolution Function

Figure 4-2 is the process flow diagram for the plutonium feed preparation.

Plutonium metal ingots and plutonium oxide are received in shipping containers. The containers of plutonium are unpacked, identified by bar code, and seal integrity is verified. Confirmatory and accountability measurements are made as necessary. The containers are stored in a plutonium vault.

Plutonium metal is removed from storage and sent via a conveyor system to a dry nitrogen-atmosphere glovebox for shearing and size reduction as necessary for the oxidation process. The metal is oxidized with air in a furnace at about 650°C (1200°F). The material is stirred to promote oxidation and ensure complete reaction. The off-gas is filtered to remove particulates, which are combined with the oxide product.

The plutonium oxide is transferred to an air-atmosphere glovebox and charged batchwise to a MEO (Mediated Electrochemical Oxidation) dissolver. The dissolver contains a nitric acid-silver nitrate solution. The oxidizing agent is silver (II) ion (Ag^{2+}), which is generated electrolytically in the dissolver system. Off-gas includes NO_x and water vapor. The dissolution product is a solution of plutonyl nitrate ($PuO_2(NO_3)_2$) in 4 *M* (molar) nitric acid and 0.1 *M* silver nitrate. The product is transferred to storage tanks, where a liquid sample is taken for analysis and accountability. The MEO dissolver and plutonyl nitrate storage tanks are a geometrically favorable design.

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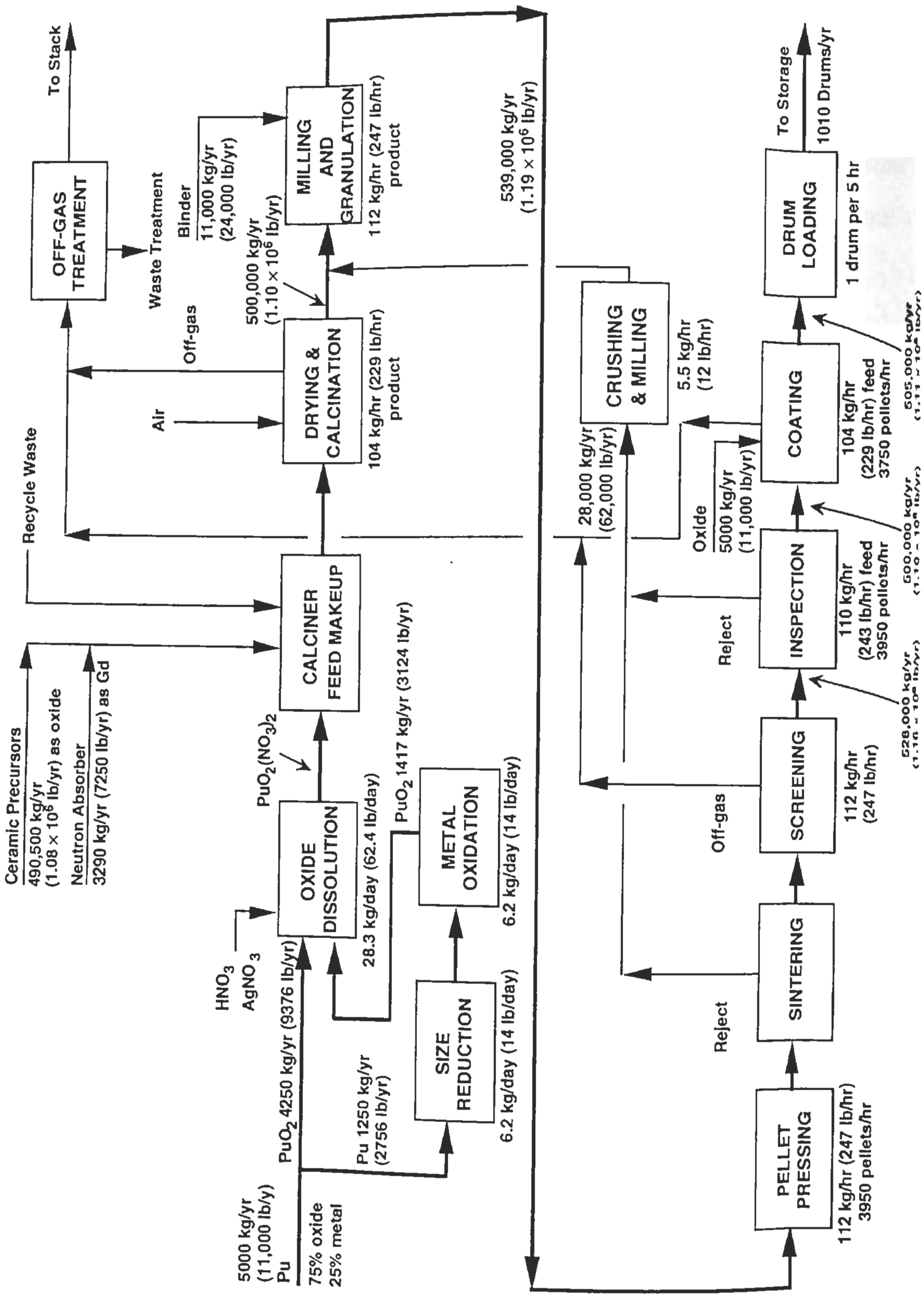

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Figure 4-1. Block flow diagram.

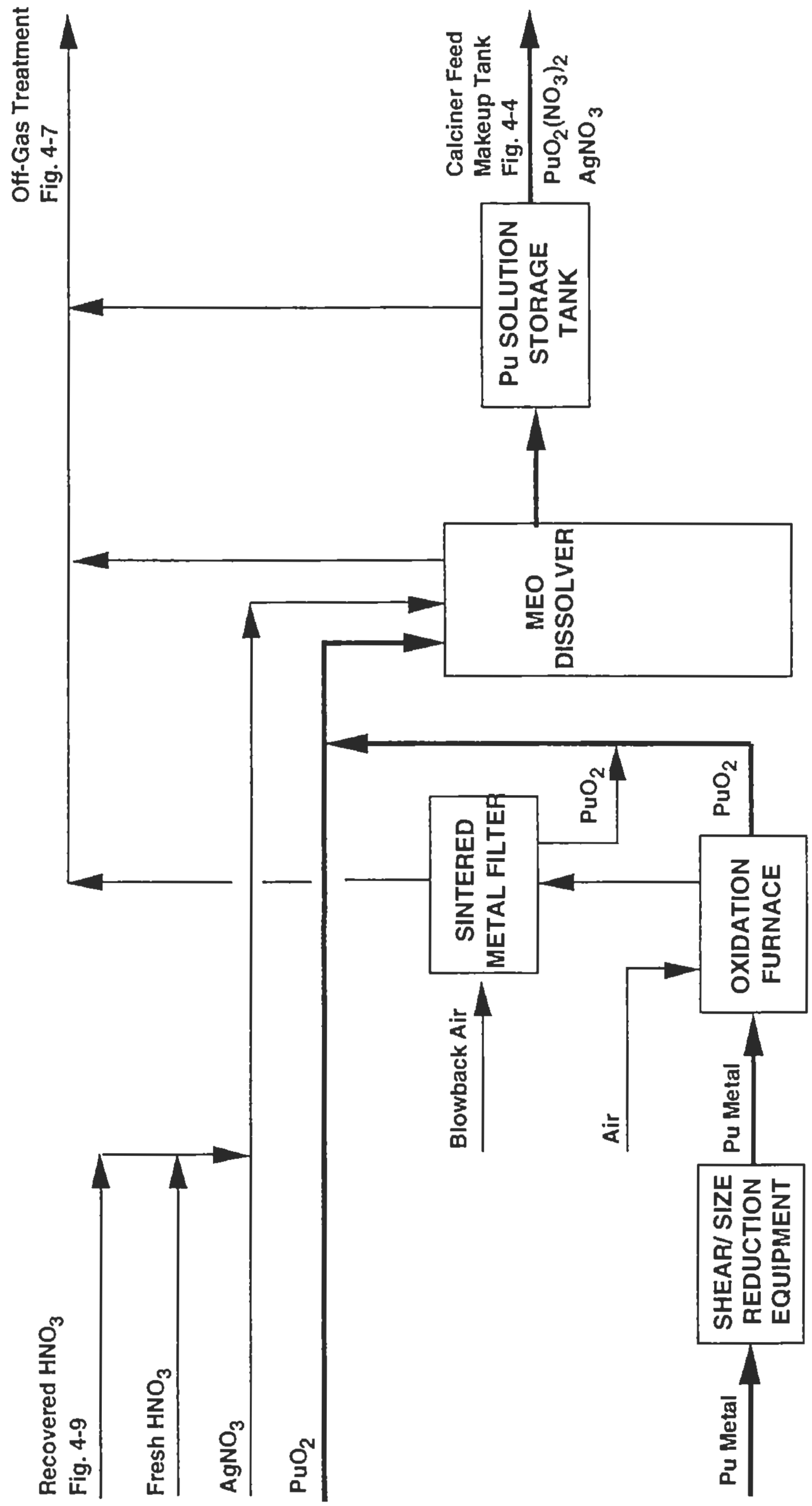

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Figure 4-2. Pu feed preparation process flow diagram.

Plutonium oxide feed is processed as above except that the oxidation step is not required. About 25 kg (55 lb) of Pu are processed per day. The oxide dissolution rate is about 1.1 kg/hr (2.4 lb/hr). About 126 L (33.3 gal) of 200 g Pu/L (26.7 oz Pu/gal) solution is produced per day.

Handling of plutonium metal, oxide and solutions, as well as the oxidation process are routine and well-established operations. Laboratory-scale MEO dissolvers have been operated extensively and production scale units have been designed and tested.

4.1.2 Plutonium Oxidation and Dissolution Feeds

The feeds are plutonium metal and plutonium oxide.

