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# Fissile Materials Disposition Program

## Alternative Technical Summary Report: Ceramic Can-in-Canister Variant

August 26, 1996

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# Fissile Materials Disposition Program

## Alternative Technical Summary Report: Ceramic Can-in-Canister Variant

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August 26, 1996

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## Executive Summary

The Department of Energy (DOE) is examining options for placing weapons-usable surplus nuclear materials, principally plutonium (Pu) and highly enriched uranium (HEU), in a form or condition that is inherently unattractive and inaccessible for use in weapons either by the host country or by a sub-national group. The potential environmental impacts of technologies to implement this objective for plutonium are described in the Fissile Materials Disposition (MD) Program's *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (PEIS).

The MD PEIS examined 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 PEIS is only part of the process of arriving at a Record of Decision (ROD) for the Fissile Materials Disposition Program (FMDP). In Phase I of this process, a number of options were eliminated from further consideration. The surviving options can be grouped into three groups of alternatives treated as reasonable in the PEIS:

(1) Plutonium burning in a once-through reactor cycle as mixed oxide (MOX) fuel followed by disposal in a repository;

(2) Immobilization or fixation in an acceptable matrix to create an environmentally benign form for disposal in a repository; and

(3) Disposal in deep boreholes (with or without prior fixation).

In Phase II of this process, variants of these alternatives are being examined in more detail to provide more complete information desired for a Record of Decision which includes consideration of technical viability, cost, schedule, and other factors.

One purpose of Phase II documents is to provide the required information for the technical cost and schedule analyses of the baseline variants plus their optional approaches. The purpose of this document is to provide the required information for one of the immobilization variants: the ceramic can-in-canister (CCC) variant with dry feed at the Savannah River Site (SRS) using HLW glass to surround the plutonium-ceramic cans. Other approaches considered in this document are a wet feed to replace the dry feed preparation operation in the immobilization step, and substitution of a hot press operation for the cold press and sinter operation.

Immobilization is the fixation of surplus fissile materials, in this case plutonium, in an acceptable matrix to create an environmentally benign form for disposal in a repository. In addition to the traditional characteristics required of an immobilization form to achieve isolation of the plutonium from the biosphere over geologic time

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periods, the immobilization form for the MD Program must also possess the property that it is inherently as unattractive and inaccessible as the fissile material from commercial spent fuel. This latter requirement is similar to the wording of the "spent fuel standard" invoked in the National Academy of Sciences (NAS) study on plutonium disposition. From this perspective, high-level wastes (HLW) or other radioactive species, such as cesium ($^{137}Cs$), can be added with the fissile material into the waste form to create a radiation field that can serve as a proliferation deterrent.

The immobilization technology considered here is incorporation of the plutonium in titanate-based ceramic pellets in cans surrounded by high level waste glass with subsequent disposal in an HLW repository. This immobilization process is shown conceptually in Figure 1, and discussed in Section 1. For this variant, the addition of SRS HLW is the source of radiation.

The immobilization of HLW in a number of ceramic waste forms has been studied extensively since the late 1970s (Boatner, L.A. and B.C. Sales. 1988. "Chapter 4 SYNROC." In: *Radioactive Waste Forms for the Future*. Lutze, W. and R.C. Ewing eds. North-Holland. Amsterdam. pp. 233-334). The ceramic form that has received the most attention is a Synthetic Rock (SYNROC) material. This is a titanate-based waste form composed primarily of zirconolite, perovskite, hollandite, and rutile phases. The ceramic waste form is attractive for immobilization purposes because of its extremely low leachability, existence of natural mineral analogues that have demonstrated actinide immobilization over geologic time scales, and the high solid solubility of actinides in the ceramic resulting in a reasonable overall waste volume.

These properties make incorporation of plutonium into ceramic an attractive option for the disposition of excess plutonium. Incorporation of plutonium into ceramic in cans surrounded by HLW glass would provide a form that would be relatively easy to store but would render retrieval of the plutonium difficult. Many of the technologies needed to prepare plutonium in a ceramic with a proliferation resistant HLW radiation spike exist today. However, the effect of chloride on the waste form ceramic formulation, the effect of formulation and redox control, plutonium reaction kinetics, optimum neutron absorber, the solubility interaction of the neutron absorber and plutonium, proper equipment design for criticality process control, and accountability after adding HLW glass are issues requiring resolution. Some of these technical issues have been addressed in various studies, to various degrees of completeness. Nevertheless research and development activities are required to verify the scalability of the production process and to demonstrate that the product is of suitable durability for disposal in a repository. The desired form of the final product will determine the extent of technical issues such as long-term criticality safety and stability of the product after repository emplacement.

In the ceramic can-in-canister variant, the disposition process begins with the transportation of plutonium feed materials (pits, metal, oxides, unirradiated reactor fuel, etc.) to the disassembly, conversion, and immobilization facility site in Department

facility space, utilities, and support systems. The front-end processing also uses existing facilities which reduces the environmental impacts from construction. The back-end processing, because it uses existing facilities as well and needs no new facilities, also reduces the environmental impact from construction. The number of additional DWPF canisters required for this case is significantly less than for the ceramic greenfield case. In the hot pressing variant, additional new facilities (but no new buildings) are needed.

Cost and schedule information for the ceramic can-in-canister at SRS variant reported here were summarized in the *Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition*, July 1996, which concludes that can-in-canister variants are the most attractive immobilization approach based on cost considerations.

# 1.0 Variant Description

## 1.1 Introduction

Immobilization is the fixation of the surplus fissile materials in an acceptable matrix such as ceramics or glass to create an environmentally benign form for disposal in a repository. In addition to the traditional characteristics required of an immobilization form to achieve isolation of the fissile material from the biosphere over geologic time periods, the immobilization form for the Fissile Materials Disposition Program (FMDP) must also possess the property that it is inherently as unattractive and inaccessible as the fissile material in commercial spent fuel. This latter requirement is similar to the wording of the "spent fuel standard" invoked in the National Academy of Sciences (NAS) study on plutonium disposition. High-level wastes (HLW) or separated cesium ($^{137}Cs$), can be added with the fissile material into the waste form to create a radiation field that increases the proliferation resistance and decreases reuse by the host nation in the following ways:

- Plutonium will be diluted with elements that must be removed by extensive chemical processing to return it to weapons-usable purity.
- The immobilized plutonium canisters will contain approximately 2 tonnes (2000 kg; 2.2 tons) of mass, thereby forcing the use of heavy equipment to move the canisters.
- A gamma radiation barrier will be added to the immobilized plutonium canister. The present concept is to add a radiation barrier that is greater than 1 Gy (100 rad) per hour at 1 m (3 ft) 30 years after fabrication.
- These canisters will then be sealed in casks and emplaced into drifts in a HLW repository where they will be monitored for 100 years before the repository is sealed.

Since the late 1970s, various ceramic waste forms have been considered for immobilization of HLW. These forms have received considerable attention because of their low leachability for actinides and fission products and the existence of mineral analogues in nature which have demonstrated immobilization of rare earths, thorium, and uranium over geologic time periods. Ceramic immobilization of simulated HLW in a Synthetic Rock (SYNROC) material has been demonstrated at full scale at the Australian Nuclear Science and Technology Organisation (ANSTO). Laboratory-scale samples have been made with greater than 30% plutonium and engineering-scale samples have been made with greater than 10% plutonium. A considerable amount of research and development has been performed on this concept including a considerable amount of work with actinides.

The ceramic-can-in-canister facility variant presented in this report describes the immobilization of plutonium in a titanate based ceramics matrix in individual cans. These cans are placed in a Defense Waste Processing Facility (DWPF) canister and glass containing high-level waste (HLW) is poured into the canister around the cans to produce a radiation field in the final product. This immobilization option uses the existing 221-F canyon building at Savannah River Site (SRS) modified to produce the plutonium ceramic cans. The canisters are filled with SRS HLW glass at the DWPF. Table 1 shows the location of each process area. This immobilization process is shown conceptually in Fig. 1 in Section 1.2.

The baseline variant uses a dry feed and cold press and sinter process for the ceramic formation operations.

Other approaches for this variant include a wet feed option and hot pressing option.

The CCC variant was selected for evaluation because it offers several process, environmental, schedule, and cost benefits over the base case Ceramic Greenfield Facility (CGF) including:

- An effective means to immobilize plutonium using existing DOE facilities. While some of these facilities will require upgrading, no new facilities will have to be constructed.
- CCC uses HLW as the radiation spike. This HLW is already slated for immobilization in borosilicate glass; therefore, this option provides a beneficial use for this waste.
- Plutonium-ceramic forms are placed in sealed stainless steel cans. These cans form a barrier between the plutonium and the HLW which is a potential concern in some of the variants with respect to intermixing actinides which would introduce the need for criticality controls.
- These stainless steel cans prevent introduction of plutonium into process systems within the DWPF reducing safeguards and security and criticality concerns.
- Using existing facilities provides significant cost and schedule benefits over other variants.
- Long term environmental concerns and costs are less than in the greenfield case with this variant because fewer additional canisters will be generated and thus fewer canisters will end up in the repository.
- Another approach to this variant (Wet feed preparation) offers the potential to substantially reduce feed preparation operations.

## 1.2 First-Level Flow Diagrams

The ceramic can-in-canister variant is shown on the first-level flow diagram (Fig. 1). The feed materials to ceramic immobilization will come from plutonium pits and the material that is stored as stabilized materials from the DNFSB Recommendation 94-1 Remediation Program. Prior to ceramic immobilization, many of the feeds require pretreatment. All of the pretreatment processing, except halide removal and oxidation which is done at Los Alamos National Laboratory (LANL), will take place in the pretreatment areas of the ceramic can-in-canister facility in glove boxes. The pretreatment will convert the feed streams to oxides. The blended oxide product will be fed to ceramic immobilization equipment also located in 221-F. The immobilized plutonium ceramic forms will be placed in metal cans. These metal cans are then placed in a DWPF canister, and transferred to the DWPF at S-Area where HLW glass will be added to create a radiation barrier.