4.1.3 Plutonium Oxidation and Dissolution Products

The product is 200 g Pu/L (26.7 oz Pu/gal) plutonyl nitrate ($PuO_2(NO_3)_2$) solution

4.1.4 Plutonium Oxidation and Dissolution Utilities Required

The MEO dissolver, oxidation furnace, size reduction equipment and pumps require electrical power. Compressed air is supplied to the sintered metal filters for blowback and to the oxidation furnace as a reactant. Vacuum is supplied to the plutonium solution storage tanks for vacuum mixing and transferring. The MEO dissolver requires cooling water.

4.1.5 Plutonium Oxidation and Dissolution Chemicals Required

Fresh nitric acid, recycled nitric acid and silver nitrate are supplied to the MEO dissolver.

4.1.6 Plutonium Oxidation and Dissolution Special Requirements

Plutonium metal is handled in a dry nitrogen atmosphere. Equipment handling plutonium metal, oxide or nitrate solutions have geometrically favorable design.

4.1.7 Plutonium Oxidation and Dissolution Waste Generated

The containers and packaging associated with the plutonium feed are waste.

4.2 Ceramic Precursor and Neutron Absorber Preparation

Figure 4-3 depicts the process for preparing the ceramic precursor (ceramic-forming ingredients) and neutron absorber.

4.2.1 Ceramic Precursor/Neutron Absorber Preparation Function

Ceramic precursor solids are assumed to have been formulated and premixed by a chemical vendor. The dry precursor is weighed and mixed with demineralized water in a mix tank to form a 30 wt% solids slurry. The tank contents are thoroughly mixed and pumped through a slurry grinder to eliminate agglomerates. The well-dispersed slurry is pumped to the calciner feed makeup tank.

Dry gadolinium solids (e.g., $Gd[NO_3]_3 \bullet 6H_2O$) are weighed and mixed with water in a mix tank. The tank contents are agitated to dissolve the gadolinium compound. After sampling, the 2 *M* (molar) solution is pumped to the calciner feed makeup tank.

4.2.2 Ceramic Precursor/Neutron Absorber Preparation Feeds

The feeds are dry ceramic precursor solids and dry gadolinium nitrate solids.

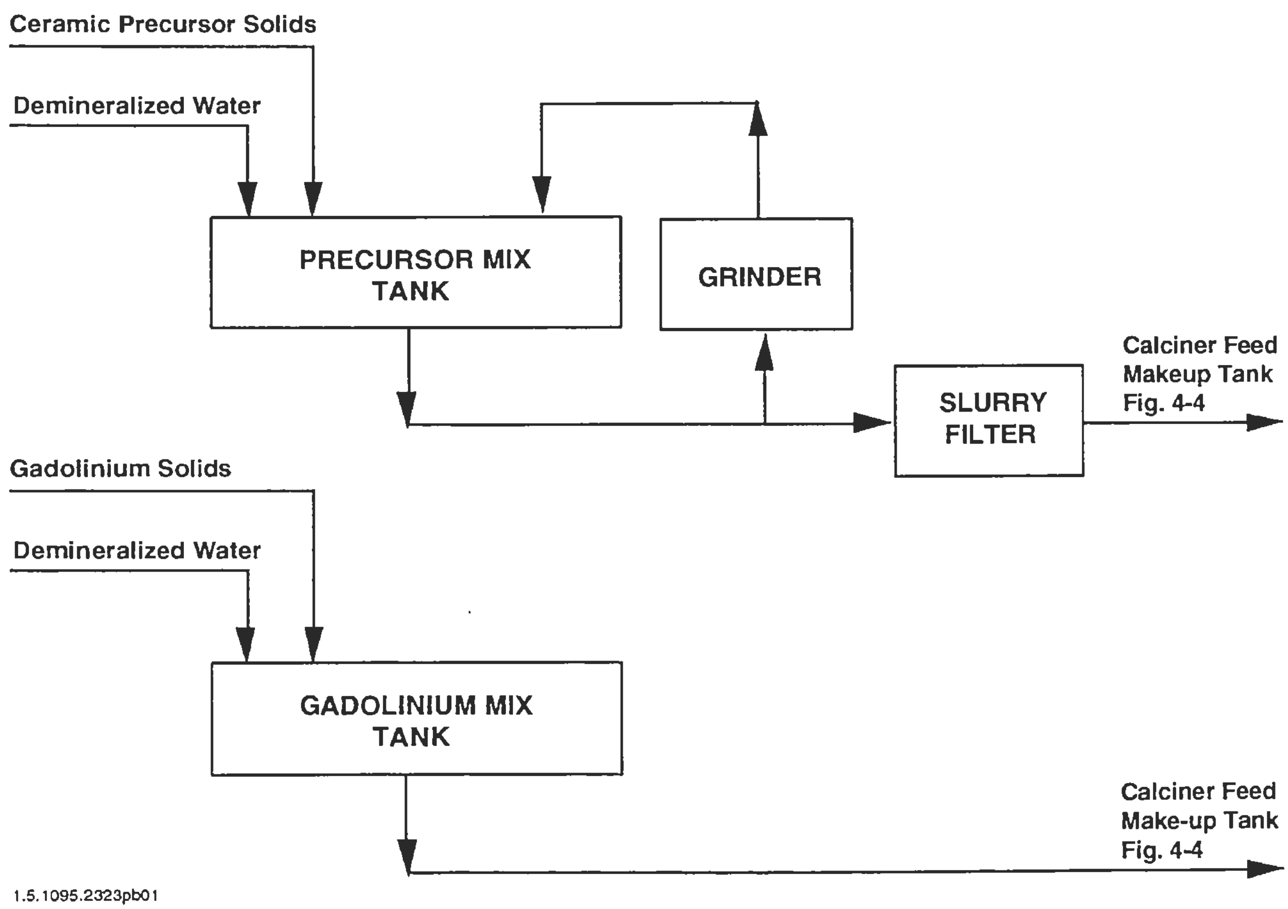

Figure 4-3. Ceramic precursor/neutron absorber makeup process flow diagram.

4.2.3 Ceramic Precursor/Neutron Absorber Preparation Products

The products are ceramic precursor slurry and gadolinium nitrate solution.

4.2.4 Ceramic Precursor/Neutron Absorber Preparation Utilities Required

The mix tank agitators, slurry grinder, and pumps require electrical power. Demineralized water is supplied to the ceramic precursor and gadolinium mix tanks.

4.2.5 Ceramic Precursor/Neutron Absorber Preparation Chemicals Required

The chemicals required are ceramic precursor solids and gadolinium nitrate.

4.2.6 Ceramic Precursor/Neutron Absorber Preparation Special Requirements

There are no special requirements.

4.2.7 Ceramic Precursor/Neutron Absorber Preparation Waste Generated

There is no routine waste generated.

4.3 Feed Makeup and Calcination

Figure 4-4 illustrates the process for mixing and calcination.

4.3.1 Feed Makeup and Calcination Function

The calciner feed makeup tank receives the ceramic precursor slurry, plutonium solution, and neutron absorber solution. Bottoms from the recycle waste evaporator are also received. The slurry is mixed and sampled and is then pumped to the calciner feed tank.

The assumption is made that the mixing and feed tanks, as well as all other downstream equipment, are not required to be critically safe by geometry because of the 1% plutonium loading and the gadolinium neutron absorber mixed uniformly in the slurry. The gadolinium absorber is assumed to be soluble solid gadolinium nitrate hexahydrate. The absorber is soluble to ensure loss of agitation does not cause the absorber to settle in a process tank.

The solution in the calciner feed tank is pumped to the calciner at a controlled rate. The rotary calciner design is based on one operating at the ANSTO demonstration plant. The calciner is an electrically heated, rotary kiln with multiple heating zones. The calciner feed first enters the drying zone, where water is driven off and a dry solid is produced. The solid flows down the calciner tube to the denitration and calcining zone operating at 750°C (1380°F), where the oxides are formed. Off-gases include water vapor, nitrous oxides (NO_x), and carbon dioxide (CO_2). The hot, dry powder discharges into the calciner product bin.

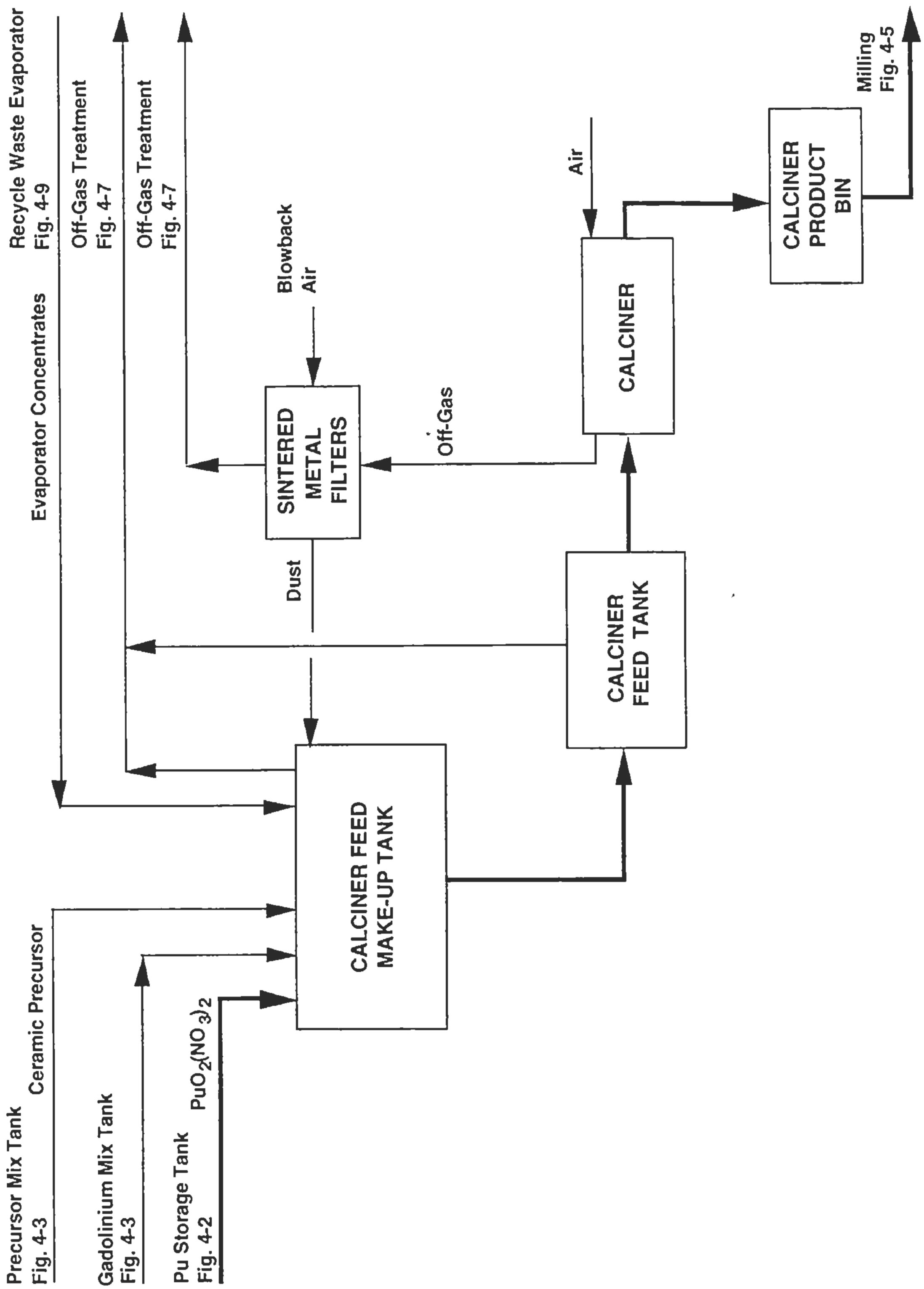

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Figure 4-4. Mixing and calcination process flow diagram.

Off-gas from the calciner enters a sintered metal filter vessel, which removes the majority of the dust from the off-gas. The filter elements are periodically blown back with air to dislodge the dust. The collected dust is recycled to the calciner feed tank.

4.3.2 Feed Makeup and Calcination Feeds

The feed is plutonyl nitrate ($PuO_2(NO_3)_2$) solution from Plutonium Oxide Dissolution and evaporator concentrates from the recycle waste evaporator.

4.3.3 Feed Makeup and Calcination Products

The product is calcined powder containing ceramic oxides, plutonium oxide and gadolinium oxide.

4.3.4 Feed Makeup and Calcination Utilities Required

The calciner heating elements and drive motor require electrical power. Tank agitators and pumps also require electrical power. Compressed air is supplied to the sintered metal filters for blowback and to the calciner as a reactant.

4.3.5 Feed Makeup and Calcination Chemicals Required

Ceramic precursor slurry and gadolinium nitrate solution are required.

4.3.6 Feed Makeup and Calcination Special Requirements

The plutonium concentration in the calciner feed must be limited to preclude criticality. The gadolinium solution acts as a neutron absorber in case the concentration limit is exceeded. Both the plutonium and gadolinium should be dissolved and well dispersed in the feed slurry to ensure that a homogeneous calcined powder is produced.

4.3.7 Feed Makeup and Calcination Waste Generated

Failed or plugged sintered metal filter elements are waste.

4.4 Granulation and Pellet Pressing

Figure 4-5 is the process flow diagram for granulation and pellet pressing.

4.4.1 Granulation and Pellet Pressing Function

The powder product from the calciner is fed to a mill (e.g., ball mill) to eliminate any agglomerates or lumps. The milled powder is mixed with recycle powder from sintering and dust collection, and is fed to a rotary drum granulator, where the powder is mixed with a liquid pellet binder (e.g., polyvinyl alcohol, carbowax). The powder, containing 2 wt% binder, forms granules, which facilitates feeding and pressing, and

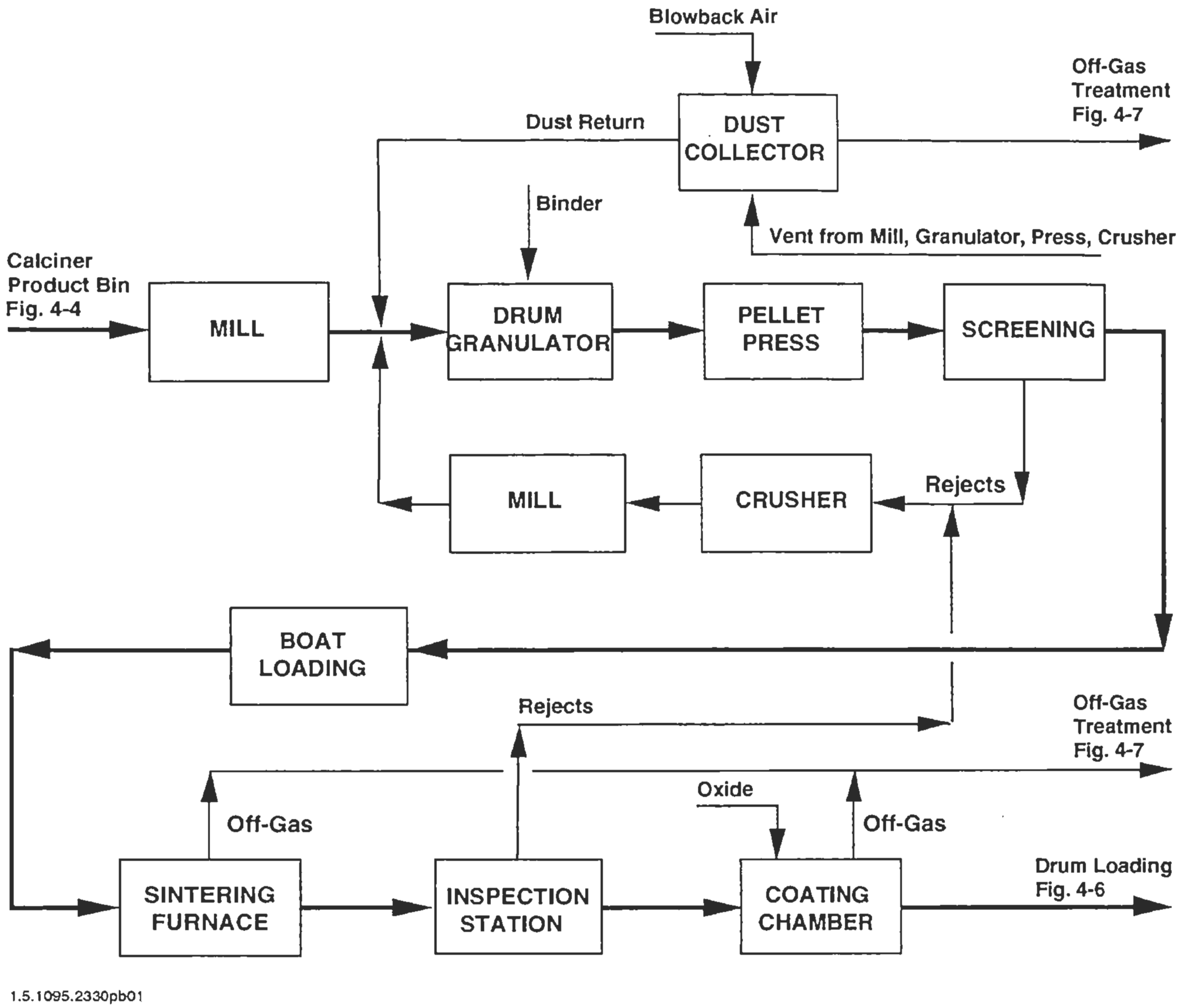


Figure 4-5. Pressing, sintering and coating process flow diagram.

reduces dusting. The granulated powder is screened to remove undersized and oversized material.

The pellet press is an anvil powder compacting press. The press cycle consists of the following three steps: feed powder to cavity, compact the powder at about 105 MPa (15,000 psi) to form the pellet, and eject the pellet. Cylindrical pellets about 2.5 cm (1 in.) diameter by 2.5 cm (1 in.) long with a density of 50–55 percent of theoretical are produced. These "green" (unsintered) pellets are automatically inspected to remove broken pellets, which are recycled. The green pellets are then loaded onto boats (trays) and sent to sintering.

The milling, granulation, and pellet pressing equipment are vented to sintered metal filters for dust collection. The filters are periodically blown back with compressed air and the collected dust is discharged to the granulator.

Use of an anvil powder press is based on experience with a unit operating at LLNL in the mixed waste treatment program.

4.4.2 Granulation and Pellet Pressing Feeds

The feed is calcined powder.

4.4.3 Granulation and Pellet Pressing Products

The product is green plutonium ceramic pellets.

4.4.4 Granulation and Pellet Pressing Utilities Required

Electrical power is supplied to the mill, granulator, pellet press and pellet handling equipment. Compressed air is supplied to the dust collector for filter blowback and to the pellet press.

4.4.5 Granulation and Pellet Pressing Chemicals Required

Liquid pellet binder is required.

4.4.6 Granulation and Pellet Pressing Special Requirements

There are no special requirements.

4.4.7 Granulation and Pellet Pressing Waste Generated

Rejected green pellets are recycled.

4.5 Pellet Sintering and Inspection

Figure 4-5 is the process flow diagram for pellet sintering and inspection.

4.5.1 Pellet Sintering and Inspection Function

Green pellets in boats are sent through a sintering furnace. A continuous line of boats is pushed through a tunnel-type furnace that has separate temperature control zones for heatup, sintering and cooldown. Sintering increases the density of the pellets and burns off the binder. Total time in the furnace is about 8 hours, which consists of a 4 hour heatup, 2 hours at 1200°C (2200°F) for sintering, and a 2 hour cooldown. A special atmosphere (e.g., a reducing atmosphere) is not required in the furnace. Off-gas from the furnace is sent to the off-gas treatment system.