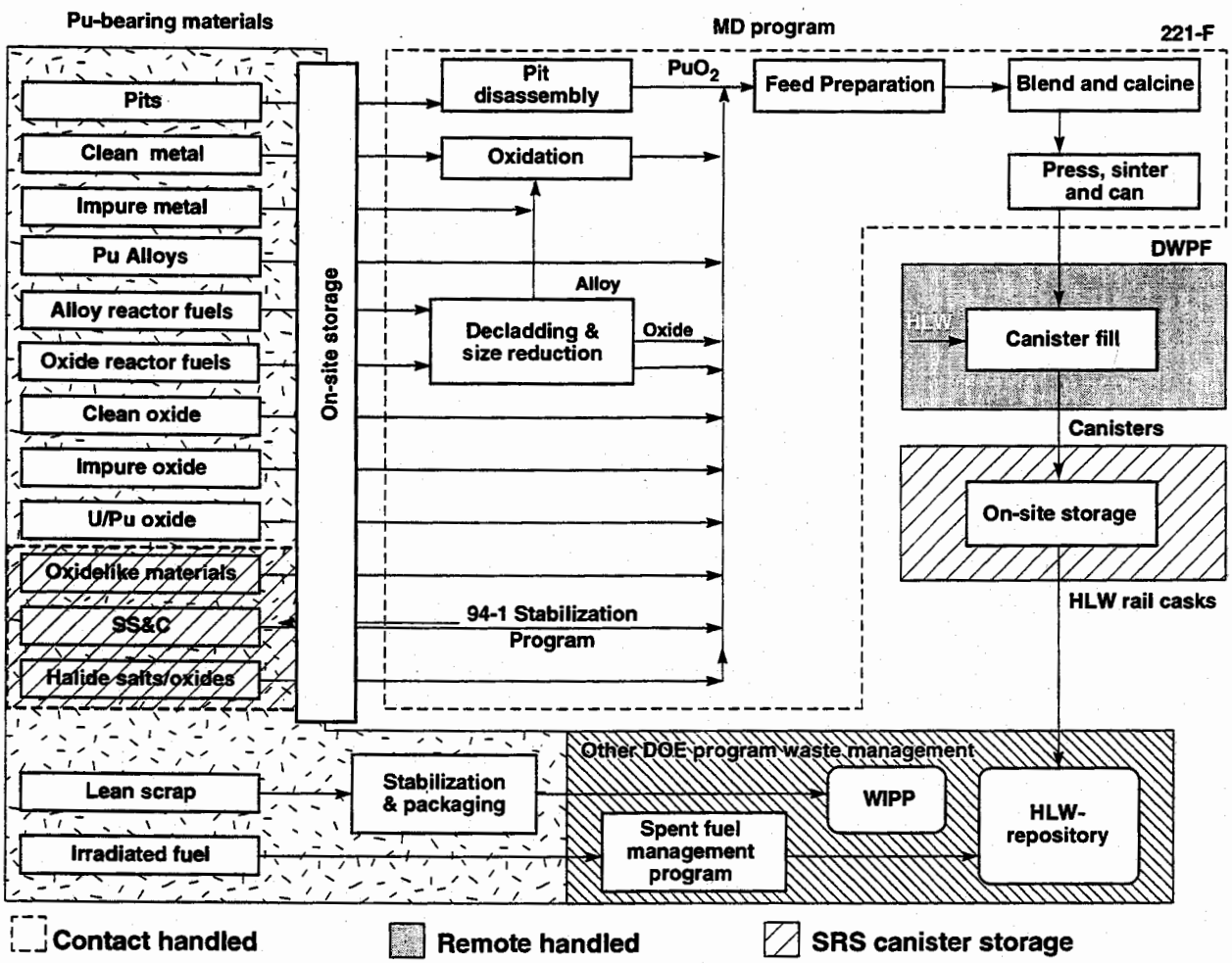



**Figure 1. First-level flow diagram, ceramic can-in-canister variant.**

### 1.2.1 Front-End Plutonium Processing—Disassembly and Conversion (D&C)

The feed materials to the plutonium disposition facility resulting from DNFSB Recommendation 94-1 storage will consist of metal (in pits or ingot form), oxides, unirradiated fuel units, and other plutonium compounds. These feed materials may need to be converted to oxides. The processing required for each feed type are:

- **Pits.** The pit is first disassembled. The metal is then removed from the pieces and converted to an oxide in the hydride/dehydride/oxidation operation. The oxide is packaged and stored as feed for the ceramic fabrication process.
- **Metals and alloys.** Metals and alloys are converted to oxide. The oxide is packaged and stored for feed to the ceramic fabrication process.
- **Metal reactor fuel.** The metal fuel could be in the form of a bundle and clad in stainless steel. Hardware and cladding are removed in a decladding operation. The metal is then converted to the oxide using the hydride/dehydride/oxidation operation. The oxide is packaged and stored as feed for the ceramic fabrication process.
- **Oxide reactor fuel.** The oxide fuel could be in the form of a bundle and clad in stainless steel. Hardware and cladding are removed in the decladding operation. The oxide is then size reduced. The oxide is packaged and stored as feed for the ceramic fabrication process.
- **Oxides.** The oxides are simply stored as feed for the ceramic fabrication process.
- **Blends.** Prior to feeding downstream unit operations, all feeds will be blended to provide a more uniform downstream feed and to minimize the amount of processing required.

### 1.2.2 Front-End Plutonium Processing-Ceramic Immobilization

The plutonium oxide material will be dissolved or size reduced in the *Feed Preparation* step so that a homogenous and fully reacted product will be obtained. In the second step, *Calcine and Fill,* the plutonium nitrate or fine particulate plutonium oxide is blended with ceramic precursors and neutron absorbers. The mixture is then calcined. In the third step, *Press and Package,* the calcined powder is densified and sintered. This portion of the operations is carried out in shielded glove boxes. The actual amount of plutonium in each can will be selected as the result of a development program. For the base case, approximately 2.6 kg (5.6 lbs) of plutonium is assumed. In the fourth step, *Can-in-Canister Fill,* the immobilized product is loaded into the canister and a canister top welded on. The actual number of cans loaded into the DWPF canisters will be selected as the result of a development program which includes a series of glass-pouring experiments. For the base case, 20 cans containing about 51 kg (113 lbs) of plutonium is assumed.

The first-level flow diagram, Fig. 1, indicates the processing steps for the front-end and back-end immobilization operations. The plutonium feed materials for this option

will be primarily blended plutonium oxide. The oxide will be received, cross-blended as required, and then converted to the ceramic form in stainless steel cans in the existing 221-F canyon building in F-Area. The cans will be subsequently loaded into a frame and placed inside an empty DWPF canister. The top head and nozzle of the canister will be welded on and the weld certified. Temporary storage may be provided in 221-F prior to transporting the canister to DWPF to be filled with HLW glass.

### 1.2.3 Back-End Processing-Adding in HLW Glass as Proliferation Deterrence

The plutonium ceramic cans in the DWPF canisters are transferred to the DWPF where the cans are surrounded by HLW glass and the canister welded shut. The filled and decontaminated canisters will be stored onsite in the interim until they are sent to final disposal.

## 1.3 Second-Level Flow Diagrams

The first-level flow diagram processing within the ceramic can-in-canister facility was expanded to two second-level flow diagrams. The two flow diagrams are designated as the front-end disassembly and conversion and the front-end ceramic immobilization and back-end processing. The front-end covers the conversions of the various feed to oxides and converting the oxides into a ceramic form. The back-end covers surrounding the plutonium ceramic cans in HLW glass.

### 1.3.1 Front-End Processing - Disassembly and Conversion

The front-end disassembly and conversion (Figure 2) converts the large number of different feed materials that come from storage to oxides. The following are more detailed descriptions for the front-end processes. These operations are common to many of the immobilization variants.

**DC-01 Truck and CRT Unloading.** Material shipments will be delivered to a truck and container restraint transport (CRT) unloading dock where the delivery vehicles safe secure trailer/transport (SST) will be washed and smear checked. The packaged plutonium cargo will then be unloaded. Initial assessments of radiation levels and container breaches are made during the unloading process to ensure a safe configuration for temporary storage while awaiting receiving and inspection. Shipping papers are checked, tamper indication devices (TIDs) inspected, and neutron counts are made on the packages. Emptied CRTS and shipping containers are inspected, decontaminated if necessary, and prepared for return.

**DC-02 Off-Site Receiving/Shipping.** Receiving includes material confirmation, accountability, safety, and inventory measurements. The plutonium cargo is unpacked from the shipping containers, and repackaged in a suitable storage container in concert with the measurement activities. The repackaged material is placed in the storage vault where it will await processing. Contaminated containers are decontaminated in a decontamination station where the material is retrieved and repackaged.

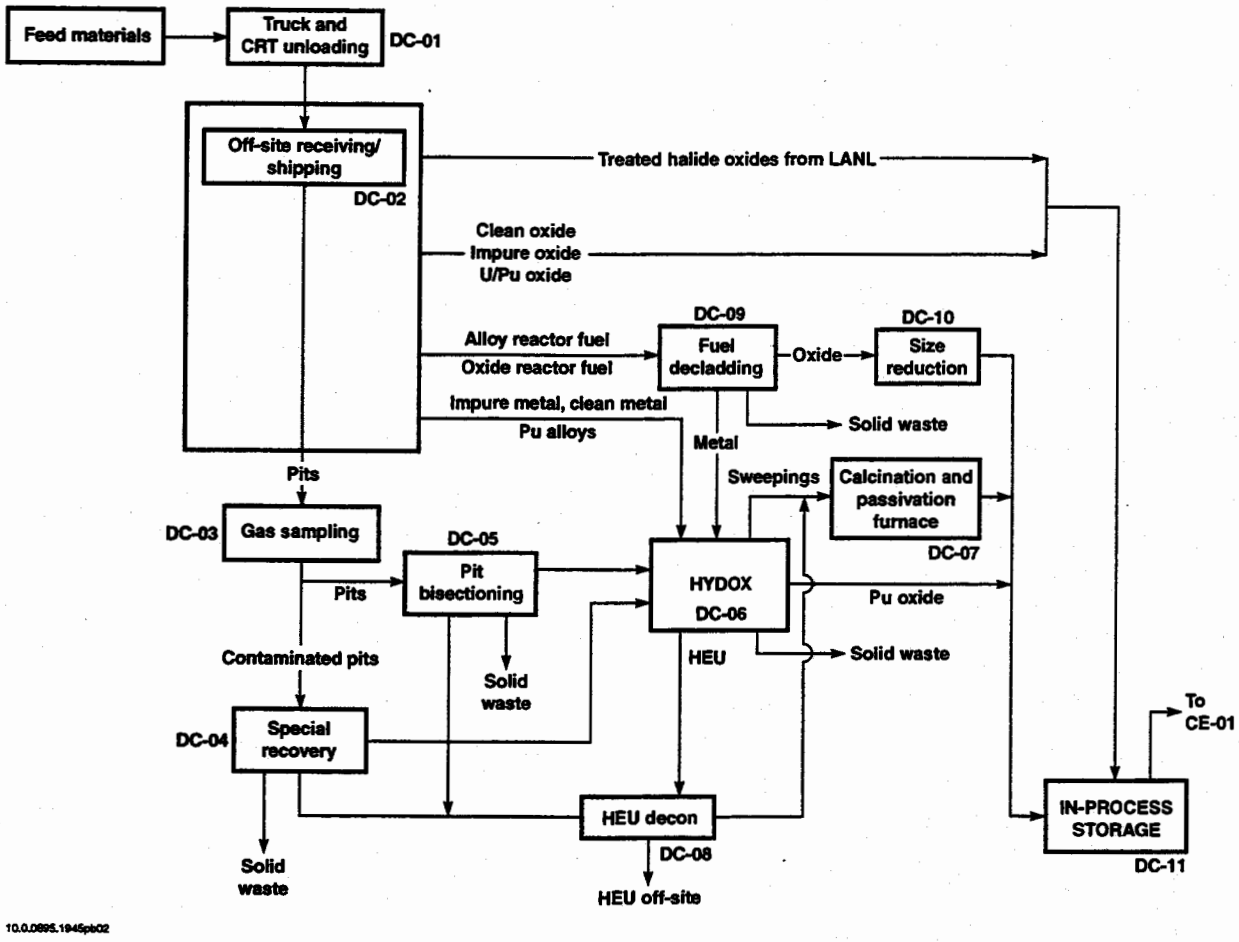



**Figure 2. Second-level flow diagram, ceramic can-in-canister, front-end disassembly and conversion.**

**DC-03 Gas Sampling.** All pits are gas sampled to check for potential contamination. Contaminated pits are sent to special recovery, while uncontaminated pits are sent to pit bisectioning.

**DC-04 Special Recovery.** Contaminated pits are disassembled and the resultant parts are cleaned. Plutonium-bearing parts are separated from other material. This operation consists of the following glove boxes and operations: disassembly, tool storage, bakeout, nondestructive analysis (NDA), off gas treatment, and sub-component packaging.

**DC-05 Pit Bisectioning.** Pits are bisected to allow for plutonium removal using hydriding. This operation consists of one workstation for receiving and one workstation for the pit bisector.

**DC-06 Hydride/Dehydride/Oxidation.** Plutonium is reclaimed from the bisected parts and converted to oxide. The hydride/dehydride process is the method used to reclaim the plutonium and produce metal. The hydride/dehydride/oxidation method

is used to reclaim the plutonium and produce oxide. This operation consists of several accountability workstations and a workstation for the hydriding unit.

**DC-07 Calcination and Passivation Furnace.** A calcination and passivation furnace will convert glove box sweepings into stable oxide. This operation will consist of an open workstation and a workstation containing the passivation furnace.