The sintered pellets have a density of 90–95 percent of theoretical density, and are about 2.2 cm (0.85 in.) diameter by 2.2 cm (0.85 in.) long. The pellets flow to an automated inspection station, where each pellet is checked for weight, size, density and surface finish. The small percentage of the pellets that fail inspection are automatically diverted and collected. These failed pellets are crushed, milled and recycled to granulation. The product pellets are collected in boats and sent to coating.

Pellet sintering and inspection equipment are similar to those used in uranium and mixed oxide fuel fabrication facilities.

4.5.2 Pellet Sintering and Inspection Feeds

The feed is green plutonium ceramic pellets.

4.5.3 Pellet Sintering and Inspection Products

The product is inspected, sintered, plutonium ceramic pellets.

4.5.4 Pellet Sintering and Inspection Utilities Required

The sintering furnace, inspection station, and pellet handling equipment require electrical power. The sintering furnace requires air for combustion of the binder.

4.5.5 Pellet Sintering and Inspection Chemicals Required

No chemicals are required.

4.5.6 Pellet Sintering and Inspection Special Requirements

There are no special requirements.

4.5.7 Pellet Sintering and Inspection Waste Generated

Inspected sintered pellets that are rejected are recycled.

4.6 Pellet Coating

Figure 4-5 is the process flow diagram for pellet coating.

4.6.1 Pellet Coating Function

The sintered pellets are coated to prevent breakage and dusting during subsequent handling. An oxide coating is applied to the pellets by plasma or thermal spraying in an automated chamber after the inspection step. In plasma spraying, an oxide material is blown through an electric arc to melt it and the molten oxide is deposited on the pellets, where it solidifies. A small quantity of ionizing gas (helium) is used for the arc, and a shield gas (nitrogen) is also used. The coated pellets are sent to drum loading.

4.6.2 Pellet Coating Feeds

The feed is sintered plutonium ceramic pellets.

4.6.3 Pellet Coating Products

The product is coated plutonium ceramic pellets.

4.6.4 Pellet Coating Utilities Required

The coating chamber requires electrical power, cooling water, nitrogen gas, and helium gas.

4.6.5 Pellet Coating Chemicals Required

Oxide powder spheres suitable for the pellet composition (such as TiO_2 or Al_2O_3 required.

4.6.6 Pellet Coating Special Requirements

There are no special requirements.

4.6.7 Pellet Coating Waste Generated

Oxide coating material which does not bond to the pellets is recycled.

4.7 Drum Handling

Figure 4-6 is the process flow diagram for drum handling.

4.7.1 Drum Handling Function

The coated pellets are loaded into 208-L (55-gal) drums in a drum filling station. T drums are then moved to the drum closure station, where the drum lids are secured a tamper-indicating seals attached. Each drum contains about 500 kg (1100 lb) of ceram pellets, which includes about 5 kg (11 lb) of plutonium.

The loaded drums are then placed in the drum decontamination station, where th exterior is decontaminated with high-pressure water. The decontamination effluent is transferred to the recycle waste evaporator. After compressed air drying, the drums a moved to the drum smear test station, where the exterior of the drums are swiped wi paper test swabs. The test swabs are placed in a pneumatic transfer unit and transferr to an analytical laboratory outside the processing room, and counted for radioactivity the smearable contamination is above DOT limits, the drum is recleaned and smear tested again.

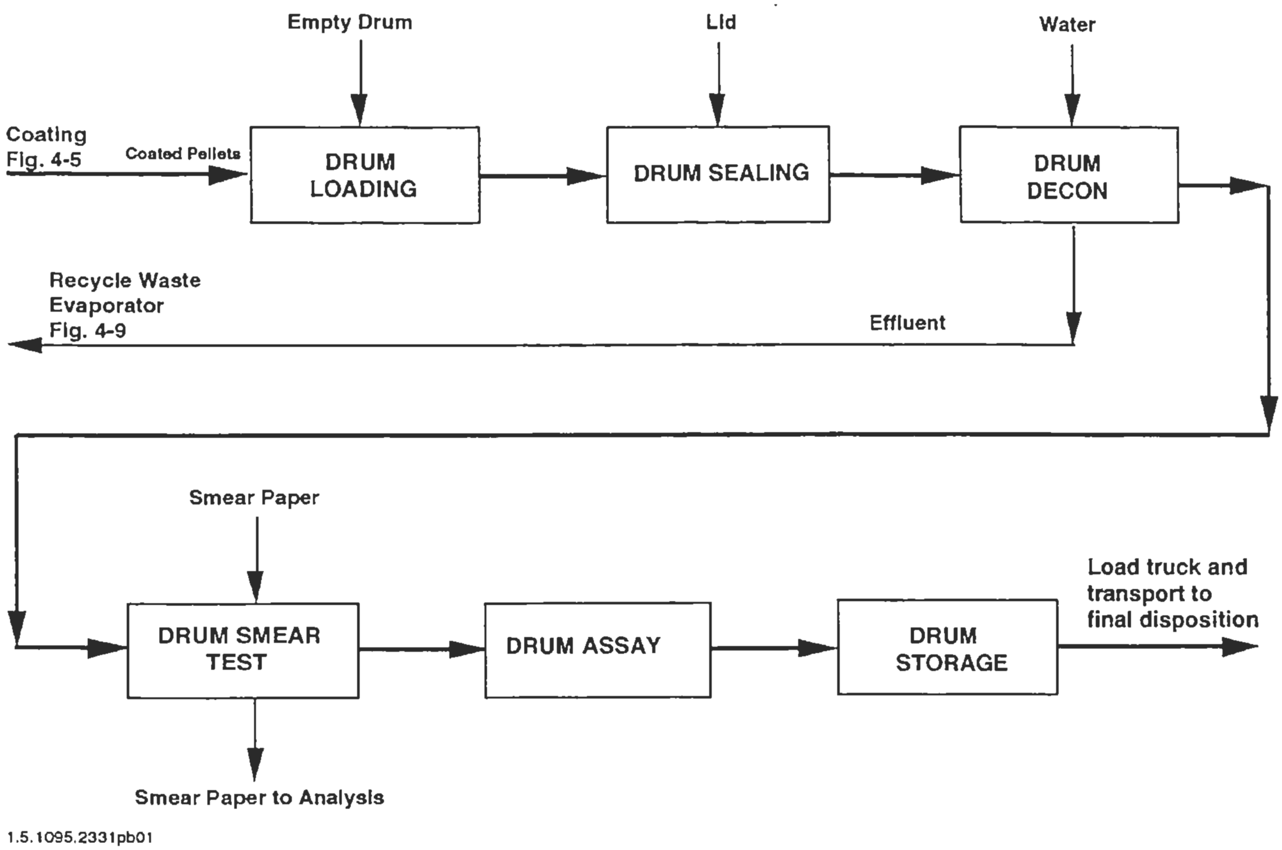


Figure 4-6. Drum handling process flow diagram.

The loaded drums are assayed to determine the plutonium content. The drums are transferred to the storage facility, where they are stored until they are loaded onto a truck for transport to the deep borehole disposal site.

4.7.2 Drum Handling Feeds

The feeds are coated plutonium ceramic pellets and empty drums.

4.7.3 Drum Handling Products

The product is a clean, sealed drum of plutonium ceramic pellets.

4.7.4 Drum Handling Utilities Required

Electrical power is required for drum decon, smear testing, assay and transport equipment. Water is required for drum decontamination. Compressed air is supplied for drum drying.

4.7.5 Drum Handling Chemicals Required

No chemicals are required.

4.7.6 Drum Handling Special Requirements

Safeguards and security requirements include periodic inspection of tamper-indicating seals and direct surveillance of drums by security police officers during dı movement.

4.7.7 Drum Handling Waste Generated

The smear papers after radiation counting are waste. Drum decontamination effluent is sent to the recycle waste evaporator.

4.8 Process Off-Gas System

Figure 4-7 shows the process off-gas system.

4.8.1 Process Off-Gas Function

Off-gas from the calciners, sintering furnaces, and coating chambers enter a condenser to condense the steam and cool the off-gas. Off-gas from the condenser is combined with process tank vents and flows to an NO_x absorption column. Urea is added to the scrub solution tank to convert some of the absorbed NO_x to nitrogen. M of the remainder of the NO_x forms nitric acid. The off-gas then flows through a heater and HEPA filter and discharges to the HVAC exhaust containing three HEPA filters i series. The treated off-gas is discharged to atmosphere through a stack.

4.8.2 Process Off-Gas Feeds

The feeds are hot off-gas from the calciner and sintering furnaces, coating chambe off-gas, vessel vent gases, and off-gas from the dust collector that serves the milling a pelletizing equipment.

4.8.3 Process Off-Gas Products

The product is treated off-gas.

4.8.4 Process Off-Gas Utilities Required

Cooling water is supplied to the off-gas condenser. Electrical power is supplied to the off-gas heater, exhausters, pumps and agitators. Water is supplied to the NO_x absorption column.