**DC-08 HEU Decontamination.** HEU having economic value will be decontaminated with an acid bath, rinsed, and packaged for shipment to a reprocessing facility.

**DC-09 Fuel Decladding.** The major feed to this operation is zero power physics reactor (ZPPR) fuel. ZPPR fuel is stainless steel clad metal fuel in the form of thin plates. The decladding operation will employ a planning operation where one side of the cladding will be removed. The fuel element will then be sent through a device that will pull the stainless steel hull away from the metal fuel. The primary waste generated in this operation will be the stainless steel cladding hulls and spent tool bits. The glove box for this operation has a receiving workstation, a planing workstation, and a dehulling workstation.

**DC-10 Size Reduction.** The oxide fuel element pellets will be fed into a vibratory grinder. The vibratory grinder uses alumina pellets as the grinding media. A very small fraction of the alumina pellets is eroded away with each batch. This adds a small amount of alumina to the ground oxide. New alumina pellets are added periodically to maintain a set volume of grinding medium. The glove box for this operation has a loading workstation, an unloading workstation, and a workstation that contains the grinder.

**DC- 11 In-Process Storage.** Oxide will be removed from the glove box line and placed into storage prior to being fed to downstream unit operations.

### 1.3.2 Front-End Ceramic Immobilization Processing

The front-end ceramic processing (second-level flow diagram, Figure 3) takes the pretreated feed materials and converts them to ceramic for storage and disposal. The following are descriptions for the front-end ceramic unit operations.

**CE-01 Feed Preparation.** Incoming plutonium oxide will be cross-blended to prepare a consistent downstream feedstock while minimizing the amount of processing required. The blended $PuO_2$ powder will be size reduced by vibramilling to meet specifications for ceramic immobilization processes. Ground oxide powder will be checked to see if particle size meets specification before transferring to calciner feed makeup (CE-02). Size characterization will be determined by an appropriate technique such as BET, SEM, or microsieving.

**CE-18 Crushing and Milling.** Pellets which have cracked after cold pressing or after sintering are crushed in a press and then ground in a milling device. After sufficient grinding, the powder is then returned to *Milling and Granulation* (CE-14).

**CE-30 Dry Pretreatment Off-Gas Operation.** The dry pretreatment off-gas system will reduce the quantity of radioactive particles in the vapors that evolve from the sizing/grinding step and melter before release to the ventilation exhaust system. Off gases will be drawn, quenched, and discharged into the off-gas condensate tank. The quenched gases from the off-gas condensate tank will be scrubbed in a steam atomized scrubber and cooled by a chilled water condenser. Gases from the condenser will then pass through the high-efficiency mist eliminator (HEME) and a set of HEPA filters before discharge into the exhaust tunnel and through a sand filter before the exhaust stack. Where the potential for plutonium and plutonium oxide dusting will exist, air flow will pass through filters before entering the ventilation ducts.

**CE-33 Can Loading.** Plutonium ceramic pellets are loaded into 12 cm (4.8 in.) diameter by 0.58 m (23 in) cans.

**CE-06 Interim Can Storage.** Cans loaded with the plutonium ceramic will be stored in storage racks in a 3rd level vault in the 221 F canyon building until they are ready to be placed in the DWPF canister.

For inventory and third party inspections, the individual cans can be moved to a surveillance station located in the canyon area where specific cans may be monitored and inspected as required.

**CE-34 Place in Canister.** The small plutonium-ceramic cans will be placed in a frame or holding rack, that will subsequently be placed inside an open DWPF canister. The canister head is then immediately welded into place. Refer to Figure 4 for a conceptual cut-away view of the DWPF canister containing plutonium cans. The final production rack has not yet been designed. A number of simple and quite feasible concepts are being considered to increase the intrinsic proliferation resistance of the container. For example, to prevent surgical extraction of cans by the use of linear shaped charges, the cans could be welded into sturdy cages which are welded to the internal holding rack. The base rack and cage would be constructed of a strong metal, perhaps stainless steel rebar—the size and strength of which would be determined by a threat risk analysis. An expanded metal shield could then be tack welded around the cage. The base rack would provide support and connect all of the cages into a single element. After the rack is placed into the canister it could be welded to the inside of the canister, then the top head would be welded onto the canister body. The loaded canister would be stored within 221-F until it is shipped to DWPF.

**CE-08 New Canister Weld and Test .** After the plutonium ceramic cans have been loaded into the canister, the head of the canister will then be welded to the body of the canister and the weld tested using procedures now used during off-site fabrication.

### 1.3.4 Onsite Canister Storage

The Glass Waste Storage Building (GSWB) Unit 1 will store the DWPF glass waste containers until a HLW repository is available. The building has been constructed and is located near the DWPF. Glass Waste Storage Building Unit 1 has a capacity of 2286 canisters. Glass Waste Storage Building Unit 2 will be built as Glass Waste Storage Building Unit 1 fills with HLW-glass canisters or when plutonium ceramic-filled HLW glass canisters are ready for storage. This new facility will be built to Category I seismic requirements and will encompass safeguard (nonproliferation) controls. Because Glass Waste Storage Building Unit 2 is scheduled to be built in support of the DWPF mission, only the upgrades required to facilitate safeguards and security are considered as costs to this project.

Approximately 6000 canisters of HLW glass will be prepared within the DWPF to accomplish the high level waste mission. To accomplish the plutonium disposition mission for the assumed 50 tonnes (56 tonnes) of plutonium, approximately 1000 of these 6000 canisters would contain cans of plutonium ceramic. The present schedule indicates that the 1000 plutonium ceramic canisters can be produced periodically or randomly during the HLW glass canister productions without significant impact in the HLW mission. Additionally, the plutonium containing canisters could be stored randomly among the HLW canisters in the Glass Waste Storage Building (GWSB). Externally, the canisters with plutonium will appear identical to the HLW-canisters. The only markings to identify the plutonium ceramic canisters from the high level waste canisters will be the unique bar code number on the side of the canisters, which are not visible by looking down into the storage cells. Each individual storage cell is plugged with a 1410 kg (3,100 lb) reinforced concrete plug that requires a specially designed grapple to lift. There is no equipment in the GWSB with which the plug or a canister could be removed since removal can only be accomplished with equipment stored in DWPF.

The concrete vault area for the GWSBs is designed to contain glass waste canisters underground and protect personnel, the public, and the environment. The vault is an earthquake-resistant and tornado-resistant concrete structure. Radiation shielding protection will be provided by concrete walls, earth embedment, and a concrete deck that forms the floor of the operating area. The stored canisters will be protected against external damage and cooled to prevent internal heat buildup.

Radioactive decay heat from the canisters will be removed by the forced air exhaust system. The exhaust air will be passed through the HEPA filter ventilation system and then discharged to the atmosphere through a stack. No condensate is expected to accumulate in the ventilation system sump; however, if condensate accumulates, it will be drummed, monitored for radioactivity, and treated. Depending on radioactivity levels, the condensate will be released or sent to F- and H-Areas Effluent Treatment Facilities.

## 1.4 Facilities

This section describes the process areas and facilities available for this variant and explains the modifications to existing facilities that will be needed. This variant takes maximum advantage of existing buildings and processes. In this way, no completely new facilities will be required. Table 1 lists the physical locations at SRS for ceramic can-in-canister processes.

Front-end processing and pretreatment operations and ceramic immobilization take place in F-Area (see Fig. 5) where facilities are designed and built to handle large quantities of plutonium and have systems to maintain criticality control and safeguards systems to maintain accountability and security.

The floor area required for the front-end primary plutonium processing function and ceramic immobilization is approximately 2045 sq m (22,000 sq ft) for plutonium processing, 1485 sq m (16,000 sq ft) for direct plutonium processing support, and 6875 sq m (74,000 sq ft) for auxiliary support functions. The use of the available space in 221-F for this function is being evaluated.

The addition of a high-level waste spike and final immobilization operations take place in S-Area (see Figure 6) where existing DWPF facilities will be upgraded and modified to support storage and handling of plutonium ceramic can-in-canisters through the entire immobilization process. Safeguards and security criteria will have to be upgraded in selected portions of the DWPF buildings.

Primary areas of the DWPF Service Building that are expected to need upgrades to accommodate the plutonium canisters are shown in Figure 7 and 8. Additionally, CCTVs will be needed in the DWPF Vitrification Building and possibly GWSB #2.

**Safeguards and Security.** Safeguards and Security upgrades are required in S-Area to accommodate the processing of special nuclear materials.

*Protection of special nuclear material and vital equipment.* Category I special nuclear material must be used or processed within material access areas requiring a material surveillance program to detect unauthorized material flows and transfers. The pretreatment facilities in F-Area meet the safeguards requirements established by DOE Order 5630.13A, *Master Safeguards and Security Agreements.*

The DWPF Vitrification Building and applicable portions of the Service Building and Glass Waste Storage Building Unit 2 will be upgraded to the criteria of DOE Order 5630.13A, as required for the attractiveness level of the material. The material stored in GWSB #2 is assumed to be Category IV-E with the addition of HLW to the canister containing the plutonium ceramic cans.

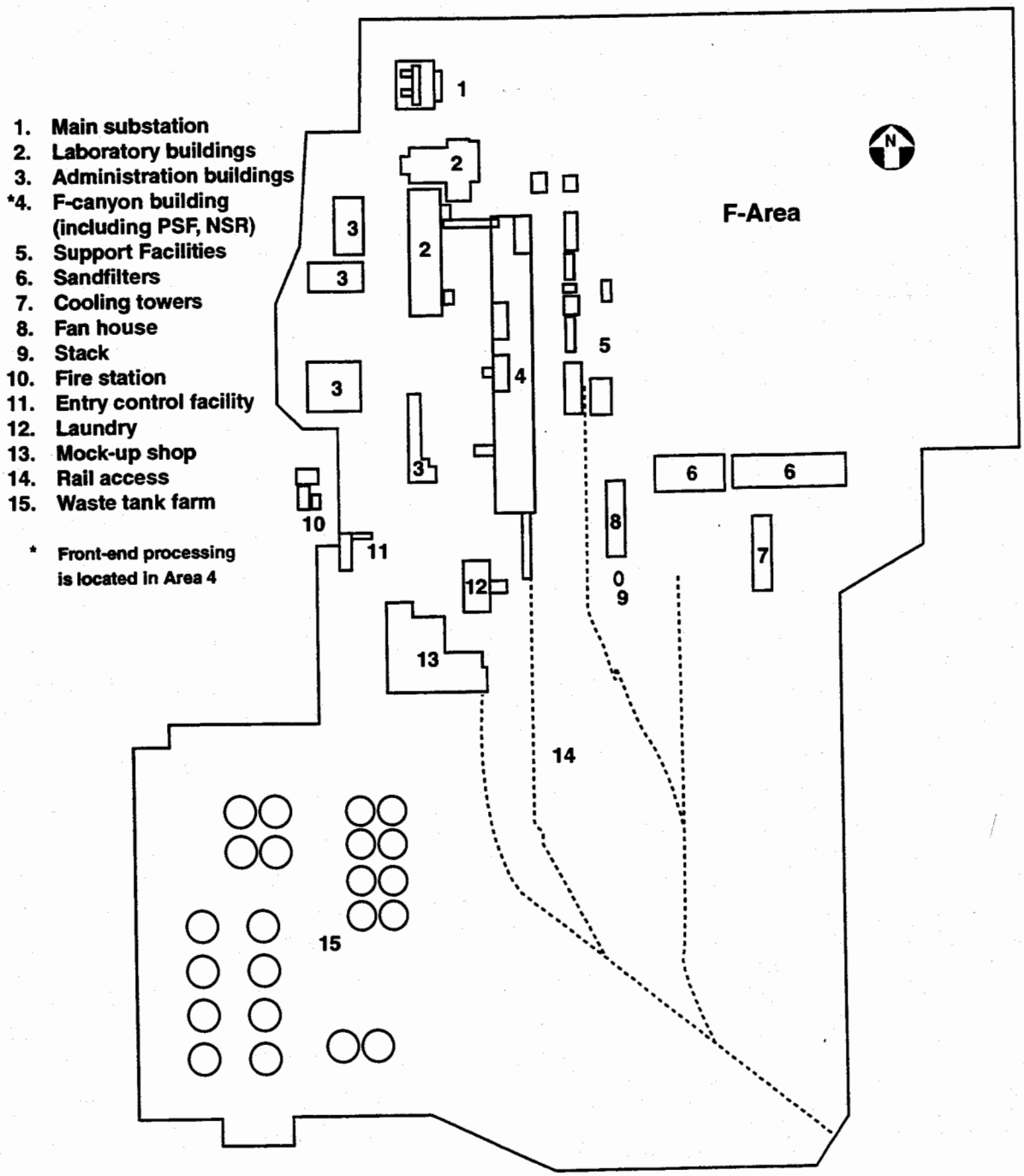



Figure 5. F-Area layout.

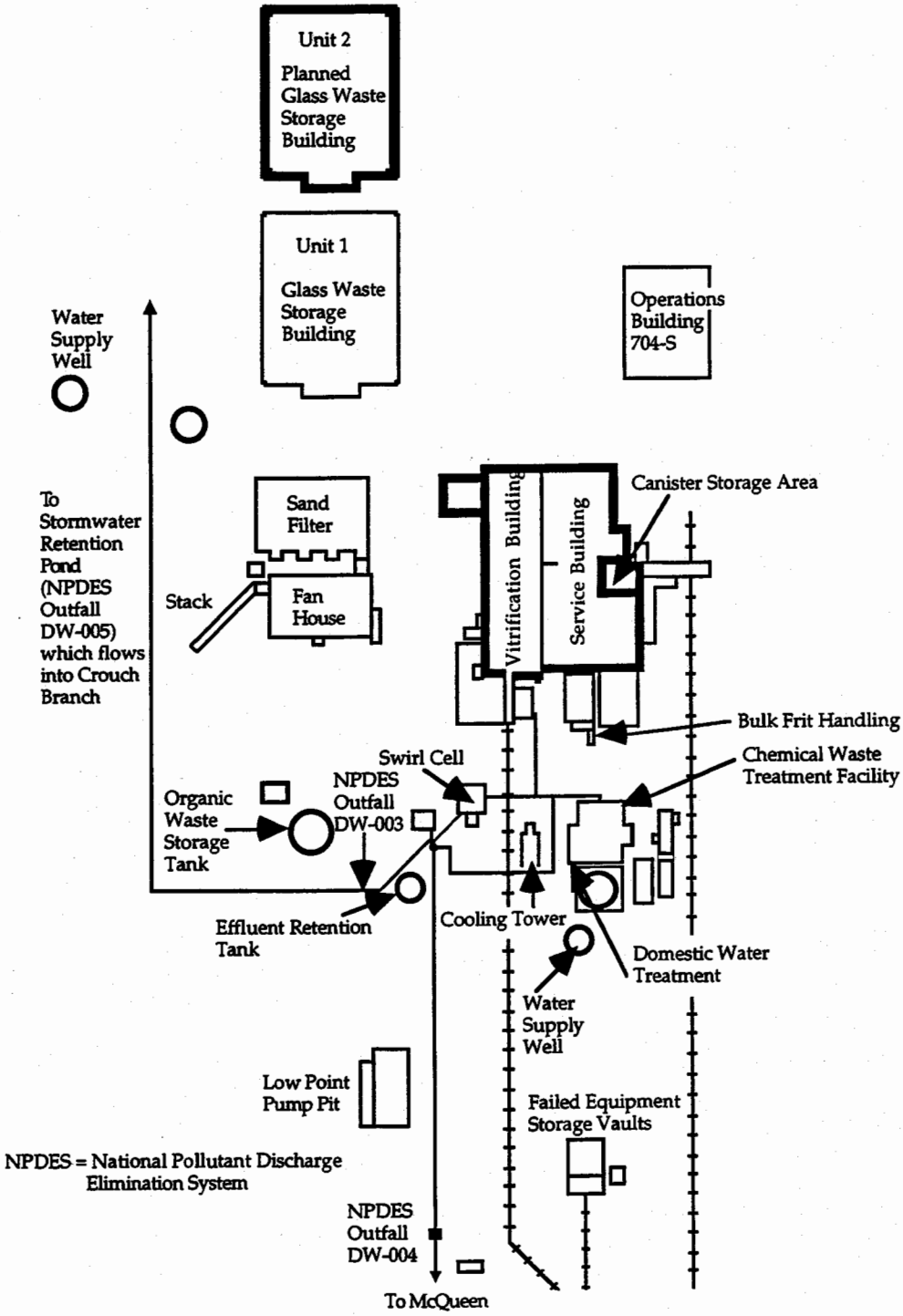
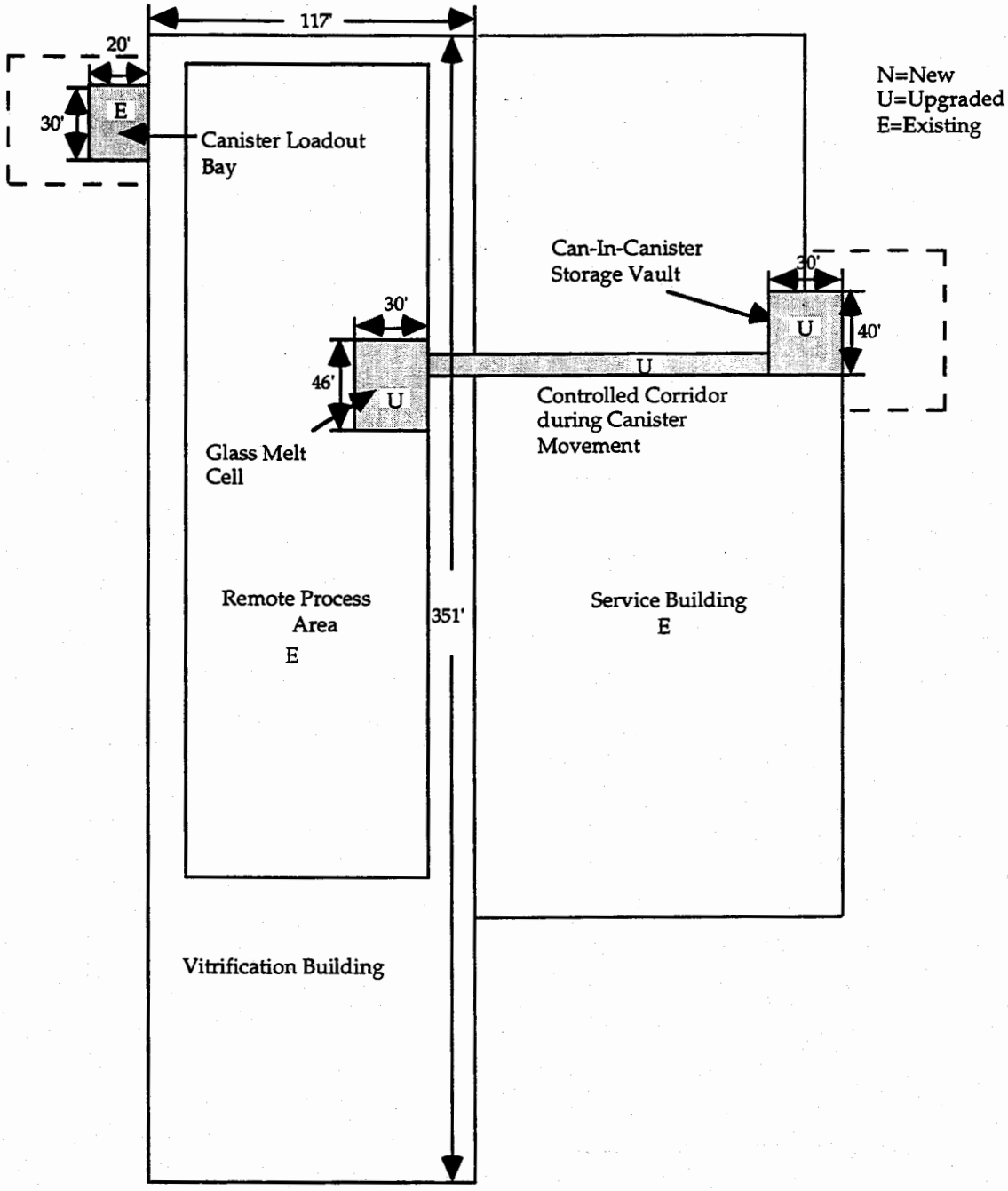



**Figure 6. S-Area layout showing plutonium canister storage area at DWPF.**




Note: Existing facility - Only upgrades are required

**Figure 7. Plutonium canister interim storage vault and transfer corridor to DWPF.**

will be the reviewing agency. For scheduling purposes, the time required is assumed to be the same for the NRC and the DNFSB.

The NRC regulation (10 CFR 71) establishes the requirements for packaging, preparation for shipment, and transportation of licensed material. This regulation also defines the procedures and standards for obtaining NRC approval of packaging and shipping procedures for fissile material and Type B quantities of other licensed materials. (A quantity of weapons-grade plutonium in excess of ~25 mg ($8.8 \times 10^{-4}$ oz) constitutes a Type B quantity per 10 CFR 71.) 10 CFR 71 incorporates, by reference, DOT regulation 49 CFR 170-189. Whenever possible, the DOE transports radioactive materials under NRC regulations. However, for the purpose of national security, 49 CFR 173.7 (b) allows the DOE to ship radioactive material under escort by personnel designated by the DOE , thus waiving the DOT regulations in 49 CFR 170-189. This exemption, however, is rarely used and its use is not anticipated for FMDP.

There are different requirements for the transportation of nuclear materials depending upon if the movement of materials is considered onsite (intrasite) vs. offsite (intersite). Currently there are no Federal regulations governing onsite transport of hazardous materials. For DOE facilities, onsite and offsite transportation requirements are defined in DOE Order 460.1: "Onsite is any area within the boundaries of a DOE site or facility that is fenced or otherwise access-controlled" and "Offsite is any area within or outside of a DOE site to which the public has free and uncontrolled access".

**Transportation System.** The transportation system is described below and shown graphically in Figure 9. There are two intersite transportation segments for the end-to-end immobilized option. The intrasite transportation occurs at the Savannah River Site (SRS) since the front-end processing and immobilization facility are co-located.

**Intersite Transportation Segment #1**

During this segment, fissile material located at various DOE facilities is transported to the onsite temporary storage at SRS. The materials requiring transport include: pits, clean metal, impure metal, impure oxide, clean oxide, alloys, U/Pu oxide, halide oxides, and reactor fuel.

*Package Description*. The pits under the FMDP will be stored and transported in the Model FL or the AT-400A container. Different pits can utilize these containers by using different internal fittings.

The other plutonium material is assumed to be at onsite storage at the various DOE facilities. The material and package is assumed to meet *The Criteria for Safe Storage of Plutonium Metals and Oxides stated in the DOE standard DOE-STD-3013-94*, July 1996. This criteria states that all plutonium metal and oxides (excluding pits) over 50 wt% plutonium shall be stored in a storage container that includes a minimum of two nested hermetically sealed containers to serve as barriers to isolate the stored materials from the environment and to prevent contamination release.