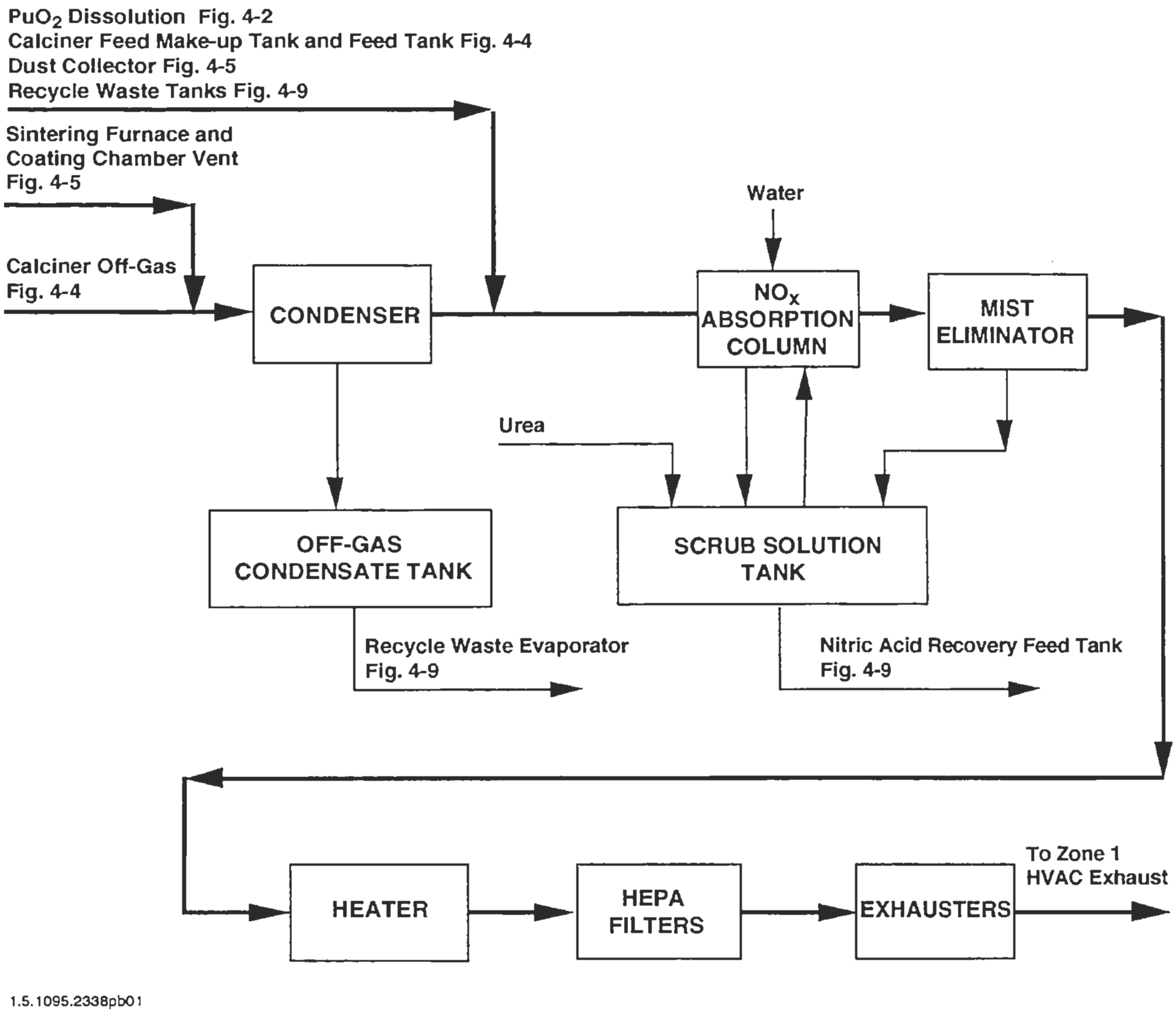


Figure 4-7. Off-gas treatment system process flow diagram.

4.8.5 Process Off-Gas Chemicals Required

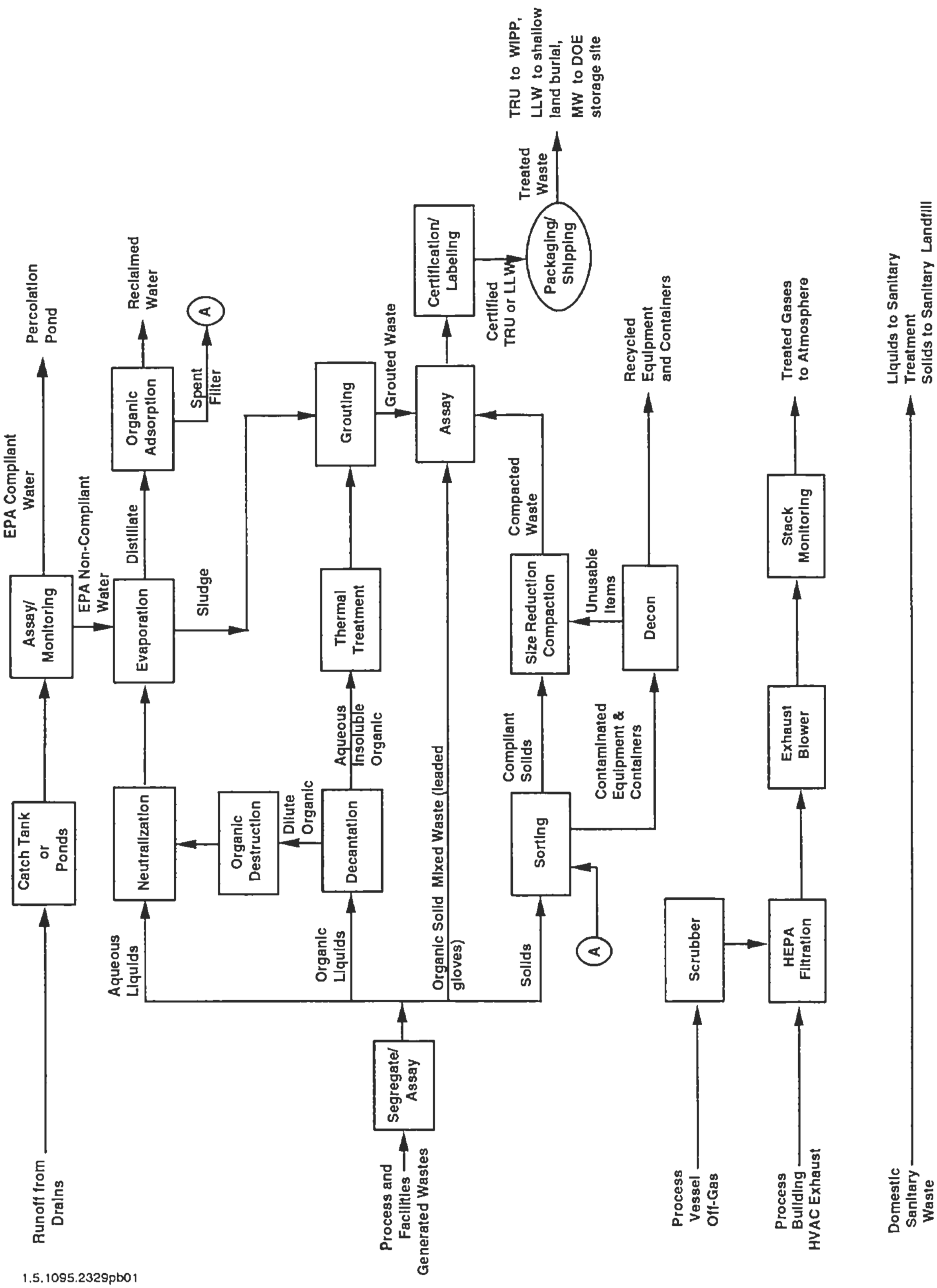
Urea is supplied to the NO_x scrub solution tank.

4.8.6 Process Off-Gas Special Requirements

The off-gas system needs to be monitored to ensure that significant quantities of volatilized plutonium do not accumulate.

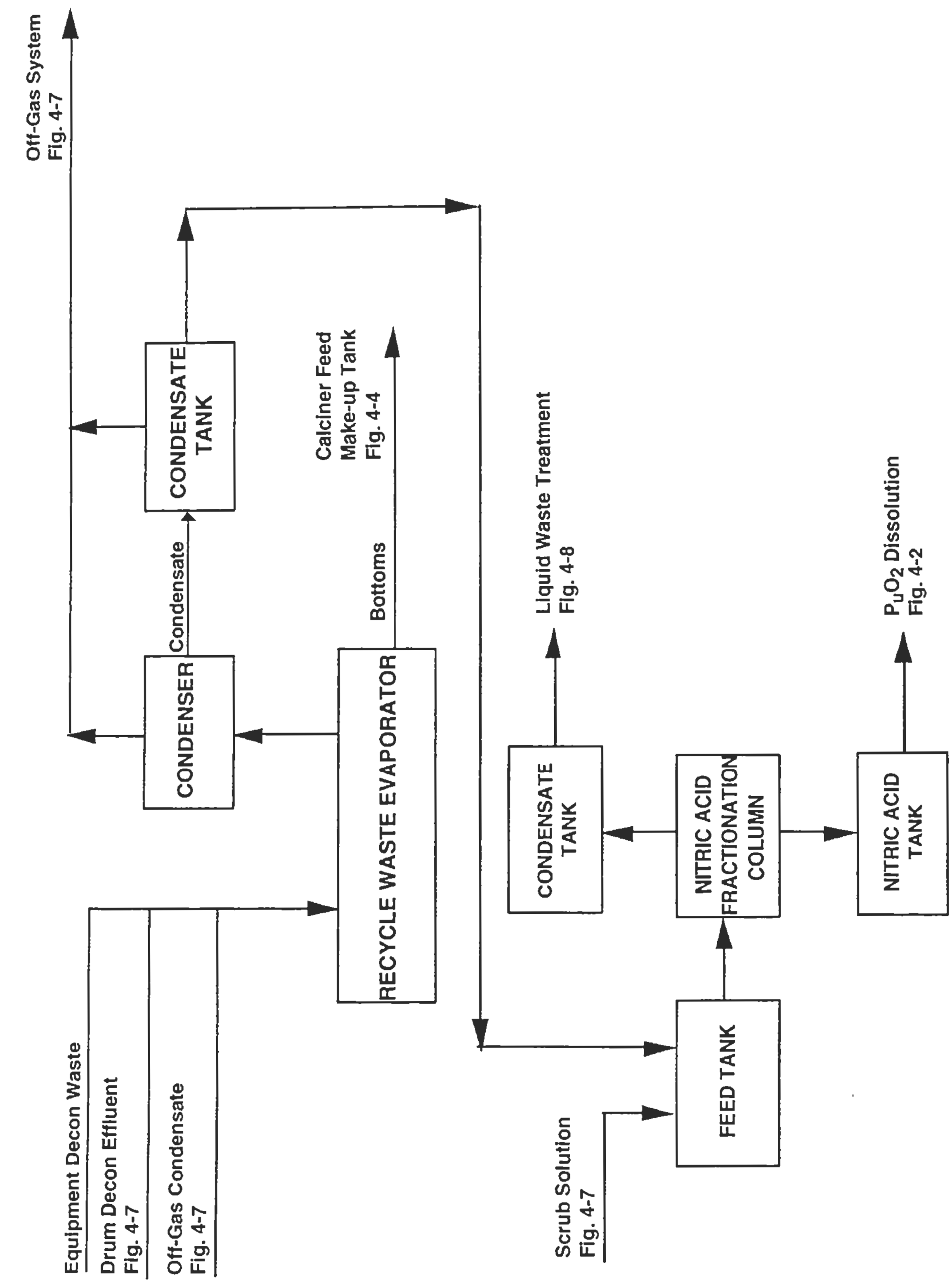
4.8.7 Process Off-Gas Waste Generated

Off-gas condensate is sent to the recycle waste evaporator. Spent scrub solution is sent to nitric acid recovery. HEPA filters that are replaced become a waste.