**Table 3. Parameters for Intersite Transportation Segment 2**

| Data | Contents with Pu cans and HLW |
|---|---|
| **Packaging** | |
| Type | DWPF canister with SRS HLW rail cask |
| Certifying agency | not currently certified |
| Wt Pu/canister | 50 kg (110 lb) |
| Plutonium ceramic and glass material weight/canister | 1680 kg (3700 lb) |
| Canisters/rail cask | 5 (maximum)/1 (minimum) |
| **Average Shipping Volumes** | |
| Quantity material/year | 5000 kg (11,000 lb) |
| Shipments/year | 20 (minimum)/100 (maximum) |
| Canisters for life of project | 1000 (200 incremental) |
| Shipping containers over life of project | 200 (40 incremental) |
| **Routing** | |
| Mode of transport | Commercial rail or truck |

### 1.5.2 Domestic Safeguards

The FMDP has established two major Safeguards and Security (S&S) criteria. Resistance to theft or diversion by unauthorized parties (Criteria 1, domestic) and resistance to retrieval, extraction, and reuse by the host nation (Criteria 2, international) consider domestic and international perspectives based on two important factors: the "threat" addressed by these criteria, and the "regimes" that exist to address these threats.

The primary purposes of FMDP domestic safeguards and security is to protect and provide nonproliferation assurance of fissile material and classified information, along with instilling public and international confidence in those actions. Domestic safeguards and security is composed of two subsystems, nuclear materials control and accounting, and the physical protection of fissile material and nuclear weapons components against threats of diversion, theft, and radiological and toxicological sabotage. Domestic safeguards primarily address unauthorized actions perpetrated by individuals and/or sub-national groups (insiders or outsiders).

The detection and prevention of an unauthorized access or removal attempt (e.g., theft or diversion) depends on the levels of safeguards and physical protection at the facility. In general, safeguards are more easily applied and more readily verified when materials are in the form of discrete, uniquely identifiable items, as opposed to difficult to measure materials in bulk form, as may be found with chemical processing activities. The DOE, and the NRC, have established requirements for domestic safeguards and security. In the U.S., both the DOE and NRC have specific orders or regulations that

identify physical protection, and material control and accountancy. There are measures that must be followed, as determined and negotiated based upon the category and attractiveness of the fissile material.

The responsibility of the domestic regime is to prevent unauthorized access to its material either by individuals or groups within its own weapons complex (such as disgruntled workers) or by national or international terrorist groups, criminal organizations, etc.

The domestic threats can be condensed as: *theft* (e.g., unauthorized removal of material by an individual or group outside of the host nation's weapons complex), *diversion* (e.g., unauthorized removal of material by a member of the host nation's own weapons complex), *retrieval* (unauthorized access by outside individuals or groups after final disposition), and *conversion* (the conversion of retrieved material into weapons usable form).

### 1.5.3 International Safeguards and Non-Proliferation

The responsibility of the international safeguards regime is to prevent the host country from diverting, retrieving, or converting material that has been declared surplus. Thus, the context of S&S should be viewed not only from the U.S. DOE perspective, but from the perspective of another country looking at the U.S.

The international threats can be condensed as: diversion (unauthorized removal of material by the host nation itself in violation of the international regime before final disposition has taken place), retrieval (unauthorized access by the host nation in violation of the international regime after final disposition), and conversion (the conversion of retrieved material into weapons usable form).

This area includes FMDP activities which may be affected by international and/or bilateral agreements to include areas which may be subject to the International Atomic Energy Agency (IAEA). International safeguards are composed of two subsystems, nuclear materials accountancy and materials containment and surveillance, which are required to satisfy international inspection agreements. International safeguards and security is focused on the independent verification of material use through material accountancy programs, and containment and surveillance systems.

The IAEA has established safeguards criteria for the materials control and accountability and the containment and surveillance of fissile material. The requirements in this area are derived from IAEA statutes and informational circulars. The IAEA, in concert with member states (most notably the U.S.) has also developed recommendations for states to develop appropriate domestic security measures, but they are recommendations, and not audited requirements. The safeguards criteria and security recommendations are typically based on practices followed in the U.S. and agreed upon by the IAEA member states.

### 1.6.2 Hot Press in Bellows

Another approach to using cold pressing and sintering to fabricate the plutonium ceramic is to use a one step fabrication, namely hot pressing or hot isostatic pressing. This would be more costly than cold pressing and sintering, but would provide a denser and more uniform product. As a result, few if any pellet failures are expected thus eliminating the need for *Crushing and Milling* (CE-18).

In this option, the first-level flow diagram remains the same, but the second level flow diagram is revised. For the hot pressing in bellows option, the following changes are made to the baseline flow diagram (Fig. 3): *Bellows Filling and Closure* (CE-04) and *Hot Pressing* (CE-05) replace *Milling Granulation* (CE-14), *Pellet Pressing* (CE-15), *Screening/Inspection* (CE-16), and Sintering (CE-17). All other processes remain the same as discussed in Section 1.3.

**CE-04 Bellows, Filling & Closure.** The dried and calcined ceramic precursor material loaded with plutonium will be removed and transferred to the bellows with minimal or no contamination to the outside of the bellows. Bellows will be connected to the powder loading area by means of a sphincter seal. This seal will minimize airborne contamination outside of the bellows. After the powders have settled, the bellows will be removed from the sphincter seal and a bellows lid with off-gas tube already attached will be attached. The lid will be welded into place and the outside of the bellows will be decontaminated as necessary to minimize the spread of contamination in further processing.

**CE-05 Hot Pressing.** Welded and filled bellows will then be transferred to the hot-press assembly. The off-gas tube is attached to the off-gas system. The bellows assembly will then be heated slowly to about 1200°C (2200°F) and pressed at 14,000 k Pa (2,000 psi) for about 45 minutes. The product will be allowed to cool slowly to a temperature that can be handled remotely (600–800°C [1180–1470°F] at the surface). After pressing, the vent tube will be removed or bent flat. The product bellows will be placed into a muffle furnace for annealing. This operation would take up to 12 hours and would operate in parallel to the hot-pressing operation. The muffle furnace will be held between 600°C and 800°C (1180-1470°F) until a number of product bellows have been loaded. Temperature will be ramped to about 1000°C (1830°F) and held for 6 hours. The furnace will then be cooled slowly to about 400°C (750°F) over a period of 6 hours. After hot pressing, the compressed bellows will be approximately 6.4 (2.5 in) diameter by 2.5 cm (1 in) high.

# 2.0 Criteria Assessment

## 2.1 Introduction

Section 2 examines technical issues associated with each step of the immobilization process from front end processing to the final repository. This disposition variant is qualitatively assessed against the following eight criteria:

- Resistance to theft and diversion.
- Resistance to retrieval by the host nation.
- Technical viability.
- Environment, safety and health compliance.
- Cost effectiveness.
- Timeliness.
- Fosters progress with Russia and others.
- Public and institutional acceptance.

This end-to-end immobilization variant combines functions from facilities previously described in and bounded by the PEIS process currently under way. For front-end processing in this variant, elimination of aqueous recovery lines results in significant reductions in aqueous waste solutions, processing equipment, associated facility space, utilities, and support systems. The use of existing facilities at SRS reduces the environmental impact from construction for both front-end and back-end processing because new facilities are not needed. The number of additional DWPF canisters required for this case is significantly less than for the greenfield cases.

## 2.2 Resistance to Theft and Diversion

### 2.2.1 Applicable Safeguards and Security Requirements and Measures

**Domestic Theft and Diversion (Criteria 1).** This criterion evaluates the system protection and resistance to theft by an outsider or an insider, and retrieval after final disposition by outside groups. Theft or diversion of material refers to both overt and covert actions to remove material from the facility. This is perpetrated by unauthorized parties including terrorists, sub-national groups, criminals, and disgruntled employees.

Protection of the material and information from these parties is a domestic responsibility, not an international one. There are a number of possible adversary groups with different motivations and capabilities. The actions could be overt such as a

direct attack on a facility or they could involve covert measures that might utilize stealth and deception as well as possible help from an "insider." It is assumed that all facilities will meet the necessary safeguards and security requirements and that existing measures will help mitigate any risks. The threats to facilities will be different depending on the form of the material, the activities at the facility, and the barriers to theft (both intrinsic to the material and also to the facility). For each of the facilities in this variant, a brief discussion is presented below of the potential risks to theft.

The safeguards and security requirements for this variant are primarily driven by the attractiveness of the material as defined in DOE Order 5633.3B and/or NRC requirements (10 CFR 73 and 74).

**Material Form.** An essential element in assuring the proliferation resistance of fissile material is the safeguards and security applied to the material, based on its form. The form of the material reflects the intrinsic properties of the material that dictates its attractiveness for its use in nuclear weapons. However, the form of the material alone does not provide proliferation resistance. Safeguards and security systems should be applied in a graded approach based on the form of the material and its attractiveness.

**DOE Category and Attractiveness Levels.** 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 4 comes from the DOE Order for *Control and Accountability of Materials* (5633.3B) dated 9-7-94.

The level of protection accorded to an attractiveness level is dependent on the quantity or concentration of the material. Each safeguards and security 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 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.

Category I and/or strategic fissile material must be used or processed within a DOE approved Materials Access Area (MAA). The requirement for an MAA and vault-type room storage may mean that certain physical protection enhancements will be needed beyond what currently is present at existing facilities. The physical barriers at the protected area boundary consists of two barriers with a redundant intrusion detection system. The protected area boundary must also provide for a barrier from unauthorized vehicle penetration. The access control points into the protected area must be made of a bullet resistant material. Duress alarms will be necessary at all manned access points. There will be enhanced entrance/exit inspections of personnel, vehicles, and hand-carried items. MAA/protected area portals typically have metal detectors, fissile material detectors, and x-ray machines for hand-carried items.

**Table 4. DOE nuclear material attractiveness and safeguards categories for plutonium.**

| | Attract-iveness level | Pu/U-233 category | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV[a] |
| **Weapons**<br>Assembled weapons and test devices | A | All quantities | N/A | N/A | N/A |
| **Pure products**<br>Pits, major components, buttons, ingots, recastable metal, directly convertible materials | B | ≥2 kg (≥4.4 lb) | ≥0.4 <2 kg (≥.9 <4.4 lb) | ≥0.2 <0.4 kg (≥.4 <.9 lb) | <0.2 kg (<.4 lb) |
| **High-grade material**<br>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 (≥.9 <4.4 lb) | <0.4 kg (<.9 lb) |
| **Low-grade material**<br>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**<br>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 |

a/ The lower limit for category IV is equal to reportable limits in this Order

### 2.2.2 Identification of Diversion, Theft, or Proliferation Risks

Tables 5–7 following this narrative provide information about the flow of plutonium through this variant, along with a description of the material and its changing attractiveness levels.

*221-F-Area Facility.* The 221-F facility is a safeguards Category I facility. A number of different forms are received by the plutonium processing area (Cat. I-B through II-D). This material is converted into oxide (Category I-C through II-D). Initially within this facility, most of the material is in a very attractive form with minimal intrinsic barriers. There are a large number of processing steps that provide increased opportunities of covert theft. Since many of the processes involve bulk material the accountability measures will involve bulk measurements. Within the facility material will be changing form and concentration, decreasing the basic levels of protection category and attractiveness. At the ceramic fabrication area the oxide is mixed

*S-Area Facility (DWPF).* In the initial stages of handling and processing, S-Area facility is assumed to be a Category I facility. Within the facility material will be changing format concentration, decreasing the protection category and attractiveness. With the addition of a self-protecting property the material meets the definition for Category IV-E.

At DWPF the plutonium cans are surrounded by HLW glass reducing the attractiveness level. The final product is encased in a stainless steel canister and contains approximately 50 kg (110 lb) of plutonium, at an average plutonium concentration of 3% when the surrounding HLW glass is included.

Once the immobilized material has been given a self-protecting barrier by the introduction of HLW glass the safeguards and security requirements are significantly reduced as the Category is now that of IV-E (highly radioactive material, i.e., a radiation dose rate in excess of 1 Sv (100 rems) per hour at a distance of 1 m [3 ft], is considered as Category IV-E). If after a period of time (approximately 100 years) the self protecting barrier no longer meets the above radiation dose criteria then it may be considered as Category III-D, depending upon the quantity of fissile material present and the additional barriers that may exist at that time (as is true with commercial spent fuel). Protection against radiological sabotage should likewise not be significantly different than for existing commercial spent fuel.

The can-in-canister variant is self-protecting and proliferation resistant with the high level waste glass in the canister which surrounds the plutonium ceramic cans. However, additional proliferation resistance measures are being investigated to potentially reduce the risk of theft and retrieval of the plutonium ceramic cans from the filled canisters by unauthorized outsiders such as terrorists and subnational groups. Potential proliferation resistance measures that are being investigated include, but are not limited to, the following:

- The cans could be encased inside a cage of steel re-enforcing bars (rebar) and the cans welded to the rebar. Steel plates will be on both the top and bottom of the cans, these plates could also be welded to the cans. The steel rebar cage could then be enclosed using a sheet of perforated metal. These welds will hold the cans in position within the canister. The welds will keep the cans attached to the rack during an activated explosive charge. The expanded metal will hold a quantity of high level waste loaded glass next to the cans. The cage structure would make the cans even more difficult to remove from the canister.

- A special coating could be developed which could be applied to the exterior of the cans and the perforated metal cage. This special coating would chemically bond to with the high-level waste glass when it contacts the cans and the expanded metal cage. As a result, some high level waste glass would remain surrounding the cans and the expanded metal following an activated explosive charge.

**DC-01 Truck and CRT Handling and DC-02 Receiving.** The operations in this area involve material handling techniques which have been utilized throughout the DOE complex for many years. Initial accountability confirmation analyses utilize nondestructive analysis technology that has been routinely used for production operation. Storage of shipping containers in a facility with an automated stacker-retriever system has been demonstrated at several sites. Accurate accountability measurements will utilize standard nondestructive methods such as calorimetry and segmented gamma scanning.

**DC-03 Gas Sampling.** The internal gas pits will be sampled utilizing a laser system similar to one utilized in production operations at the Pantex site. Improvements in the system are currently under development at the Los Alamos National Laboratory.

**DC-04 Special Recovery.** The processes for handling contaminated pits have been demonstrated on a production-scale at the Los Alamos National Laboratory.

**DC-05 Pit Bisectioning.** Disassembly of pits has been performed on a production-scale at the Rocky Flats plant using modified lathe technology. Improved techniques and equipment which cut the pits without the formation of chips and turnings are under development at Lawrence Livermore National Laboratory.

**DC-06 Hydride/Dehydride/Oxidation.** This process has been demonstrated by unit operation on both a full-scale and engineering test scale at LLNL. Hemishells for returned weapons pits have been processed through the separate steps sufficiently to demonstrate operational and design data; however, combined operation in a single production unit is still required. Ceramic experiments with oxides produced by hydride/dehydride/oxidation from a weapons pit are in process at Lawrence Livermore National Laboratory.

**DC-07 Calcination and Passivation Furnace.** The passivation furnace is basically a muffle-type furnace which is commercially available. Plutonium-bearing materials (e.g., glove box floor sweepings) have been oxidized in this type furnace for many years throughout the DOE complex.

**DC-08 HEU Decontamination**. HEU parts have been decontaminated by nitric acid washing at Rocky Flats on a production-scale for several years. Los Alamos National Laboratory is developing an electrolytic process which is expected to significantly reduce the generation of liquid waste. Feasibility of the process has been demonstrated on a laboratory-scale, but requires demonstration on a production-scale.

**DC-09 Fuel Decladding.** These operations are currently used in industrial scale processes.

**DC-10 Size Reduction**. Size reduction of plutonium oxide utilizes vibratory grinding which is a standard operation in commercial industry. Plutonium grinding has been performed on production-scale in the manufacture of mixed oxide fuel (plutonium/uranium oxide fuel).

**DC-11 In-Process Storage**. This interim lag storage of oxide will be similar to the vault storage techniques used in DOE complex facilities for many years.

### 2.4.2 Technical Viability of Front-End Ceramic Immobilization and Back-End HLW Glass Immobilization

The ceramic immobilization front-end process calcines the plutonium oxide feed, and cold presses sinters that product into a ceramic waste form suitable to send to the geologic repository. The major unit operations are *Feed Preparation* (CE-01), *Dry and Calcine* (CE-03), *Pellet Pressing* (CE-15), *Sintering* (CE-17), and *Canister Filling. (GL-25)*

**Feed Preparation (CE-01).** Dry-feed processing includes the receipt of plutonium oxide containing cans and the feeding of oxide powder. The feed of dry calcine is an established operation.

Wet feed preparation has been demonstrated world wide on a production scale for a number of years. Dissolution of plutonium oxide in nitric acid solutions with hydrogen fluoride is a standard process in the DOE weapons complex.

For the $PuO_2$ input specifications and the processing conditions to obtain fully reacted, homogenous, and dense products are not known. It is expected that particle size requirements for the input $PuO_2$ powder will require that its size is around 10 μm or less. Obtaining good product homogeneity and density is not expected to be a problem. Obtaining complete reaction may require longer sintering times and well blended input material, but will be achievable if the input $PuO_2$ particle size is sufficiently small. As long as the product is fully reacted, product durability will remain unchanged.

**Calciner Feed Makeup (CE-02) and Dry and Calcine (CE-03).** These steps have been demonstrated at a production scale using surrogate HLW solutions. Ceramic waste forms developed at ANSTO and LLNL are generally fabricated by adsorption onto a high surface area precursor powder or granules using a nitrate solution of the waste elements. The slurry is then dried, calcined, and loaded into a stainless steel bellows and hot pressed at around 1300°C (2400°F). This process is known to yield a homogenous and dense product (>98% density) where the waste constituents are fully reacted with the immobilization matrix.

**Pellet Pressing (CE-15) and Sintering (CE-17).** For the cold press and sinter process, the precursor material will probably be relatively coarse. Precursor particle size will be optimized to obtain maximum product densities which will be probably between 90 and 95% of theoretical density but not greater than 98% as obtained when hot pressing. The cold press and sinter fabrication method has been demonstrated with considerable success at LLNL for making ceramic waste forms with a variety of Resource Conservation and Recovery Act (RCRA) metals and radioactive surrogates. This is similar to the process used in the nuclear fuel industry. The fabrication of plutonium loaded SYNROC ceramics by this method has been underway but only limited data on reaction time vs. $PuO_2$ input size is available. It is expected that ceramics made in this

manner will initially be slightly less durable than hot pressed ceramics, but after long time periods when the form has turned metamict, it is expected that the durability of the two forms will probably be about the same.

For the hot pressing variant, the ceramic will be fabricated (roughly the same size as cold press and sinter) by sintering under pressure. This process has been demonstrated at a production scale using surrogate HLW. Scale of the process was approximately 30 kg (66 lb.) ceramics hot pressed in 30 cm (12 in.) diameter bellows. Scale of processes in the ceramic can-in-canister facility will be considerably smaller than the demonstrated scale of the SYNROC demonstration plant at ANSTO. The demonstrated fabrication rate was 10 kg/hr (22 lb./hr) which vastly exceeds that proposed in this variant. Although ceramic immobilization has been demonstrated at full scale using surrogates, full scale demonstration of the process using plutonium and neutron absorbers is still needed.

**Canister Filling (GL-25).** Canister filling is an existing DWPF process which has been demonstrated through qualification tests and initial operations to date. The canisters containing the small ceramic cans are designed to be substantially transparent to the existing DWPF canister filling and handling process. The filling of canisters containing small cans of a surrogate glass (slightly larger than the proposed ceramic cans) was demonstrated in DWPF prior to the start of radioactive operations.

**GL-26 Interim Canister Storage.** Interim canister storage is the modification of the DWPF canyon building to provide vault storage of DWPF canisters containing plutonium glass cans. Construction and operation of vault storage of Category I material is a routine operation in the DOE complex.

**Other DWPF Operations.** GL-14 blend tank, GL-17 off-gas treatment, GL-15 canister decontamination, GL-08 weld and test are existing facilities that are not expected to be affected by the can-in-canister option.

### 2.4.3 Technical Viability—Repository (Ceramic Can-in-Canister)

**Regulatory Risk.** Any waste form accepted for disposal in a HLW repository must comply with the provisions of the Nuclear Waste Policy Act, as amended (NWPA). According to Section 2(12)A of the NWPA, the definition of high-level waste does not explicitly include a ceramic form loaded with plutonium. However, under Section 2(12)B of the NWPA, the NRC has the authority to classify this waste form as high-level waste through rulemaking. Such rulemaking or clarification in the authorizing legislation will be necessary before this waste form can be considered for disposal in an NWPA repository. The final disposal of this waste form will have to follow the licensing provisions of 10 CFR Part 60 and the applicable NEPA process. Further, it is current policy of the DOE not to accept any wastes that include components regulated as hazardous under RCRA in the first HLW repository; absence of such RCRA regulated materials will have to be demonstrated prior to acceptance into the repository.

**Technical Risk.** The primary technical viability and risk issue related to the disposal of immobilized ceramic waste forms in a repository is associated with long-term performance. This is necessary to satisfy the licensing requirements of 10 CFR 60. The long-term performance issues are comprised of doses to a population in the accessible environment, and precluding criticality (as fabricated, degraded mode, and external) during all phases of the repository operation, including the period of isolation.

The contributions to dose by the ceramic waste form appears to be small compared to that predicted from uranium-based commercial spent fuel. However, the cumulative doses, from both the commercial spent fuel and the ceramic, must be shown to be within the envelop permitted by regulation. Since the EPA has remanded the regulation governing long-term performance and since a repository has not yet been licensed, calculations of such cumulative affects are not currently possible.

The NRC regulations for criticality control require that "the calculated effective multiplication factor ($k_{eff}$) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation." [10 CFR Part 60.131 (b)(7)]. Preliminary calculations on as-fabricated criticality for the ceramic option, with a 1:1 molar ratio of plutonium to neutron absorber, shows that the $k_{eff}$ of 0.95 or less as prescribed by NRC can be met. The effects of waste form and waste package degradation and the potential loss of neutron absorbers on criticality control are currently uncertain. An experimental program and further analyses are underway to assess these risks.

Although the NRC allows only limited credit for neutron absorbers for the commercial SNF, in recent communications with DOE, the NRC has postulated the potential use of low solubility neutron absorbers for weapons plutonium for criticality control. This suggestion has been made as part of the early development efforts that DOE should undertake in establishing a strong rationale for criticality control, especially where excess weapons-usable fissile materials are being disposed in a repository. The experimental program and additional analyses are completely consistent with these suggestions.

## 2.5 ES&H Summary (Deltas/Improvements Over PEIS)

The PEIS analysis currently underway is based on individual data calls for separate pit disassembly and conversion, conversion and stabilization, and immobilization facilities.

This immobilization end to end variant combines functions from the previously described facilities. The PEIS impact analysis is considered bounding for this variant; however facility consolidation and process simplifications and improvements result in substantial ES&H improvements over the bounding case being analyzed in the PEIS. These improvements are discussed below.

### 2.5.1 Front-End Plutonium Processing—Disassembly and Conversion

The front-end processes for disassembly and conversion and ceramic immobilization presented in this report offer substantial ES&H improvements over the base case being analyzed in the PEIS.

The pit disassembly, conversion, plutonium conversion and stabilization new facilities, and process flow diagrams being analyzed in the PEIS are the base case, and produce clean metal or >50% oxide to meet the long-term storage standard. This requires residue processing lines that generate aqueous waste solutions.

For this variant, all of the front-end processes will take place in the modified existing 221-F facility at SRS. No new facilities are to be constructed for the front-end which results in significant reductions from the base case environmental impacts for construction.

The front-end flow diagram for immobilization has been tailored and simplified to meet the immobilization process requirements. Aqueous recovery lines and process steps to purify oxide have been eliminated since impure oxide is satisfactory feed for the immobilization process. The process to separate plutonium from uranium solutions has been eliminated; the plutonium contaminated uranium is fed directly to the immobilization process.