1.5.1095.2329pb01

Figure 4-8. Waste management process flow diagram.



1.5.1095.2324pb01

Figure 4-9. Waste treatment process flow diagram.

4.9.3 Waste Management Products

The products are packages of low-level waste, transuranic waste and mixed waste. Treated liquid and gas effluents are released to the environment. Nitric acid and water are recovered and purified for reuse in the facility.

4.9.4 Waste Management Utilities Required

Electrical power, cooling water, compressed air, and steam are required.

4.9.5 Waste Management Chemicals Required

Cement will be used for grouting. Other chemicals may be required depending on the waste management system.

4.9.6 Waste Management Special Requirements

The waste management products shall meet the acceptance criteria set by the receiving facility or disposal site. Effluents shall conform with discharge permit limits.

4.9.7 Waste Management Waste Generated

The waste generated is recycled and processed.

5.0 Resource Needs

This section describes the estimated resource impacts due to the construction of a new plutonium ceramic immobilization facility (CIF) using coated pellets without radionuclides. Included are impacts during construction and operation of the CIF.

During the construction and operation of the CIF, various resources will be required. These resources will consist of utilities such as electricity, water, and fuels; chemicals such as cleaners, solvents, and lubricants; and other consumable materials and resources such as safety equipment, personal protective equipment, office spaces, and construction equipment.

The CIF will consist of the buildings and support facilities necessary to receive plutonium and other feed materials, maintain material control and accountability, process, incorporate into a ceramic matrix, and properly store the ceramic pellets until a deep borehole repository becomes available.

5.1 Materials/Resources Consumed during Operation

The CIF will require operations personnel for the process line, security forces to protect the SNM, maintenance personnel, administrative staff, engineers, health physics personnel, QA/quality control (QC) engineers, and laborers. The CIF will require personnel for transport of process feed materials, operating the process line, operation of cooling tower, maintenance shops, offices, cafeteria, and the remainder of the support facilities.

These new facilities will require chemicals (e.g., cleaning supplies, paints, concrete sealers), materials (e.g., administrative supplies, cleaning equipment), and resources (e.g., trucks, forklifts). The impacts are described in this section with expected consumption for a ceramic process line average throughput and an estimated peak throughput.

Operation of the CIF will require consumable materials and resources. Consumable materials will be items that will be used and eventually disposed. Resources will be functions, facilities, and equipment necessary to support the activities and are intended to be removed as serviceable at the completion of the project.

Consumable material use will generate sanitary waste and will include used safety equipment, cleaning equipment, plastic sheeting, and office waste. No hazardous waste is expected to be generated from consumable items. Operating equipment powered by an internal combustion engine (e.g., trucks, forklifts) will result in exhausts accounted for in current permits. Small amounts of hazardous waste will be generated by the antifreeze and lubricating fluids removed from equipment during maintenance. Use of the other resources (e.g., administrative offices and support buildings) will not impact the environment.

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1 including electricity, fuel and water usage. This is followed by Table 5-2 showing consumable chemical material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5–1. Utilities consumed during annual operation.

Utilities	Annual average consumption	Peak demand[1]
Electricity	35 GWh	5 MW
Liquid fuel[3]	210,000 L (55,000 gal)	N/A
Natural gas[2]	3.8×10^6 scm (135×10^6 scf)	N/A
Raw water	3.2×10^8 L (85×10^6 gal)	N/A

[1] Peak demand is the maximum rate expected during any hour.
[2] Standard cubic feet measured at 14.7 psia and 60°F.
[3] Assume 50% gasoline and 50% diesel fuel.

5.1.2 Water Balance

A preliminary conceptual water balance diagram for the Ceramic Immobilization Facility is shown in Fig. 5-1. This balance is based on the generic EPRI standard hypothetical east/west central site for nuclear power plants (as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3). The only effect on the water balance for a Greenfield site in a different location will be the stormwater runoff.

5.1.3 Chemicals Consumed

See Table 5–2.

Table 5–2. Annual chemicals consumed during operation.

Chemical	Quantity kg (lb)
Solid	
Silver nitrate	430 (950)
Ceramic precursors (as oxides)	5.0×10^5 (1.1×10^6)
Gadolinium—as $Gd(NO_3)_3 \cdot 6\ H_2O$	9,500 (21,000)
Pellet coating oxide	5,000 (11,000)
Cement	1,100 (2,400)
Decontamination detergent	3,000 (6,600)
Resins	140 (300)
Nonionic polymers for cooling water	150 (330)
Phosphates for cooling water	750 (1,650)
Phosphonates for cooling water	150 (330)
Liquid	
Nitric acid	3,500 (7,800)
Sodium hydroxide	1,800 (4,000)
Potassium hydroxide	110 (240)
Urea	8,600 (19,000)
Pellet binder	11,000 (24,000)
Gaseous	
Nitrogen	9,000 (20,000)
Helium	900 (2,000)

5.1.4 Radiological Materials Required

Annual requirements for radiological materials consist of the following:

- 5 tonne (11,000 lb) per year of plutonium—75% as plutonium oxide and 25% as plutonium metal.

5.2 Materials/Resources Consumed during Construction

Table 5-3 provides an estimate of construction materials consumed during construction.

6.0 Employment Needs

6.1 Employment Needs during Operation

Table 6-1 provides an estimate of total employment during operations.

Table 6-1. Employment during operation.

Labor category	Number of employees
Officials and managers	40
Professionals	40
Technicians	100
Office and clerical	20
Craft workers (maintenance)	180
Operators / line supervision	300
Safeguards and security	220
Total employees	900

6.2 Badged Employees at Risk of Radiological Exposure

Table 6-2 is a projected breakdown of dosimeter badged employees at the Ceramic Immobilization Facility who are expected to be routinely at risk of radiological exposure:

Table 6-2. Employees at risk of radiological exposure.

Labor category	Number at risk	Est'd annual man-rem
• Operators/line supervision	200	57
• Craft workers (maintenance)	120	36
• Technicians	60	10
• Professionals/managers	10	1
• Safeguards and security	60	6
Total	450	110

In addition to the above, a small number of badged visitors may enter the radiological area, but this is envisioned to be on a nonroutine basis.

7.0 Wastes and Emissions from the Facility

This section provides the annual emissions, effluents, waste generation and radiological emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering judgment and preliminary calculations due to the preconceptual nature of the design.

7.1 Wastes and Emissions during Operation

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operation. Table 7-2 summarizes annual radiological emissions during operation.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the Ceramic Immobilization Facility and the final waste products after treatment are shown in Table 7-3. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce estimated in Table 6-1.

7.1.2.1 High-Level Wastes. There is no high-level radioactive waste generated from operation of the Ceramic Immobilization Facility.

7.1.2.2 Transuranic Wastes. Transuranic wastes will be generated from process and facility operations, equipment decontamination, failed equipment and used tools. Transuranic wastes are treated onsite in a waste handling facility to form grout or compact solid waste. Treated transuranic waste products are packaged, assayed, and certified prior to shipping to the Waste Isolation Pilot Plant (WIPP) for disposal.

7.1.2.3 Low-Level Wastes. Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

Criteria pollutants	

Other effluents	

Cooling tower chemicals	

Table 7–3. Annual waste volumes during operation.

Category	Generated quantities		Posttreated	
	Solid m^3 (yd^3)	Liquid L (gals)	Solid m^3 (yd^3)	Liquid L (gal)
Radioactive and hazardous wastes				
Transuranic waste (TRU)	150 (200)	110,000 (30,000)	150 (200)	—
Low–level waste (LLW)	23 (30)	10,000 (2,700)	15 (20)	—
Mixed transuranic waste	1.5 (2)	0	1.5 (2)	—
Mixed low–level waste	0.3 (0.4)	0	0.3 (0.4)	—
Hazardous waste	23 (30)	4,500 (12,000)	23 (30)	4,500 (12,000)
Nonhazardous wastes				
Solid waste	910 (1,200)	—	910 (1,200)	—
Industrial waste water	—	2.8×10^7 (0.75×10^7)	—	2.8×10^7 (0.75×10^7)
Cooling water blowdown	—	7.9×10^7 (2.1×10^7)	—	7.9×10^7 (2.1×10^7)
Process Waste Water	—	1.9×10^6 (5×10^5)	—	1.9×10^6 (5×10^5)
Sanitary waste water	—	1.5×10^7 (0.4×10^7)	—	1.5×10^7 (0.4×10^7)
Storm water runoff[1]	—	1.6×10^8 (4.2×10^7)	—	1.6×10^8 (4.2×10^7)
Recyclable wastes	15 (20)	—	15 (20)	---

[1] Stormwater runoff based on generic EPRI site at Kenosha, Wisconsin per Appendix F of *DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies*, ORNL/TM-10071/R3.