These changes result in significant reductions in aqueous waste solutions, processing equipment associated facility space, utilities, and support systems. Personnel radiological exposure will also be reduced since the eliminated equipment will not be operated, maintained, decontaminated, and decommissioned.

### 2.5.2 Back-End HLW Glass Immobilization

Using SRS DWPF facilities for the addition of HLW glass uses existing hot cell facilities. Support facilities that would be needed are also existing. Thus, building of new facilities is minimal and considerably less than assumed in the PEIS.

Additionally, since only about 200 additional DWPF canisters will be required for this option, versus 600 additional canisters for the base case, significant reductions from the base case environmental impacts for operations will also result. No additional waste streams will be generated for the final immobilization process for this option, which also results in significant reductions from the base case environmental impacts for operations.

## 2.6 Costing Data—Ceramic Can-in-Canister Variant

The approach to costing the ceramic can-in-canister variant is a life cycle cost (LCC) methodology. Costs are developed for the total overall project including initial R&D, licensing/permitting, design, construction, operation and final decommissioning.

The capital cost estimate includes direct costs, indirect field costs, total field costs, contractors costs and profit, construction management, A-E cost, management costs, initial spares, and contingency.

The operation and maintenance (O&M) cost estimate include costs for personnel wages, consumables, material and maintenance expenditures, and waste disposal.

Operation costs for personnel wages are based on the increase in DWPF facility manpower loading attributed to this mission. The cost for facility maintenance and spares is estimated based on percent of capital cost for increased operations and capital investment. Consumables items such as chemicals are based on data in the *Chemical Marketing Report* dated 1989. The cost for incremental DWPF utilities and services, including materials, safety, environmental and security to operate the facilities, is estimated using a factor of 10% of the personnel wages. These cost factors are based on previous experience with projects of similar scope.

Waste disposal is based on unit volume costs for disposal of TRU waste to the Waste Isolation Pilot Plant (WIPP) and low-level solid wastes to a shallow land burial site. A 15% contingency is included in the operating cost.

Table 12 shows the summary of the back-end HLW glass processing LCC costs using DWPF at SRS.

### 2.6.3 Repository Costs

The estimated cost for disposal of the immobilized waste forms in a repository is based upon information contained in the Federal Register notice (52 FR 31508) published by the DOE on August 20, 1987, and entitled *Civilian Radioactive Waste Management: Calculating Nuclear Fund Disposal Fees for DOE Defense Program Waste*. This document from the OCRWM is a public notice of its approach to interpreting the requirement, under the Nuclear Waste Policy Act of 1982, for allocating the costs of developing, constructing, and operating repositories between atomic energy defense wastes and commercial high-level spent fuel.

In this notice, DOE identified a preferred cost sharing approach between defense and civilian wastes. According to this formula, the repository cost per canister of DHLW is approximately $500K based on a total life cycle cost analysis completed in September 1996, "Analysis of the Total Life Cycle Cost of the Civilian Radioactive Waste Management Program," DOE/RW-0479, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, September 1995.

This activity for certification of a transportation container is well within the nominal five year NRC licensing application duration shown on the schedule.

A family of potential packages, 6M/2R-like packages, can be used for transporting the fissile material (excluding pits). These packages would require modifications to insure that the package criteria stated in DOE-STD 3013-94 are met. Further modifications would be required to insure that the packaging configuration incorporates the primary containment vessel, analysis/testing is performed to show the abnormal and normal accident scenarios, that the Safety Analysis Report (SAR) is modified to show the changes, and the package is certified for the material considering the packaging configuration.

**Disposal.** Following rule making or clarification in authorizing legislation for emplacing the immobilized forms in an HLW repository, a license amendment will have to be submitted to NRC for these waste forms. Further, the NEPA process which incorporates these wastes into a repository will also have to be followed.

### 2.7.2 Uncertainties

The preliminary, estimated schedule presented in tabular form in Tables 13 and 14 and in Gantt-chart form in Figures 15 and 16 is a logic network defined by activity durations and logical ties between them. As such, the logic lends itself to examination of the impacts in schedule variations. However, at this stage such analysis has not been done.

**Permitting and Licensing.** Any new facility will be regulated/licensed by NRC. However, DOE external oversight activities may influence the planning basis for these facilities. The Advisory Committee on External Regulation of DOE Nuclear Facilities made recommendations to the Secretary on external regulation in early 1996. Recommendations from this committee will influence decisions on whether and what facilities will be regulated externally, and what external organization will be responsible. The DOE is currently preparing an action plan for implementing these recommendations. Decisions on external regulation could impact the permitting and licensing schedule durations. The same five year critical path activity for licensing has been assumed for both new facilities or use of existing facilities.

**Congressional Funding.** The congressional funding cycle is a critical path activity. Improvements are not anticipated. However, delays would impact the overall disposition completion date.

**R&D.** The program identified to develop and demonstrate the immobilized formulation and process equipment will be better defined in the long range R&D plans being prepared. However, relative to NEPA, and other critical path activities the needed development and demonstration will either be readily achievable in time to support the baseline schedule, or critical problems that disqualify an variant will be identified early.

**Table 13. Front-end facility schedule breakout.**

| Task no. | Task name | Duration | Start date | Finish date | Predecessors |
|---|---|---|---|---|---|
| 1 | Congressional funding and initial activities | 1287d | 10/2/95 | 9/5/00 | |
| 2 | ROD KD 0 Approval for Mission Need | 0d | 1/1/97 | 1/1/97 | |
| 3 | Title I Authorization Process | 104w | 1/1/97 | 12/29/98 | 2 |
| 4 | Full Funding Authorization Process | 88w | 12/30/98 | 9/5/00 | 3 |
| 5 | R&D funding | 0d | 10/2/95 | 10/2/95 | |
| 6 | A-E selection | 12w | 1/1/97 | 3/25/97 | 2 |
| 7 | Select NEPA contractor | 12w | 1/1/97 | 3/25/97 | 2 |
| 8 | R&D, demo, test, integrated prototyping and proc. eng | 1584d | 10/2/95 | 10/25/01 | |
| 9 | HYDOX | 522d | 10/2/95 | 9/30/97 | 5 |
| 10 | NDA | 522d | 10/2/95 | 9/30/97 | 5 |
| 11 | Bisector | 522d | 10/2/95 | 9/30/97 | 5 |
| 12 | ARIES Integrated dismantlement prototype | 522d | 10/2/95 | 9/30/97 | 5 |
| 13 | OY Decon | 522d | 10/1/97 | 9/30/99 | |
| 14 | Salt processing | 522d | 10/1/97 | 9/30/99 | |
| 15 | Non-Pu component declass. | 522d | 10/1/97 | 9/30/99 | |
| 16 | ZPPR fuel proc. | 522d | 10/1/97 | 9/30/99 | |
| 17 | Integrated prototyping and eng | 108w | 10/1/99 | 10/25/01 | 12,13,14,15,16 |
| 18 | Conceptual design, NEPA , permitting | 1660d | 3/26/97 | 5/13/03 | |
| 19 | Preferred site selection | 48w | 1/1/97 | 12/2/97 | 2 |
| 20 | NEPA/EIS and site selection | 660d | 12/21/98 | 6/29/01 | 7,22 |
| 21 | Permitting | 320w | 3/26/97 | 5/13/03 | 6,7 |
| 22 | Conceptual Design | 108w | 3/26/97 | 4/20/99 | 6 |
| 23 | Project authorization, Title I design, PSAR | 900d | 1/1/97 | 6/3/00 | |
| 24 | KD#1 Approval for start | 0d | 1/1/97 | 1/1/97 | 2 |
| 25 | Title I Authorization | 0d | 12/29/98 | 12/29/98 | 3 |
| 26 | Title I Des & PSAR | 60w | 4/21/99 | 6/13/00 | 3,22 |
| 27 | Documentation to DNFSB, review process, Title II des., FSAR, DNFSB release for construction | 1200d | 6/13/00 | 1/18/05 | |
| 28 | KD#2- Start Title II Design | 0d | 9/5/00 | 9/5/00 | 4,20,26 |
| 29 | Submit documentation to DNFSB | 0d | 6/13/00 | 6/13/00 | 26 |
| 30 | DNFSB oversight process | 240w | 6/14/00 | 1/18/05 | 29 |

**Table 13. (continued).**

| Task no. | Task name | Duration | Start date | Finish date | Predecessors |
|---|---|---|---|---|---|
| 31 | NRC NEPA | 104w | 6/14/00 | 6/11/02 | 29 |
| 32 | NRC issues | 0d | 6/11/02 | 6/11/02 | 31 |
| 33 | Title II Design & FSAR | 96w | 7/2/01 | 8/23/02 | 28 |
| 34 | NRC license | 0d | 1/18/05 | 1/18/05 | 30,20 |
| 35 | DNFSB approval/KD#3/Release for Construction | 0d | 1/21/04 | 1/21/04 | 30FS-52w |
| 36 | Construction, equipment installation, startup, test, ORR | 1320d | 1/21/04 | 2/10/09 | |
| 37 | Construction | 240w | 1/21/04 | 8/26/08 | 36 |
| 38 | Procurement | 138.4w | 1/21/04 | 9/14/06 | 36 |
| 39 | Equipment Installation | 99.8w | 1/6/06 | 12/5/07 | 39FS-36w |
| 40 | Startup, Preop testing, ORR | 48w | 3/12/08 | 2/10/09 | 38FS-24w,40 |
| 41 | Operations | 2400d | 2/10/09 | 4/24/18 | |
| 42 | KD#4 Commence Operation | 0d | 2/10/09 | 2/10/09 | 41 |
| 43 | Operation | 480w | 2/11/09 | 4/24/18 | 43 |
| 44 | D&D | 720d | 5/24/17 | 2/25/20 | |
| 45 | D&D | 144w | 5/24/17 | 2/25/20 | 40FS-48w |

**Table 14. (continued).**

| Task no. | Task name | Duration | Start date | Finish date | Predecessors |
|---|---|---|---|---|---|
| 31 | Construction, equipment installation, startup, test, ORR | 1320d | 1/21/04 | 2/10/09 | |
| 32 | Construction | 240w | 1/21/04 | 8/26/08 | 30 |
| 33 | Procurement | 138.4w | 1/21/04 | 9/14/06 | 30 |
| 34 | Equipment Installation | 99.8w | 2/1/06 | 12/31/07 | 33FS-36w,11 |
| 35 | Startup, Preop testing, ORR | 48w | 3/12/08 | 2/10/09 | 32FS-24w,34 |
| 36 | Operations | 2400d | 2/10/09 | 4/24/18 | |
| 37 | KD#4 Commence Operation | 0d | 2/10/09 | 2/10/09 | 35 |
| 38 | Operation | 480w | 2/11/09 | 4/24/18 | 37 |
| 39 | D&D | 720d | 5/24/17 | 2/25/20 | |
| 40 | D&D | 144w | 5/24/17 | 2/25/20 | 38FS-48w |

Note: Schedule durations are nominal, the detailed date and day information is not significant, it is merely a function of the scheduling program calendar.

**Waste Form Certification and Qualification.** Ceramic waste forms, similar to the form proposed for CCC, have been developed and evaluated as a candidate form for HLW disposal, plutonium loading has been demonstrated, and natural analogs exist. The schedule shown assumes full certification can be accomplished within the activity duration for the balance of R&D, demonstration and test.

**Site-Specific EIS and Permitting.** For the non-NRC front-end and immobilization facilities, using existing SRS facilities, site specific NEPA and site selection activities are critical path activities, delays or improvements would impact the overall disposition completion date. Other permitting activities are not shown as critical path activities, but would need to be monitored closely during implementation to determine if delays would impact the overall disposition completion date.

**Title I & II Design, Procurement, Construction, and SAR Preparation.** For the front end and immobilization facilities, using existing SRS facilities, these activities offer opportunities to refine and improve on the schedule as more definition is achieved. Some are critical path activities, others may or may not impact the overall disposition completion date.