7.1.2.4 Mixed Transuranic (TRU) Wastes. A small quantity of solid mixed waste, mainly rubber gloves and leaded glovebox gloves from the waste handling facility, will be generated during operations of the Ceramic Immobilization Facility. The mixed TRU waste is packaged to meet WIPP waste acceptance criteria (WIPP-WAC) and stored on site until TRU waste can be shipped to WIPP.

7.1.2.5 Mixed Low-Level Wastes. Mixed wastes generated from the facility with radioactivity levels below the TRU waste level (3700 Bq/g [100 nCi/g]) will be classified as mixed low-level wastes and will be treated to the land disposal standards of RCRA.

7.1.2.6 Hazardous Wastes. Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

7.1.2.7 Nonhazardous (Sanitary) Wastes. Nonhazardous sanitary liquid wastes generated in the facility are transferred to an on-site sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an off-site municipal sanitary landfill for disposal.

7.1.2.8 Nonhazardous (Other) Wastes. Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.2 Wastes and Emissions during Construction

7.2.1 Emissions

Estimated emissions from construction activities of the Ceramic Immobilization Facility during the peak construction year are shown in Table 7-4. The emissions are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption (for chemical pollutants) estimated in Table 5-3. The peak construction year is based on a construction schedule at the labor force distribution shown in Table 6-3.

Table 7–4. Emissions during the peak construction year.

Criteria pollutants	Quantity tonne (ton)
Sulfur dioxide	6.4 (7)
Nitrogen oxides (NO_x)	100 (110)
Volatile organic compounds	9.1 (10)
Carbon monoxide	450 (500)
Particulate matter PM–10	1,100 (1,200)
Hydrocarbons	18 (20)

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7-5. The waste generation quantities are based on factors from historic data on construction area size and construction labor force estimated in Table 6-3.

Table 7–5. Total wastes generated during construction.

Waste category	Quantity
Hazardous solids	120 m^3 (150 yd^3)
Hazardous liquids	83,000 L (22,000 gal)
Nonhazardous solids (construction debris)	1,100 tonne (1,200 ton)
Nonhazardous liquids	
Concrete batch plant[1]	1.9×10^7 (5×10^6 gal)
Service water[2]	1.9×10^7 (5×10^6 gal)
Sanitary waste[3]	1.1×10^8 (30×10^6 gal)
Construction storm water[4]	1.1×10^9 (3×10^8 gal)

[1] Based on yards of concrete produced
[2] Based on estimated construction needs
[3] Based on average construction workforce size and 5-year construction duration
[4] Based on total land area disturbed and duration of disturbance

7.2.2.1 Radioactive Wastes. There are no radioactive wastes generated during construction of the Ceramic Immobilization Facility since the site is assumed to be a Greenfield site.

7.2.2.2 Hazardous Wastes. Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc., for construction vehicles will be managed and hauled to commercial waste facility off-site for treatment and disposal according to EPA RCRA guidelines.

7.2.2.3 Nonhazardous Wastes. Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to off-site facilities for treatment and disposal.

- Gloveboxes containing plutonium in powder form (Seismic Category I per NF Regulatory Guide 3.14).
- Plutonium storage and process containers, including tankage and piping, that are not contained in DBE resistant gloveboxes (Seismic Category I per NRC Regulatory Guide 3.14).

The accidents postulated for nuclear facilities can be divided into three categories depending on the accident initiator: natural phenomena events, external events, and internal events. The following sections describe accidents in each of theses categories considered for this assessment. Table 8-1 summarizes the accident scenarios and releases.

Table 8-1. Ceramic process postulated accident summary—no Cs spiking.

Accident	Frequency (DOE-STD-3005-YR)	Source	Respirable airborne fraction	Fractior source rel
Design basis accidents (DBAs)				
Earthquake	Extremely unlikely	20 kg (44 lb) Pu	10^{-3}	10^{-9}
Tornado	Extremely unlikely	No release	N/A	N/A
Flood	Extremely unlikely	No release	N/A	N/A
Glovebox fire	Extremely unlikely	20 kg (44 lb) Pu	10^{-3}	10^{-9}
Glovebox criticality	Extremely Unlikely	10^{18} fissions	1 noble gases .25 halogens	1 noble gas .25 haloger
Calciner feed tank criticality	Extremely unlikely	10^{18} prompt fissions 47 pulses of 10^{17} fissions at 10 minute intervals	1 noble gas .25 halogen 5×10^{-4} salts	1 noble gas .25 haloger 5×10^{-12} sa
Ceramic can drop	Unlikely	0.5 kg (1.1 lb) Pu	10^{-4}	10^{-12}
Pellet container breakage	Unlikely	5 kg (11 lb) Pu	10^{-7}	10^{-15}
Dissolver spill	Anticipated	0.4 kg (0.9 lb) Pu	6×10^{-6}	6×10^{-14}
Calciner feed spill	Anticipated	1.4 kg (3.1 lb) Pu	5×10^{-6}	5×10^{-14}
Calciner product spill	Anticipated	2.5 kg (5.5 lb) Pu	7×10^{-4}	7×10^{-12}
Loss of off-site power	Anticipated	No release	N/A	N/A
Beyond DBAs				
Sintering furnace explosion	Incredible	3 kg (6.6 lb) Pu	10^{-1}	10^{-7}
Uncontrolled chemical reaction	Incredible	14 kg (30.8 lb) Pu	10^{-1}	10^{-9}
Pu storage criticality	Incredible	10^{18} fissions	1 noble gases .25 halogens	1 noble gase .25 halogens
Plutonyl nitrate tank criticality	Incredible	10^{18} fissions	1 noble gases .25 halogens	1 noble gase .25 halogens
Pellet storage criticality	Incredible	10^{18} fissions	1 noble gases .25 halogens	1 noble gase .25 halogens

8.1.1 Operational and Design Basis Accidents

8.1.1.1 Natural Phenomena. The following natural phenomena are considered applicable to the CIF and are treated as design basis events:

- Earthquake
- Tornado
- Flooding

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the CIF site. Such events would be addressed in the future if warranted by the site selected for the facility.

Earthquake. The design basis earthquake (DBE) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). Safety class systems, structures, and components (SSCs) are designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3005-YR. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

Given the safety class items assumed for the CIF, an earthquake would not directly cause a release of radioactive material nor would it cause a criticality accident. It is postulated, however, that the earthquake starts a fire in the room housing the plutonium metal glovebox line. The fire is unimpeded and breaches a glovebox containing plutonium metal. The inert atmosphere is lost and the fire ignites the plutonium. The ventilation removes plutonium-containing gases from the area. The gases pass through a filtration system and are then released to the environment. It is assumed that 0.1% of the plutonium at risk becomes airborne in respirable form. This glovebox line processes 20 kg (44 lb) of plutonium per day. Therefore, at most 20 kg (44 lb) of Pu are at risk as a result of the earthquake.

This material is released to ventilation Zone 2. Assuming a two-stage HEPA filter system, the fraction of particles released penetrating the filter would be 10^{-6}. Therefore, 10^{-7}% of the plutonium at risk would reach the environment as respirable particles.

Tornado. The design basis tornado (DBT) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). Safety class systems, structures, and components (SSCs) are designed to withstand the DBT and DBT-generated tornado missiles. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3005-YR. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

Safety-related SSCs for the CIF are enumerated in section 8.1 above. Given these SSCs, it is reasonable to assume that it is not credible for a tornado to cause a release of radioactive material or an accidental criticality event at the CIF.

Floods. Flooding is of particular concern at plutonium processing facilities such as the CIF because of the potential for nuclear criticality accidents. The CIF will be designed to preclude flooding of areas that contain Pu. The design basis flood (DBF) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). Safety class systems, structures, and components (SSCs) are designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3005-YR. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

Safety-related SSCs for the CIF are enumerated in section 8.1 above. Given these SSCs, it is reasonable to assume that it is not credible for a flood to cause a release of radioactive material or an accidental criticality event at the CIF.

8.1.1.2 External Events. These are events originating off-site. They are site-specific and are not considered at this stage of conceptual design. External events that will be addressed in the future include the following:

- Aircraft hazards
- Hazards from nearby facilities (explosions, missiles, chemicals)
- Transportation hazards (explosives, chemicals)

8.1.1.3 Internal Events—Glovebox Fire. An unimpeded fire begins in the process room housing the glovebox line. The fire breaches a glovebox containing plutonium metal. The inert atmosphere is lost and the fire ignites the plutonium. The ventilation removes plutonium-containing gases from the area. The gases pass through a filtration system and are then released to the environment. This glovebox line processes 20 kg (44 lb) of plutonium per day. Therefore, at most 20 kg (44 lb) of plutonium are at risk in this scenario. It is assumed that 0.1% of the Pu at risk becomes airborne in respirable form.

This material is released to ventilation Zone 2. Assuming a two-stage HEPA filter system, the fraction of particles released penetrating the filter would be 10^{-6}. Therefore, 10^{-7}% of the plutonium at risk would reach the environment as respirable particles.

This is judged to be an unlikely accident as defined in DOE-STD-3005-YR.

Glovebox Criticality. The criticality safety of the glovebox operations at CIF depend on controlling the inventory and configuration of fissile material in the glovebox. The mass limits will be chosen to preclude criticality in the event of double batching, and automated accountability systems will be employed. However, these criticality controls depend on procedures to some extent. In this scenario, controls are violated so that additional fissile material is introduced into a double batched glovebox. This results in a criticality accident.

This event is modeled based on NRC Regulatory Guide 3.35. The critical assembly is disrupted by the initial energy release, and the event is terminated. There are 10^{18} fissions in the initial pulse. One hundred percent of the noble gases, 25% of the halogens, and 0.1% of the ruthenium become airborne. This activity is released to the Zone 1 ventilation system. The exhaust HEPA filters do not mitigate the release of noble

the material at risk will reach the environment. This is judged to be an unlikely accident as defined in DOE-STD-3005-YR.