**Cold Startup and Preoperational Testing.** These activities offer opportunities to refine and improve on the schedule as more definition is achieved in the future. These are critical path activities, thus delays or improvements would impact the overall disposition completion date.

**Hot Startup and Operations.** These activities offer opportunities to refine and improve on the schedule as more definition is achieved in the future. Process improvements, plutonium immobilization experience, and increased plutonium loading could shorten the operational schedule. These are critical path activities, thus delays or improvements would impact the overall disposition completion date.

**Decontamination and Decommissioning.** D&D activities occur after disposition, and are not well defined at this point. While they are important to conclusion of the overall program, they do not impact the overall disposition completion date.

**Repository Availability.** Uniform linear shipments to a HLW-repository are assumed. However, the immobilization variant facilities planning basis includes storage for the entire inventory of dispositioned material. Thus material can be processed into the dispositioned form, and stored until a HLW-repository is available.

## 2.8 Institutional Issues

### 2.8.1 International Issues

In the U.S., institutional issues have come to play every bit as important a role as technology in arriving at major Federal decisions. It is vital that Federal agencies, in developing policy initiatives, recognize the key roles that building public and political

### 2.8.3 Sociopolitical Issues

**Inspection by the IAEA.** As noted by the NAS study, efforts to stem the spread of nuclear weapons are critically dependent on the strength and credibility of the systems and organizations given the responsibility to carry them out. A "key element" of the President's September 27, 1993 Nonproliferation and Export Control Policy is to "Submit U.S. fissile materials no longer needed for our deterrent to inspection by the International Atomic Energy Agency." Inspection by IAEA will provide added assurance to the public that all fissile material is accounted for and that risks of theft and proliferation are minimized. The IAEA's traditional approach to safeguards focused on verifying declared facilities at declared sites. Even though the IAEA has always had statutory authority to inspect other sites, support from its key member states has not been sufficient to enable it to do so meaningfully to date. The IAEA does not have an enforcement or security function but rather it provides independent accounting and auditing functions. To participate in monitoring fissile materials released from nuclear weapons programs, IAEA will need greater resources.

### 2.8.4 Environment, Safety, and Health Issues

According to the NAS report, "the greatest dangers to public welfare associated with the existence and disposition of weapons plutonium are unquestionably those connected with national and international security. The preeminence of these security dangers, however, should not obscure the need for careful attention to the environment, safety, and health (ES&H) risks implied by the different approaches to weapons dismantlement, fissile materials storage, and long-term disposition of weapons plutonium."

The Stabilization Program is assumed to convert the plutonium to a form compatible with the DNFSB Recommendation 94-1. The short term ES&H concerns must be coordinated with the nuclear nonproliferation objectives. The December, 1995 *Plutonium Stabilization and Immobilization Workshop* is an example of the ongoing effort needed to maintain communication and promote a common understanding on stabilization and immobilization technology requirements.

New and more stringent ES&H regulations are being imposed on the U.S. nuclear weapons complex. These are dynamic standards, and can be expected to continue to change over time. Currently, ES&H requirements set the pace for each stage of plutonium processing through out the immobilization processes. The time required to implement any immobilization choice will be heavily influenced by the licensing and approval process, including the extended safety and environmental analysis requir for each option. Ultimately, these ES&H standards will affect the ease and cost of achieving different immobilization options.

**Uranium/Plutonium Oxide.** Uranium oxides are easily incorporated into multiphase ceramics.

### 2.9.1.3 Implementation

The hybrid analyzed is depicted in Figure 17. Approximately 32.5 tonnes (36.4 tons) of plutonium in the form of pits, clean metal, and clean oxide are converted to MOX fuel which is burned in existing LWRs. The remainder, about 17.5 tonnes (19.6 tonnes) of plutonium in various impure forms, would be vitrified through the can-in-canister variant.

*Schedule.* The schedule assumed in the analysis for this hybrid option is slightly changed from that presented in Figure 15; preparing ceramics in the small cans would begin in 2004. There may be an opportunity to further modify the schedule to optimize the hybrid option, if this is option were to be chosen in the upcoming ROD. Potentially, construction, start-up and processing could take place in a shorter period of time. However, it may be desirable to have the plutonium ceramics operations proceed in parallel with the fabrication of MOX fuel so that the plutonium-bearing scrap from MOX fuel fabrication operations could be fed into the ceramics process.

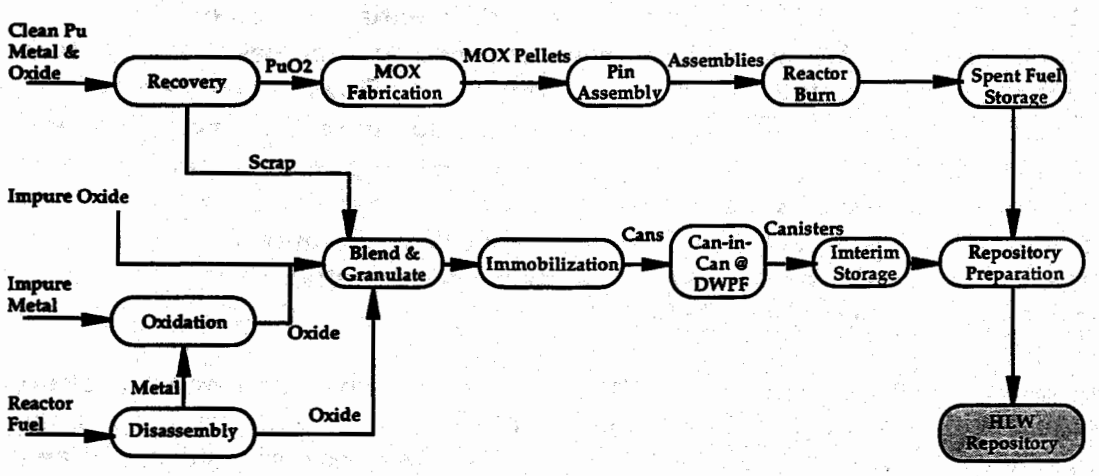



**Figure 17. Hybrid option, ceramics can-in-canister with MOX fuel fabrication for reactor burn.**

### 2.9.2 Low Assay Plutonium Immobilization

Hybrid disposition approaches, in which low assay feed materials (e.g. incinerator ash, etc.) are blended with higher assay materials prior to immobilization, open the possibility of utilizing existing facilities in different ways to achieve the objectives of both EM-60 Stabilization Program (DNFSB Recommendation 94-1) and FMDP objectives. As an example, DOE/EM-60 is considering transferring low assay materials to WIPP after treatment by a variety of methods including recovery of plutonium and

its and purification to MOX fuel requirements. These materials could be blended with higher grade plutonium materials without prior treatment and then immobilized in multiphase ceramics thereby avoiding much of the required processing. This would possibly allow an even wider range of existing DOE facilities to be utilized. Immobilization techniques in general require that any single tramp impurity be less than 1.0 wt % in the final immobilized product. However, non-proliferation and criticality concerns require that the plutonium content of the immobilized form be less than 10 wt%. Therefore, as a general statement, tramp impurities in the plutonium feed must be less than 10 wt % to give a final immobilized product containing less than 1 wt % of that individual tramp impurity. Many of the materials in the DOE stockpile could be blended to this level without any form of processing other than calcination.

The discussion presented below assumes that 32.5 tonnes (36.4 tons) of plutonium is converted to MOX fuel and the other 17.5 tonnes (19.6 tons) of the less pure plutonium are vitrified. This discussion also assumes that all plutonium coming to FMDP has been stabilized in accordance with the DNFSB Recommendation 94-1, but that purification to a plutonium concentration of ≥ 50 wt % has not occurred.

#### 2.9.2.1 Logic and Benefits of Low Assay Plutonium Ceramics Hybrid

Immobilization of surplus plutonium by ceramics has been studied in this report for all plutonium-bearing materials forms that could potentially become part of the disposition mission. The present MD program, however, assumes that all materials to be dispositioned will have a plutonium concentration ≥ 50 wt%. Since the composition, chemical, and isotopic characteristics of the U.S. plutonium inventory vary over a wide range, a variety of processing steps requiring varying degrees of chemical purification and final form processing will be required depending on the disposition route chosen. By combining and optimizing the plutonium treatment operations associated with unstable residues with ceramics, significantly processing efficiencies, cost reduction and schedule enhancements could be realized.

Multiphase ceramics has the potential to convert much of the low assay plutonium to ceramics without extensive separation of the plutonium from inert matrix materials. Much of the existing impure plutonium inventory exists because of economic and technical difficulties of separating plutonium from these materials. The flexibility of multiphase ceramics to incorporate these troublesome impurities up to 1 wt% in the final product could provide technical, economic, and institutional incentives to use ceramics for this portion of the inventory.

Benefits of the low assay hybrid approach include:

- It reduces the need to, and avoids the cost of, separating plutonium from much of the residue or scrap inventory.
- It offers the potential to reuse facilities developed for other plutonium missions to dispose of these more problematic materials, therefore providing the U.S. Government a much greater return-on-investment.

calcination. The remaining elemental impurities easily can be blended to less than 10 wt%.

### 2.9.3 Non-Plutonium Feed Materials Hybrid

DOE owns other materials which are also expected to be declared excess. Multiphase ceramics is also particularly well suited for some of these non-plutonium surplus fissile materials. These include $^{233}U$ in the form of uranium oxide or a mixed thorium/uranium oxide.

About two tonnes of $^{233}U$ exists at various DOE sites. This isotope is weapons-usable and is part of the fissile materials disposition program, but is not a part of the plutonium disposition study. Most of it is located at ORNL and INEL. The material at ORNL is primarily impure uranium oxides. A significant fraction of this material contains other uranium isotopes and impurities such as CdO and $Gd_2O_3$. A small portion of the inventory is metal and uranium fluoride with a LiF impurity. The material at INEL is exclusively unirradiated Th-uranium oxide fuel pellets. Material at other sites is primarily in the form of uranium oxides.

The uranium oxides containing $^{233}U$ behave chemically the same as the other isotopes of uranium. Thus, multiphase ceramics waste forms are well suited for incorporation of $^{233}U$. The thorium-uranium oxides fuel pellets containing $^{233}U$ are also suitable feed to the multiphase ceramics waste form. Thorium can also be accommodated in the multiphase ceramics form with high solubilities.

## 3.0 Acronyms

| | |
|---|---|
| ANL-W | Argonne National Laboratory-West |
| ALARA | As Low As Reasonably Achievable |
| ANSTO | Australian Nuclear Science and Technology Organization |
| BET | Brunauer-Emmett-Teller equation |
| CCC | Ceramic Can-in-Canister |
| C/S | Containment and Surveillance |
| CCTV | Closed Circuit Television |
| $^{137}Cs$ | Cesium 137 |
| CFR | Code of Federal Regulations |
| CGF | Ceramic Greenfield Facility |
| CRT | Container Restraint Transport |
| CRWMS | Civilian Radioactive Waste Management System |
| DHLW | Defense High-Level Waste |
| DNFSB | Defense Nuclear Facilities Safety Boards |
| DOE | Department of Energy |
| DOT | Department of Transportation |
| DP | Defense Programs |
| DWPF | Defense Waste Processing Facility |
| EM | Environmental Management |
| EPRI | Electric Power Research Institute |
| ET | Electrometallurgical Treatment |
| EIS | Environmental Impact Statement |
| FCF | Fuel Conditioning Facility @ ANL-W |
| FMDP | Fissile Materials Disposition Program |
| FMD PEIS | Fissile Materials Programmatic Environmental Impact Statement |
| FMF | Fuel Manufacturing Facility @ANL-W |
| GMODS | Glass Materials Oxidation Dissolution System |
| Gy | Gray |
| HEME | High-Efficiency Mist Eliminator |
| HEPA | High-Efficiency Particulate Air (filter) |
| HFEF | Hot-Fuel Examination Facility |