Plutonyl Nitrate Dissolver Spill. A dissolver overflows spilling 2 L (0.53 gal) of solution (10% of the vessel contents) onto the floor from a height of 3 m (9.8 ft). The spill spreads out in a safe geometry. The spill is cleaned up within 2 hr. Some of the spill is aerosolized and becomes airborne as respirable particles. There is little or no entrainment from the spill because of the quick response time. The spill contains 400 g (14.1 oz) of plutonium.

Approximately 0.0006% of the spill becomes airborne as respirable aerosol. This material is released to ventilation Zone 1. Assuming a three-stage HEPA system, 10^{-6}% of the airborne material is released to the environment. Therefore, 6×10^{-12}% of the material at risk reaches the environment.

This is judged to be an anticipated accident as defined in DOE-STD-3005-YR.

Calciner Feed Makeup Tank Spill. A tank overflows spilling 757 liters (200 gallons) of solution (10% of the vessel contents) onto the floor from a height of 3 meters (9.8 ft). The spill spreads out in a safe geometry. The spill is cleaned up within 2 hours. Some of the spill is aerosolized and becomes airborne as respirable particles. There is little or no entrainment from the spill because of the quick response time. The spill contains 1.4 kg (3.1 lb) of plutonium.

Approximately 0.0005% of the spill becomes airborne as respirable aerosol. This material is released to ventilation Zone 1. Assuming a three-stage HEPA system, 10^{-6}% of the airborne material is released to the environment. Therefore, 5×10^{-12}% of the material at risk reaches the environment.

This is judged to be an anticipated accident as defined in DOE-STD-3005-YR.

Calciner Product Bin Spill. A product overflows spilling 250 kg (550 lb) of powder (10% of the vessel contents) onto the floor from a height of 3 m (9.8 ft). The spill spreads out in a safe geometry. The spill is cleaned up within 2 hr. Some of the spill becomes airborne as respirable particles. There is little or no entrainment from the spill because of the quick response time. The spill contains 2.5 kg (5.5 lb) of plutonium.

No more than 0.07% of the spill becomes airborne as respirable aerosol. This material is released to ventilation Zone 1. Assuming a three-stage HEPA system, 10^{-6}% of the airborne material is released to the environment. Therefore, no more than 7×10^{-10}% of the material at risk reaches the environment.

Loss of Off-site Power. CIF incorporates emergency and uninterruptible power sources as required to cope with a complete loss of off-site power. Therefore, a loss of off-site power will not directly result in a release of radioactivity.

This is judged to be an anticipated accident as defined in DOE-STD-3005-YR.

conditions based on the use of concrete between storage slabs to reduce neutron interaction. Therefore, a nuclear criticality accident in the plutonium storage vault is judged to be beyond extremely unlikely accident as defined in DOE-STD-3009. However, this is an area that will be further evaluated.

MEO Dissolver and Plutonyl Nitrate Storage Tank Criticality. These are geometrically favorable vessels. While the diameter of these tanks is larger than the single parameter limit for metal plutonium systems, the combination of favorable geometry and process controls is such that this is judged to be an incredible accident as defined in DOE-STD-3005-YR.

Pellet Drum Storage Criticality. The pellet drum storage array is critically safe. The designed plutonium concentration in the ceramic pellet is sufficiently low to maintain criticality safety under all postulated accidents and natural phenomena conditions. The facility is designed to preclude flooding of this area. Therefore, a nuclear criticality accident in the pellet storage vault is judged to be beyond extremely unlikely accident as defined in DOE-STD-3005-YR for the CIF.

8.2 Facility-Specific Potential Mitigating Features

See Section 2.2.

9.0 Transportation

9.1 Intrasite Transportation

Intrasite transport of radiological materials will be limited to the transport of shipping containers of plutonium metal and oxide. All other handling or use of radiological materials will be confined to the Plutonium Processing Building, the Radiologically Controlled Maintenance Shop and the Radwaste Management Building.

Plutonium metal or oxide may be received at the Plutonium Processing Building via Safe Secure Trailer (SST).

Any radiological material shipped offsite will be in the form of waste which will be packaged and shipped from either the Product Storage Building or the Radwaste Management Building in accordance with DOT requirements.

Hazardous chemicals will be received from offsite and stored in the building where they are used so that there will be no intrasite transport required. Hazardous chemicals will be used in the Plutonium Processing Building, the Radwaste Management Building, the Radiologically Controlled Maintenance Shop, the Support Utilities Building, the Cooling Tower, the Industrial Waste Treatment Facility, and the Sanitary Waste Treatment Plant.

9.2 Intersite Transportation

Intersite transportation data for off-site shipment of radioactive feed and product materials is shown in Table 9-1.

Plutonium feed to the plant is assumed to arrive in either metal or oxide form. The plutonium is assumed to arrive in standard DOT/DOE/NRC-approved 6M/2R-like shipping packages with a maximum of 4.5 kg (9.9 lb) of plutonium per package. The number of packages per shipment is 40, although the number of packages may vary depending on the amount of plutonium in a package. Since the plant throughput is 5 tonne (5.6 ton) Pu per year, the maximum number of plutonium shipments expected per year is 28 and the maximum expected total number of plutonium shipments over the life of the project is 280.

Immobilized plutonium-coated ceramic pellets are transported in a Type B 208-L (55-gal) drum (proposed Westinghouse Type B drum). Consistent with the current deep borehole report, these drums are assumed to be shipped in SSTs containing

Table 9-1—Intersite transportation data.

	Input material #1	Output material #1
Transported materials		
Type	Plutonium	^{239}Pu-loaded ceramic coated ceramic pellets
Physical form	Metal, oxide	1% Pu immobilization in 3-cm (1-in) diam cylindrical ceramic coated ceramic pellets: no Pu in ceramic coating
Chemical composition	Pu or PuO_2	See Sec. 2.1.1
Packaging		
Type	6M/2R-like	210-L (55-gal Type B) drums (proposed Westinghouse Type B drum)
Certified by	DOT/DOE/NRC e.g., Package Certificate of Compliance Number (C of C#) 9966 (SR Chalfant)	Not currently certified
Identifier	6M/2R-like	None
Package weight	86 to 286 kg (190 to 630 lb)	590 kg (1300 lb)
Material weight	max of 4.5 kg (9.9 lb) Pu	510 kg (1120 lb)
Isotopic content (%)	93% ^{239}Pu, 6% ^{240}Pu, 1% trace isotopes	1% Pu; 0.7% Gd; 98.3% ceramic-same isotopics as feed
Average shipping volume		
Quantity/year	5 tonne (5.6 ton) Pu	5 tonne (5.6 ton) of Pu loaded at 1% within the ceramic
Average number of packages[1] shipped/year	1,100	980
Estimated number of packages[1] shipped over life of the project	11,000	9800
Average number of packages[1] per shipment	40	5
Number of shipments/year	28	200
Number of shipments over the life of the project	280	2000
Routing		
Mode of transport:	SST	SST
Destination facility type	SNM vault	Deep borehole

[1] Packages are individual quantities of material, not the shipping containers in which multiple packages will be shipped.

5 drums per shipment. Since each drum contains 500 kg (1100 lb) of pellets containing about 5 kg (11 lb) of plutonium, 200 shipments per year or 2000 total shipments over the 10-year life of the program are expected.

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11.0 Glossary

List of Acronyms

Ag	silver
AGNS	Allied-General Nuclear Services
ANS	American Nuclear Society
ANSI	American National Standards Institute
ANSTO	Australian Nuclear Science Technology Organisation
NFO	Bechtel Nuclear Fuel Operations
NL	Brookhaven National Laboratory
AS	criticality alarm system
TV	closed-circuit television
n	cubic feet per minute
R	Code of Federal Regulations
:	Ceramic Immobilization Facility
	cesium
)	decontamination and decommissioning
	Design Basis Accident
	Design Basis Earthquake
	Design Basis Flood
	Design Basis Tornado
	Department of Energy
	Department of Transportation
	Defense Waste Processing Facility
	Environmental Impact Statement
	Environmental Protection Agency
	Electric Power Research Institute
	Environment, Safety, and Health
	Full-Time Equivalent
	gallons per day
	gallons per minute
	gigawatt hours
	High-Efficiency Particulate Air
	Heating, Ventilation, and Air Conditioning
	highly enriched uranium
	high-level waste
	International Atomic Energy Agency
	Institute of Electrical and Electronics Engineers
	Idaho National Engineering Laboratory
	kilovolt
	effective neutron multiplication factor

LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
Lpd	liters per day
Lpm	liters per minute
MAA	Material Access Area
MC&A	Material Control and Accountability
MEO	Mediated Electromechanical Oxidation
MOX	mixed oxide (fuel)
MPa	megapascals
MW	MegaWatt
NAS	National Academy of Sciences
NEPA	National Environmental Protection Act
NFPA	National Fire Protection Association
NMC&A	Nuclear Material Control and Accountability
NO_x	nitrous oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PAP	Personal Assurance Program
PEIS	Programmatic Environmental Impact Statement
PIDAS	Perimeter Intrusion Detection and Assessment System
PNL	Pacific Northwest Laboratory
PSAP	Personal Security Assurance Program
psi	pounds per square inch
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act
redox	reduction oxidation
ROD	Record of Decision
SAS	Secondary Alarm Station
scf	standard cubic feet
SFM	Surplus Fissile Material
SIS	Special Isotope Separation
SNM	Special Nuclear Material
SPO	Security Police Officer
SSC	Safety class Systems, Structures, and Components
SST	Safe Secure Trailer
TBD	To Be Determined
TID	Tamper Indicating Device
TPSS	Two-Person Surveillance System
TRU	transuranic
UBC	Uniform Building Code
UCNI	Unclassified Controlled Nuclear Information
UCRL	University of California Radiation Laboratory
UPS	Uninterruptible Power Supply
USNRC	United States Nuclear Regulatory Commission
VA	Vulnerability Assessment
WIPP	Waste Isolation Pilot Plant